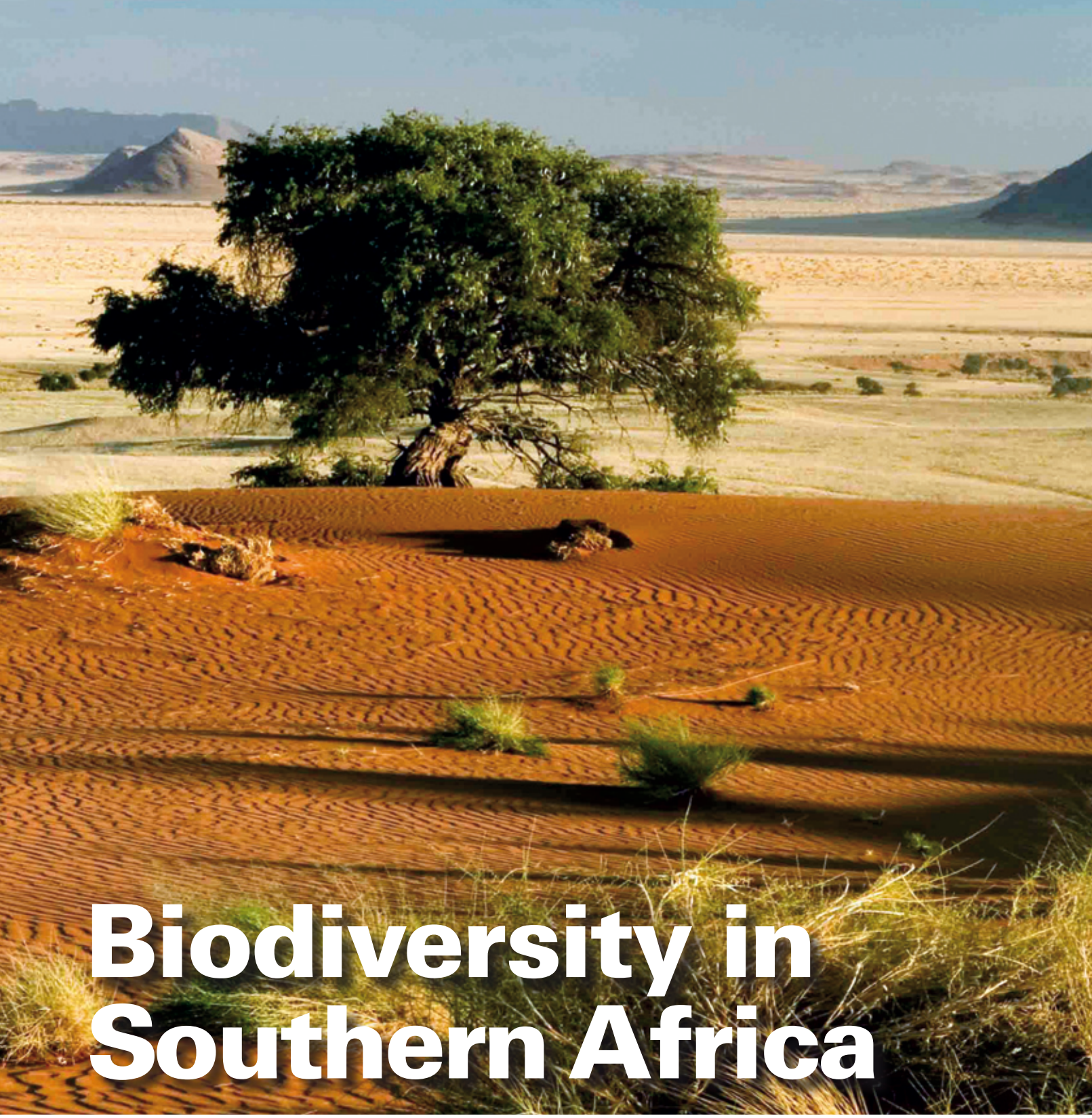

Biodiversity in Southern Africa

Vol. 1

Patterns at Local Scale
The BIOTA Observatories

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BIOTA

BIOTA transect and the Biodiversity Observatories in southern Africa.

Boundaries

- International Boundary
- Provincial Border

Hydrography

- River
- Periodical River
- Salt Pan
- Lake
- Wetland

Contour Levels

- up to 300 m
- up to 600 m
- up to 900 m
- up to 1200 m
- up to 1500 m
- up to 1800 m
- more than 1800 m

Communications

- Motorway
- Road
- Railway

Populated Places

- City
- Provincial Capital
- Capital

- Transect
- S32 Elandsberg — BIOTA Observatory

0 250 500 km

Uwe Ulrich Jäschke & Karen Langner • HTW - University of Applied Sciences Dresden

Number, name and respective biome of the BIOTA Biodiversity Observatories.
Page number refers to the description of the Observatory in Volume I.

(S01) Mile 46 ■ Woodland Savanna ..... Vol1 page 70
(S02) Mutompo ■ Woodland Savanna ..... page 92
(S03) Sonop ■ Woodland Savanna ..... page 118
(S04) Toggekry ■ Thornbush Savanna ..... page 168
(S05) Otjiamongombe ■ Thornbush Savanna ..... page 194
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(S27) Ratelgat ■ Succulent Karoo ..... page 698
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(S39) Narais ■ Nama Karoo ..... page 320
(S40) Duruchaus ■ Nama Karoo ..... page 348
(S41) Sandveld ■ Thornbush Savanna ..... page 280
(S42) Ogongo ■ Woodland Savanna ..... page 140
(S43) Omano go Ndjamba ■ Woodland Savanna ..... page 152
(S45) Nieuwoudtville ■ Fynbos ..... page 790

Biodiversity in southern Africa

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Biodiversity in southern Africa

Volume 1:

Patterns at local scale – the BIOTA Observatories

Norbert Jürgens, Daniela H. Haarmeyer, Jona Luther-Mosebach,
Jürgen Dengler, Manfred Finckh & Ute Schmiedel

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If you want to refer to one of the specific Sections or to a single Observatory description you should insert the citation to the Section or Observatory description as follows:
Example: ... the Lichen Section as described in Haarmeyer et al. (2010) ...
Example ... the Observatory S01 as described in Haarmeyer et al. (2010) ...

Corrections brought to our attention will be published at the following location: http://www.biota-africa.org/biotabook/

Preface

The BIOTA Southern Africa project carried out a wide array of research activities in Namibia and western South Africa, over nearly a full decade, from 2001 till 2010. As a summary of this first period of long-term observation and related research, this book presents the many and diverse results of the project. The introductory chapters, which follow, report on the background and context, the challenge and rationale, as well as the approach and structure and, finally, the history of the project.

"BIOTA Southern Africa", was just one (though very large) element within a continent-wide cluster of projects, namely "BIOTA Maroc", "BIOTA West Africa" and "BIOTA East Africa" (see map on page XX). These four regional projects, collectively referred to as BIOTA AFRICA, had a lot in common regarding their scientific goals and methods and there are a number of important overarching results. The focus on "BIOTA Southern Africa" only, which is presented here, already fills a book of three volumes.

There were several motivations for this book and they all had an impact on its content and structure.

The first and most important motivation is the wish to deliver data, results, and products to the many partners who collaborated and had been involved with the project since its inception. This includes a wide range of quite different groups of people. BIOTA Southern Africa embodies a complex cooperation between Namibia, South Africa, and Germany based on interactions between people, institutions, and governments.

There is the group of local farmers, land owners, and landuser communities, who are directly interested in knowing about their specific land in a local context. They would like to get information regarding the value of "their" biodiversity and "their" local ecosystem services, the changes and trends and the vulnerability of "their" ecosystems. Of course, they would also like to get recommendations for sustainable and economically viable management options available to them.

There are also the various groups of resource managers (using "resource" in a wide sense), including all the institutions responsible for the sustainable utilisation of rangeland, forests, biodiversity, water, soils, etc., ranging from the national Departments to NGOs. Irrespective of whether they are following a "conservation approach" (with an emphasis on conservation areas and programmes for endangered species and resources) or a management approach (with a focus on efficient and sustainable provision and human use of resources), they are interested in assessments, change analyses, future projection scenarios, and management recommendations. However, this interest is focussed at a larger geographical scale.

Both scales are relevant for those project partners from the education sector and from the field of academic research. Scientists are also, in addition to all of the above, interested in new methods and results of their application. In addition, there is a wider public in all countries involved, often represented by the media, who would like to be informed about the state of biodiversity and the ecological condition of the environment. Has it changed, is the environment "getting worse" or is it "improving", what is likely to happen in the future if we continue doing what we are doing? These are all questions, which we, as a society, like to know about.

Last but not least, a large project like BIOTA Southern Africa also forms an "experiment" regarding international cooperation. Therefore, the public, but also funding institutions, may be very interested to hear about lessons learnt during the course of the project. The funding institutions, in this case especially the German Federal Ministry of Education and Research (BMBF), the South African National Research Foundation (NRF), the Namibian Ministries of Environment and Tourism (MET), and the Namibian Ministry of Agriculture, Water and Forestry (MAWF) also wish to see a public record, which shows that their investments have generated high quality, useable products.

It is not an easy task to satisfy such a broad range of target groups, ranging from local farmer communities, often without access to electronic media, to government representatives within the single concept of a book, which we have opted for here. Clearly, the book had to integrate a wide range of information in different formats for all the different potential user groups and bring it together in an easily-readable, somewhat "hybrid" format. A part of our solution is the subdivision of the book into three separate volumes. Therefore, it is important to understand the specific aims of each of the three volumes.

Volume 1 serves the needs of **local users** and is concerned primarily with the findings associated with each of the 37 BIOTA Biodiversity Observatories (standardised, biodiversity long-term monitoring plots, see Part II) located along the BIOTA Southern Africa transect. It has been designed specifically for all **land owners, and landusers as well as the managers of conservation areas and members of municipalities and local communities**. Together with a relatively brief introductory section (i.e. Part I), the volume consists of a more comprehensive Part II, entitled "The BIOTA Observatories". This Part consists of detailed information on each of the standardised Biodiversity Observatories, grouped into six Chapters according to the six biomes, to which they belong. It begins (Chapter II.1) with a detailed description of the methods and spatial sampling design used to gather and analyse the data. The bulk of Part II, however, provides information on the observed local patterns in Observatory-related climate, soil fertility, plants, animals, and microorganism as well as on their observed trends and changes over time.

Volume 2 (i.e. Part III) is of interest for **all users**. Based on the data from the 37 Observatories (as presented in Part II) and beyond, in Part III all the data are integrated, compared, and discussed in a wider context. Part III starts with a reconstruction of the history of environmental changes (Chapter III.1) followed by a regional perspective (Chapter III.2). The direct comparison of the single Observatories along the BIOTA transects is presented as Chapter III.3, supplemented by a series of case studies, which highlight research results on specific groups of organisms (Chapter III.4). The next four Chapters of Part III deal with the understanding of the drivers and processes of biodiversity change. Chapter III.5 describes how humans have impacted on biodiversity over time. Chapter III.6 reports on the results of experiments, which improve our understanding of the nature of these changes. Chapter III.7 highlights the insight that scientific models provide in understanding the impact of different factors and processes on environmental change and also in widening our ability to project present dynamics into the future. Finally, Chapter III.8 reports on stakeholder interactions, knowledge exchange and various ways to develop additional capacities for better management of biodiversity.

Volume 3 is of interest for all **decision makers** regarding landuse and for **resource managers**, irrespective of the geographical scale, at which they operate. Here (i.e. Part IV), we use an approach, which acknowledges the similarity of ecosystems and organismic compositions within each of the major biomes along the transect (i.e. Woodland Savanna, Thornbush Savanna, Nama Karoo, Succulent Karoo, and Fynbos). This approach allows for general statements to be made regarding the implications of our research results for landuse and management of biodiversity within the biome. Therefore, each of the five biome Chapters forms a summary of all the results with a focus on the implications of these findings for management. At the end of this Volume, Part V contains three useful indices, i.e. one that explains the abbreviations used throughout the book, one with all scientific names occurring in the book, and one with biosketches and contact data of all authors.
Finally, an **Electronic Appendix** (CD at the back cover of Volume 3) provides original data, complete species lists, and further additional information. A symbol and the reference in the text (Electronic Appendix) indicate, for which aspect additional information or data can be found on the CD. The information on the CD is structured according to the sequence of the Chapters and Subchapters.

Norbert Jürgens, Ute Schmiedel & M. Timm Hoffman

Organisations that participated in BIOTA Southern Africa

Namibia
Desert Research Foundation of Namibia (DRFN)
Gobabeb Training & Research Centre (GTRC)
National Botanical Research Institute of Namibia (NBRI, Windhoek)
National Museum of Namibia (Windhoek)
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University of Namibia (UNAM)

South Africa
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Biodiversity in southern Africa was produced in a relatively short period of time and we would like to express our sincere gratitude to everybody involved for their friendly and fruitful cooperation even under continuous time pressure and tight deadlines.

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Norbert Jürgens, Ute Schmiedel, Daniela H. Haarmeyer, Jona Luther-Mosebach,
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The editors and authors

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Patterns at local scale—the BIOTA Observatories

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Fig. 1. Overview of the regional projects BIOTA Maroc, BIOTA West Africa, BIOTA East Africa, and BIOTA Southern Africa within the framework of BIOTA AFRICA.

Part I

BIOTA Southern Africa

Challenges and international framework

Norbert Jürgens*, Ute Schmiedel & M. Timm Hoffman

The ultimate justification for a large biodiversity research project like BIOTA AFRICA (see Fig. 1 on the left side) is the perceived decline of biodiversity and its impact on human societies. However, this justification is merely the general context while the concrete goals and activities of the project are driven by the global discussion on global change in general and change of biodiversity in particular. This foundation of the project needs to be acknowledged. The integration of the project into the global discussion makes us confident that its products will be acknowledged as a contribution to the solving of a problem of global dimension and hence will be turned into application by the different stakeholder groups involved. It is also important to recall the roots of the project within an international political and societal process because it strongly influenced the scope of the project, which again defines the role and value of each single subproject, work package, and activity.

At the highest level of international political mechanisms, the project follows the definition of biodiversity of the UN Convention on Biodiversity (CBD) by integrating both **conservation** of biodiversity and sustainable **use** of biodiversity. This also includes the view that the decline of biodiversity is not only man-made but implies one of the grand challenges of humankind, i.e. to shift from an ever-growing and ever-expanding exploitation of natural resources to sustainable management within feasible limits. This obviously requires a transition from spontaneous and relentless economic expansion driven by necessities or opportunities to sound, knowledge-based, planning and management becoming a mainstream within societies. Therefore, the scope of biodiversity research is much wider than just studying organisms and ecosystems. It rather integrates the study and understanding of environmental and biological processes with the study of societal processes. This integration has the ultimate goal to inform and potentially redesign societal processes in order to support and enable sustainable management decisions. This also implies the adjustments of governance systems and the education of future generations.

At another level, the International Global Change Science Programmes, combined within the Earth System Science Partnership (ESSP), and especially the International DIVERSITAS programme, played an eminent role in defining the agenda of the BIOTA AFRICA project.

Within DIVERSITAS and its core projects, in parallel with the lifetime of the BIOTA project, scientists from many countries have developed and implemented science plans, which have also been used as an orientation for many elements of BIOTA. Therefore, the BIOTA project is regarded by DIVERSITAS as a flagship project, and has been presented as such in many publications. This was also true for the development of the Biodiversity Observation Network GEO BON within GEOSS (for details see Chapter I.3).

Structure and elements of the project and course of the project over the three Phases

Norbert Jürgens*, Ute Schmiedel & M. Timm Hoffman

Due to the increasing public awareness of global environmental change and its socio-ecological impacts, the scope and structure of the BIOTA Southern Africa project was adapted over the project period.

Phase I (2000–2003)

During Phase I the structure of the project was mainly defined by four main topics, which were understood as a cascade of elements being built on each other.

Structure of BIOTA Southern Africa during Phase I

i **Assessment** of existing biodiversity
ii **Monitoring** of the changes of biodiversity
iii **Understanding** of drivers and mechanisms of change
iv **Interventions:** Tools for management, restoration & conservation

Looking back, this was an entirely appropriate structure for the starting period. It had a critical mass of activities dealing with the basic currency of biodiversity research i.e. organismic diversity. It explicitly dealt with change in time and the understanding of key processes affecting this change. The final goal was clearly defined at the end of the cascade in terms of improved management, restoration, and conservation.

Phase II (2004–2006)

There were quite visible changes in moving from Phase I to II of the project,

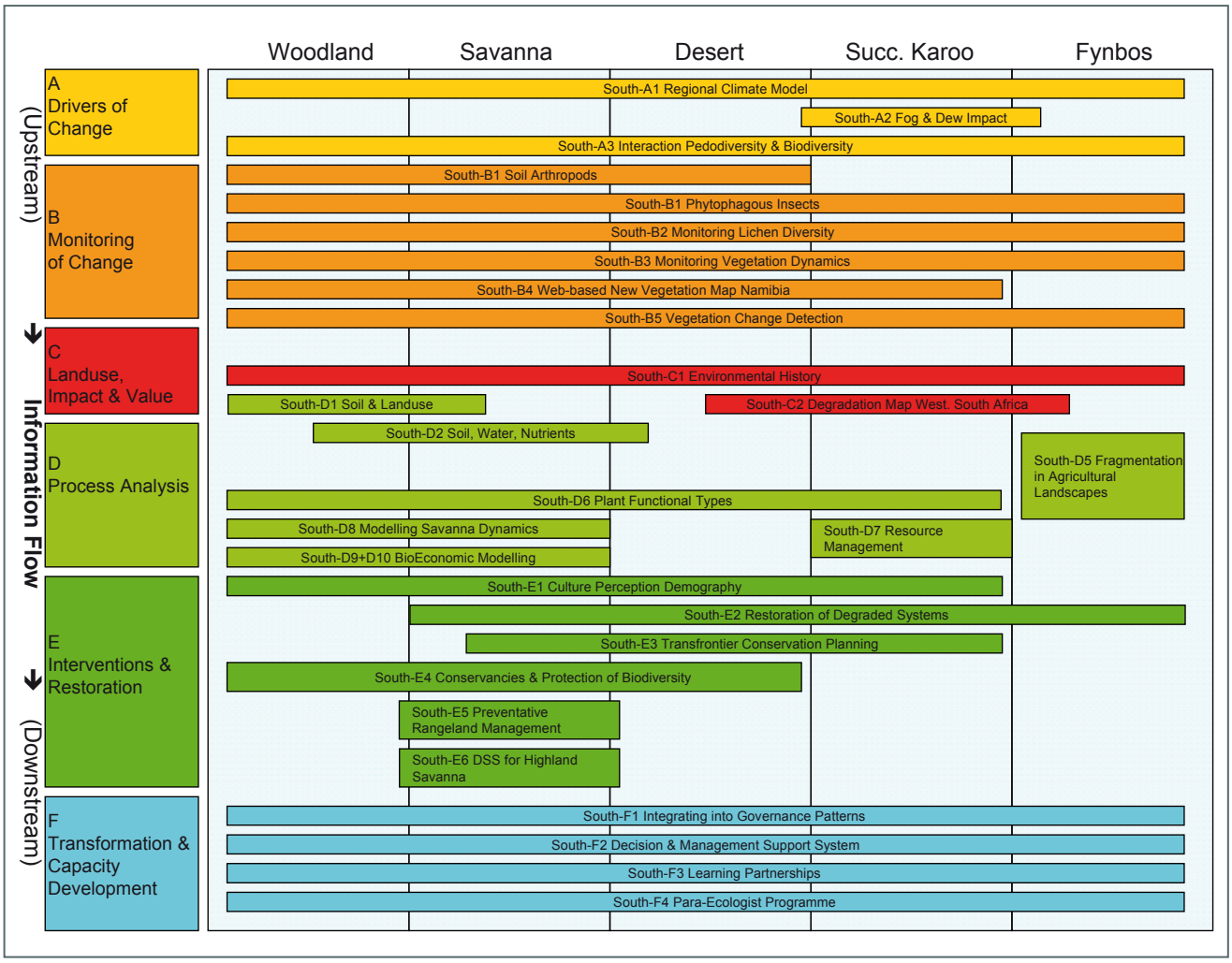

Fig. 2: Work packages in Phase III of BIOTA Southern Africa (2007–2010).

Photo 1: The German Federal Chancellor Angela Merkel (left) and the Federal Minister of Economic Cooperation and Development Heidemarie Wieczorek-Zeul (center) discussing with Professor Norbert Jürgens (right) the concept and research findings of BIOTA Southern Africa. Cape Town, October 2007. Photo: Bundesregierung / Guido Bergmann.

which were not only due to the general maturation of the goals of biodiversity science itself. A very important difference to the design of Phase I was the much stronger involvement of the African partners. While African partners where involved in Phase I of the project, such involvement was based largely on earlier cooperation between individuals. The bringing together of whole research communities within a structured joint planning process was critical for the success of Phase II. During the initial planning period for Phase I, resources were limited and the funding of even one international planning workshop was out of the question. However, the situation was very different during the planning for Phase II. At that time, the major planning was done during well-structured and facilitated workshops in several African venues. Therefore, the needs of African landusers were more strongly reflected in Phase II than was possible in Phase I and a stronger emphasis was also placed on people-centred research activities

"Inventories and basic assessments", one of the four major topics in Phase I, disappeared from the agenda for Phase II whereas the monitoring activities continued. Process analysis was focused at functional types and interactions. In Phase II, three of the integrative themes were focussed directly on human aspects. Theme iii addressed not only the impact of landuse on the environment but also the value that different landuse practices had for humans. Theme iv aimed at developing tools and instruments for interventions towards restoration and management while Theme v aimed to inform policy at multiple levels.

Integrative main themes of BIOTA Southern Africa during Phase II

Theme i	Natural **dynamics** in space and time
Theme ii	Understanding natural **processes** of change
Theme iii	Understanding **human use**, value and impact in space and time
Theme iv	**Interventions** (strategies, tools, techniques) for sustainable use of biodiversity and biodiversity management
Theme v	**Inform policy** on local, national, and international level

Phase III (2007–2010)

During the preparation of Phase III, there was a clear shift of paradigms communicated by the BMBF as the funding institution. The German Ministry strongly emphasised the need for the application of scientific knowledge. As a consequence, the BIOTA Southern Africa project adjusted the project activities. Each work package was defined as a stepping stone in a cascade of steps (see Fig. 2) resulting in a contribution for finally applicable results in terms of either

E **Interventions** and **restoration**
or
F **Transformation** and **capacity development**

During Phase III the project was well developed and its reputation grew in Africa, as well as in Germany. The visit of the German Federal Chancellor Angela Merkel to BIOTA research sites near Cape Town, South Africa, in October 2007 (Photo 1) was a highlight that gave BIOTA excellent media visibility. In February 2008, the German Federal Minister of Edcuation and Research Annette Schavan visited BIOTA Observatories in the Savanna Biome southwest of Windhoek, Namibia, and discussed the needs for scientific contributions for sustainable management with Ministers and local landusers. In September/October 2008 some 400 participants met for the BIOTA AFRICA Congress, which was organised by BIOTA Southern Africa at Spier (South Africa).

BIOTA's contribution to global biodiversity monitoring and standardisation— in the past, at present, and in the future

Norbert Jürgens

The production of a book that summarises nearly a decade of BIOTA research is a good reason to also re-consider the value of the established observation network. What has been the contribution of the BIOTA observation network in the past, what lessons have we learnt and what is the road ahead of us?

Proving a concept

When BIOTA started to set up the first long-term observation sites, there was no comparable project worldwide. BIOTA established a standardised and coherent observation system at a large number of sites across the African continent (see Fig. 1 on page XX), within an ecosystem context, including a number of organismic groups and integrating measurements of important drivers i.e. weather and landuse. There were also a number of experiments, especially within the context of restoration and ecophysiological research, which added to the monitoring component at the observation sites. Until today, we are not aware of any project with a similar depth and breadth regarding biodiversity monitoring. Therefore, BIOTA played the role of a flagship project for DIVERSITAS INTERNATIONAL with its bioDISCOVERY core project and for the Biodiversity Observation Network (GEO BON) within GEOSS.

In addition, the implementation of BIOTA's Observatory network played a very motivating role for the scientific communities and for NGOs within the subregion. The fact that one project set up a network of standardised observation sites and, thereby went beyond the never-ending discussion about how the implementation of a long-term observation scheme can be harmonised within different scientific paradigms, made a huge difference for the scientific networks. It has even proven that such a large, ambitious objective is indeed possible! As a consequence, many new observation activities were initiated or at least discussed. For example, there were numerous discussions about the extension of the BIOTA observation transects into other countries cooperating within the ELTOSA network (Environmental Long-Term Observation network of Southern Africa). For Phase II of the BIOTA project, Namibia explicitly asked for the establishment of west-east transects, which subsequently ran from Walvis Bay to the Kalahari (compare Chapter II.1). In addition, researchers from outside BIOTA started to use BIOTA Observatories for additional monitoring activities.

Secondly, the continuous monitoring activity at the BIOTA Observatories that have been presented and discussed at international scientific fora, provided important information for the discussion regarding the extent and speed of environmental changes especially land degradation and loss of biodiversity. The value of such a spatial network of standardised observation sites is very obvious and relevant for decision-making. For example, the results of the botanical monitoring activities at the Observatories from the Cape to the Kavango, from the Namib coast to the Kalahari shows a cumulative increase in species number and cover during the last decade, probably mainly caused by above-average rainfall at the majority of the Observatories (see Article III.3.8, Fig. 8). This observation of a present "recovery" of the vegetation during a full decade is a very important message. This message might allow many local farmers to understand the projected climate change rather as a sign for the need for long-term adaptation and to a lesser degree as an instant Armageddon, which can only be escaped by immediate emigration to other regions.

Thirdly, the observation system facilitated a strong involvement of local rural communities into monitoring and research activities (see Article III.8.2 for some examples). This was even further enhanced with the full-time employment and training of members of local landuser communities as para-ecologists at several of the BIOTA observation sites (see Article III.8.3 for further details). The para-ecologists were involved in regular biodiversity monitoring and socio-ecological research activities. Through their work they understood the research aims, processes, and results and could thus help to facilitate the process of sharing the research findings with the landusers and other stakeholders. The integration of local knowledge into the scientific findings through mutual learning between researchers and para-ecologists also improved the applicability of the research results.

Today

Today, the BIOTA observation system is well organised, the monitoring methods have been improved based on field experience, and various steps of quality control have been set up, based on lessons learnt during the first years. The following lessons are worthwhile sharing.

1. Good biodiversity monitoring requires good taxonomic training and knowledge. As monitoring work needs to be repeated regularly (in our case, annually), it is rather an excep-

tion that plants for instance are found in good ecological condition, or in flower or with fruits, which then enables the identification of the species and replacement of former nicknames by proper scientific names.

2. It can therefore not be recommended to run a long-term monitoring activity with students, even PhD students, replacing each other every three or four years. Permanent staff with academic or even merely practical on-the-job training, supervised by a senior scientist, is the better solution. This is particularly true for vegetation monitoring, which requires identification of most of the plants at the site. Each change of staff requires a new process of learning species concepts and the identification of species in their different states of development and damage. During this learning phase, errors are inevitable. It requires a large effort on quality control, including additional field trips to verify preliminary identification, regarding past records.

3. As a response to the two above-mentioned problems, the project tried to ease the identification of the high diversity of plants. In countries with a long scientific tradition there are comprehensive identification keys for the flora of the whole country. However, country-wide keys like this are missing for Africa. Therefore, the project compiled large numbers of photographs well suited for fast identification in the field. More than 12000 images showing more than 1500 species are available at www.southernafricanplants.net (see also Article III.8.6). These numbers are rapidly growing and this collection represents the best botanical photo guide of the region.

4. Individual-based monitoring of plant populations is far more sensitive and reliable than monitoring based on cover estimates. For individual based monitoring the youngest development states need to be clearly discriminated from established states. In many climates with a defined unfavourable season this normally means that individuals, which have germinated during the most recent favourable season, need to be separated from those that are somewhat older and have survived the unfavourable season. Depending on the date of recording within the year, this may mean that only individuals that survived at least one unfavourable season (drought or winter), which normally is easily apparent, will be recorded.

5. While fixed-site monitoring is feasible for plants, it is more challenging when related to zoological taxa, due to the more unpredictable activity patterns of animals. In other cases the high number of species found in traps (such as during the good rainfall years between 2000 and 2009) can consume all available human-power in collecting, sorting, and identifying specimens from the field. In contrast, the observation of e.g. numbers of ant nest or active termite mounds is more feasible.

6. It may be reasonable to focus the work on specific functional types or guilds, which may be suitable as indicators, depending on the research goals and the desired temporal resolution. For example, it is very obvious that annual plant species in arid regions show a very specific response to timing, amount, and temporal pattern of rainfalls within one season. In contrast, for long-term trends, it may be more important to monitor only perennial aboveground species.

Future

It is well possible that the present favourable trend in climate and biodiversity response may turn into a decline in future. Then, it will be very important to use the BIOTA observation data as an early warning system. Hopefully, it will be possible to distinguish between various potential causes, be they related to climate, landuse, biological invasions, diseases, pollution, or other influences.

Therefore, and based on the public statement by Minister Schavan that she will not allow such an important project to be stopped, the botanical teams at the NBRI Windhoek and the team at the Biocentre Klein Flottbek of the University of Hamburg have made a commitment to continue the annual monitoring, albeit not at all Observatories every year, after the end of BMBF funding in April 2010.

At the same time, we are trying to find new funding in order to maintain the existing observation system and to expand these activities into new countries and regions. Whether such funding will be provided and from which institution for which part of Africa, cannot be foreseen today.

Fig. 1: BIOTA transects in southern Africa (see map by Keil et al. in Article III.2.2 for further details on topography).

Part II The BIOTA Observatories

Daniela H. Haarmeyer, Jona Luther-Mosebach, Jürgen Dengler, Ute Schmiedel, Manfred Finckh, Klaus Berger, Jürgen Deckert, Stephanie E. Domptail, Niels Dreber, Tarig Gibreel, Constanze Grohmann, Alexander Gröngröft, Andreas Haensler, Wiebke Hanke, Anke Hoffmann, Lara Husted, Fransiska N. Kangombe, Manfred Keil, Cornelia B. Krug, Timo Labitzky, Theresa Linke, Denise Mager, Wolfram Mey, Gerhard Muche, Christiane Naumann, Magdalena Pellowski, Leslie W. Powrie, Michael Pröpper, Michael C. Rutherford, Ute Schneiderat, Ben J. Strohbach, Katrin Vohland, Bettina Weber, Dirk Wesuls, Ulrike Wisch, Luciana Zedda, Burkhard Büdel, Tatyana Darienko, Kirstin Deutschewitz, Stephanie Dojani, Elke Erb, Thomas Falk, Thomas Friedl, Sven-Eric Kanzler, Cornelia Limpricht, K. Eduard Linsenmair, Kathrin I. Mohr, Tessa Oliver, Andreas Petersen, Gerhard Rambold, Ulrich Zeller, Jennifer Bausch, Britta M. Bösing, Nikolaus Classen, Jens Dorendorf, Wouter Dorigo, Karen J. Esler, Sophia Etzold, Angelika Graiff, Lisa Grotehusmann, Judith Hecht, Patrick Hoyer, Raphael Y. Kongor, Hartmut Lang, Lena A.B. Lieckfeld, Jens Oldeland, Jan Peters, Inga Ute Röwer, Zuna M. September, Tene Kwetche Sop, M. W. Gretel van Rooyen, Janne Weber, Jan Willer & Norbert Jürgens.

Methods

The BIOTA transects in southern Africa

[U. Schmiedel, N. Jürgens, J. Oldeland, J. Dengler, J. Luther-Mosebach, D.H. Haarmeyer & M. Finckh]

The BIOTA Southern Africa transects (Fig. 1, on left side) have been designed to describe biodiversity changes in space and time along two major climatic gradients in the western part of southern Africa (see also Articles III.2.1, III.3.1). The main transect runs from northeast Namibia (Observatory S01) to the Cape Peninsula (Observatory S33) in southwest South Africa. It is characterised by an extensive and varied rainfall gradient from a zone with high summer rainfall (536 mm a^{-1}) in the north to a region of high winter rainfall (698 mm a^{-1}) in the south (Figs. 2 & 3). Lowest mean annual rainfall along the transect (see also Table 1) is recorded at the very steep transition zone between summer and winter rainfall at the Gariep River at the border between Namibia and South Africa (Fig. 3). The Observatory with the lowest annual precipitation in the summer rainfall zone is the Observatory Karios (S12; 98 mm) and the Observatories with the lowest annual precipitation in the winter rainfall zone are Numees (S20) and Groot Derm (S21) each of which receives about 57 mm annual precipitation and Koeroegap Vlakte (S18) with 73 mm (compare Fig. 3). The Observatories Karios

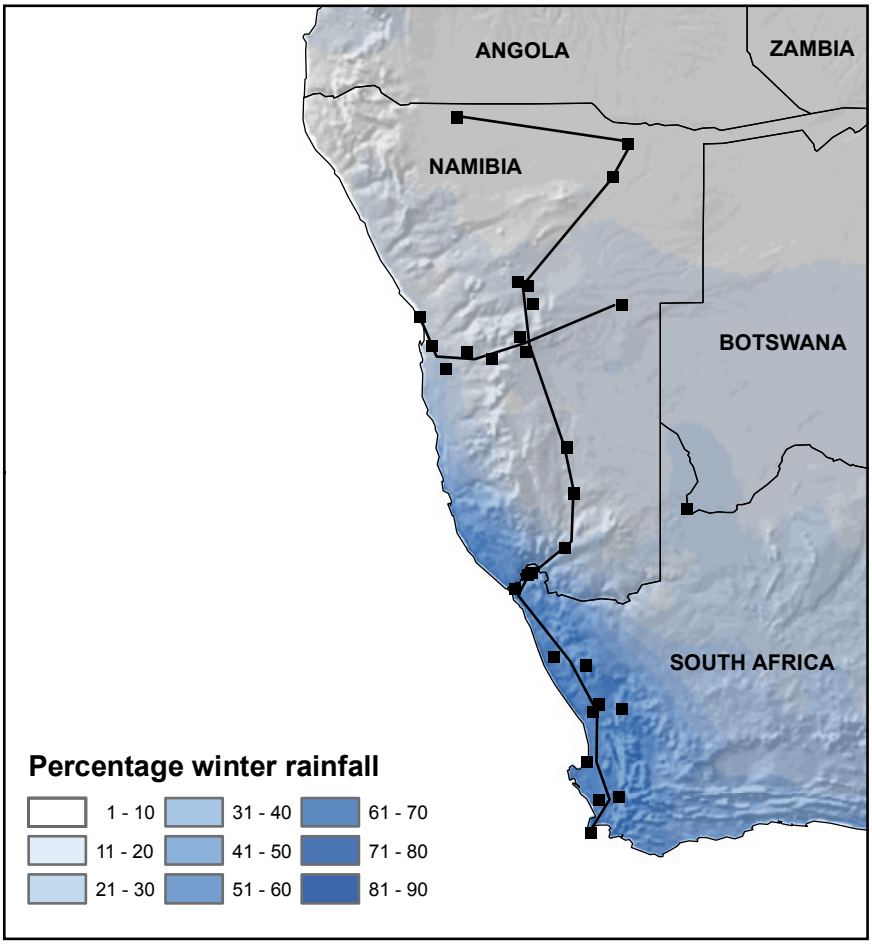

Fig. 2: Percentage of winter rainfall in the BIOTA Southern Africa study region (based on data from Hijmans et al. 2005).

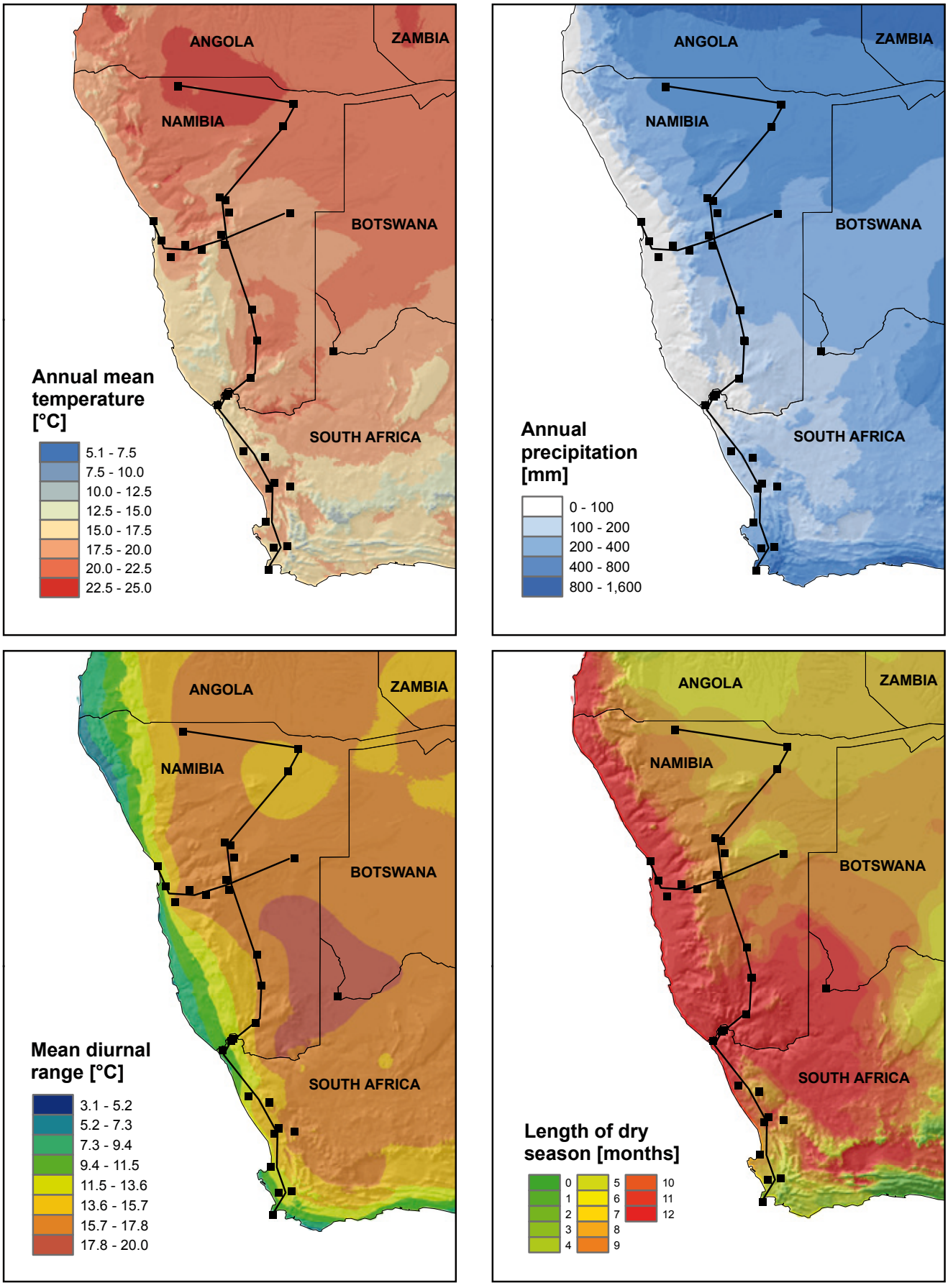

Fig. 3: Climatic features of the BIOTA Southern Africa study region (based on data from Hijmans et al. 2005).

Table 1: Overview of the established BIOTA Observatories in southern Africa (as June 2010) with their main characteristics (see also Electronic Appendix)

Obs. No.	Name	Country	Province/region	District/constituency	Locality	Farm name and number	Rainfall season	Imple-mentation	Latitude	Longitude	Altitude (a.s.l.)	Biome
S01	Mile 46	Namibia	Kavango	Rundu	near Cove	Alex Marunda LDC	Summer	2001	18.301826 S	19.247311 E	1180 m	Woodland Savanna
S02	Mutompo	Namibia	Kavango	Rundu	near Cove	Mutompo	Summer	2001	18.301782 S	19.258331 E	1180 m	Woodland Savanna
S03	Sonop	Namibia	Otjozondjupa	Grootfontein	near Maroelaboom	Sonop 903	Summer	2001	19.073818 S	18.903897 E	1236 m	Woodland Savanna
S42	Ogongo	Namibia	Omusati	Uutapi	Ogongo	Ogongo	Summer	2006	17.697198 S	15.305209 E	1103 m	Woodland Savanna
S43	Omano go Ndjamba	Namibia	Omusati	Uutapi	Ogongo	Omano go Ndjamba	Summer	2006	17.708034 S	15.264798 E	1100 m	Woodland Savanna
S04	Toggekry	Namibia	Otjozondjupa	Okahandja	Omatako	Toggekry-Omatako	Summer	2001	21.501438 S	16.729326 E	1519 m	Thornbush Savanna
S05	Otjiamongombe	Namibia	Otjozondjupa	Okahandja	Erichsfelde	Otjiamongombe West 44	Summer	2001	21.596834 S	16.935106 E	1495 m	Thornbush Savanna
S06	Okamboro	Namibia	Otjozondjupa	Omatako	Ovitoto	Ovitoto 55	Summer	2001	22.019179 S	17.062480 E	1490 m	Thornbush Savanna
S37	Rooisand	Namibia	Khomas	Windhoek	Rooisand Desert Ranch	Chausib	Summer	2004	23.294542 S	16.104978 E	1160 m	Thornbush Savanna
S38	Claratal	Namibia	Khomas	Windhoek	Windhoek	Claratal	Summer	2004	22.779382 S	16.774852 E	1865 m	Thornbush Savanna
S41	Sandveld	Namibia	Omaheke	Gobabis	near Drimiopsis	Dipcadi 389	Summer	2004	22.043351 S	19.133903 E	1523 m	Thornbush Savanna
S17	Alpha	South Africa	Northern Cape	Siyanda	Askham	Alpha	Summer	2001	26.760917 S	20.614021 E	896 m	Thornbush Savanna
S39	Narais	Namibia	Khomas	Windhoek	Rehoboth	Narais	Summer	2004	23.120380 S	16.896578 E	1624 m	Nama Karoo
S40	Duruchaus	Namibia	Khomas	Windhoek	Rehoboth	Duruchaus	Summer	2004	23.133184 S	16.899996 E	1614 m	Nama Karoo
S08	Niko North	Namibia	Hardap	Mariental	near Gibeon	Niko 377	Summer	2001	25.342506 S	17.839093 E	1070 m	Nama Karoo
S09	Niko South	Namibia	Hardap	Mariental	near Gibeon	Niko 377	Summer	2001	25.333413 S	17.848966 E	1076 m	Nama Karoo
S10	Gellap Ost	Namibia	Karas	Berseba	near Keetmanshoop	Gellap Ost 3	Summer	2001	26.401195 S	18.004842 E	1099 m	Nama Karoo
S11	Nabaos	Namibia	Karas	Berseba	near Keetmanshoop	Nabaos 7	Summer	2001	26.390643 S	17.995478 E	1045 m	Nama Karoo
S12	Karios	Namibia	Karas	Karasburg	Gondwana Cañon Park	Karios	Summer	2001	27.676516 S	17.803958 E	909 m	Nama Karoo
S16	Wlotzkasbaken	Namibia	Erongo	Swakopmund	Wlotzkasbaken	Wlotzkasbaken - Mile 14	Summer	2001	22.315003 S	14.459480 E	73 m	Namib Desert/Succ. Karoo
S34	Kleinberg	Namibia	Erongo	Swakopmund	Walvis Bay	Kleinberg	Summer	2004	22.989838 S	14.725183 E	188 m	Namib Desert/Succ. Karoo
S35	Gobabeb	Namibia	Erongo	Swakopmund	Gobabeb	Gobabeb	Summer	2004	23.532409 S	15.046890 E	419 m	Namib Desert
S36	Ganab	Namibia	Erongo	Swakopmund	Namib-Naukluft Park	Ganab	Summer	2004	23.121820 S	15.538440 E	995 m	Namib Desert
S18	Koeroegap Vlakte	South Africa	Northern Cape	Namakwa	Sendelingsdrif	Koeroegap Vlakte	Winter	2001	28.226646 S	17.025668 E	635 m	Succulent Karoo
S20	Numees	South Africa	Northern Cape	Namakwa	Sendelingsdrif	Numees	Winter	2001	28.293087 S	16.953805 E	362 m	Succulent Karoo
S21	Groot Derm	South Africa	Northern Cape	Namakwa	Alexander Bay	Grootderm	Winter	2001	28.612340 S	16.654331 E	193 m	Succulent Karoo
S22	Soebatsfontein	South Africa	Northern Cape	Namakwa	Soebatsfontein	Soebatsfontein Commonage	Winter	2001	30.186502 S	17.543373 E	392 m	Succulent Karoo
S24	Paulshoek	South Africa	Northern Cape	Namakwa	Leliefontein	Leliefontein 624	Winter	2001	30.385680 S	18.275790 E	1048 m	Succulent Karoo
S25	Remhoogte	South Africa	Northern Cape	Namakwa	Leliefontein	Remhoogte 416	Winter	2001	30.395364 S	18.275695 E	1027 m	Succulent Karoo
S26	Goedehoop	South Africa	Western Cape	West Coast	Van Rhynsdorp	Flaminkvlakte 111	Winter	2001	31.276713 S	18.591521 E	245 m	Succulent Karoo
S27	Ratelgat	South Africa	Western Cape	West Coast	Van Rhynsdorp	Luiperskop 211	Winter	2001	31.285881 S	18.600308 E	239 m	Succulent Karoo
S28	Moedverloren	South Africa	Western Cape	West Coast	Vredendal	Moedverloren 208	Winter	2001	31.460932 S	18.439058 E	140 m	Succulent Karoo
S29	Rocherpan	South Africa	Western Cape	West Coast	Piquetberg	Rocherpan	Winter	2001	32.600848 S	18.305600 E	35 m	Fynbos
S31	Riverlands	South Africa	Western Cape	West Coast	Malmesbury	Riverlands	Winter	2001	33.489343 S	18.580119 E	140 m	Fynbos
S32	Elandsberg	South Africa	Western Cape	Cape Winelands	Wellington	Elandsberg	Winter	2001	33.431134 S	19.030690 E	95 m	Fynbos
S33	Cape of Good Hope	South Africa	Western Cape	City of Cape Town	Table Mountain National Park	Olifantsbos	Winter	2001	34.260204 S	18.392285 E	83 m	Fynbos
S45	Nieuwoudtville	South Africa	Northern Cape	Namakwa	Nieuwoudtville	Glenlyon	Winter	2007	31.390019 S	19.128797 E	722 m	Fynbos

Methods

Fig. 4: Biomes of southern Africa, modified after Mucina & Rutherford (2006) and Mendelsohn et al. (2002) (map drawn by Uwe Ulrich Jäschke and Karen Langner).

and Koeroegap Vlakte are only 100 km apart, and this short distance is indicative of the extremely steep rainfall seasonality gradient that exists between summer and winter rainfall zones in this part of southern Africa.

The other main rainfall gradient in southern Africa is described by the central Namibian coast-inland transect that runs from the Observatories Wlotzkasbaken (S16) and Kleinberg (S34) at the coast of the Namib Desert with only 12 or 16 mm precipitation per year to the eastern part of central Namibia (Observatory Sandveld, S41) with almost 400 mm precipitation per year. This transect is also characterised by a steep increase in the mean annual diurnal temperature range (Fig. 2), which describes the mean annual difference in the temperature between day and night. This diurnal range is lowest (< 5°C) along the coast but increases significantly inland (< 17.8°C) and is most extreme in the Kalahari basin where the Observatory Alpha (S17) is located (20°C).

The northern Namibian west-east transect is represented by the Observatories Ogongo (S42) and Omano go Ndjamba (S43) in the west with 469 mm a^{-1} and the more humid Observatories Mile 46 (S01) and Mutompo (S02) with 698 mm a^{-1} in the east. The Observatories in the northwest (S42, S43) also experience the highest mean annual temperature compared with other Observatories in the study area (Fig. 2). The areas with the lowest annual rainfall in the study region of southern Africa also experience the longest dry seasons (up to 12 months per year). New sites for Observatories in Kaokoveld and Damaraland towards the west coast of northern Namibia have been identified and preliminary sampling of botanical data has been done.

These gradients straddle distinct biomes (Fig. 4), which are characterised by different climatic regimes (see Article III.2.1 on climate patterns in southern Africa). This, in turn, influences the geomorphology and soils (Article III.3.3) and drive the composition of plant life forms (Article III.3.9) as well as the other biota in the biome.

Climate change projections (Articles III.2.1, III.3.1) suggest that the western part of southern Africa will be severely affected by changes in rainfall seasonality and total amount of rainfall, by increase in rainfall variability as well as in changes in temperature. These projected changes will also have effects on the geographical distribution of the biota of the biomes that will most likely be detectable along gradients and at the transition zones between the biomes.

Therefore, the focal study sites of BIOTA Southern Africa's interdisciplinary research and long-term monitoring programme, the BIOTA Biodiversity Observatories (see Subchapter II.1.2), have been placed along this major climatic gradient, covering all six biomes in the region.

The BIOTA Observatories have been placed in landscapes that are representa-

tive of larger parts of the respective biome by being exposed to zonal conditions in terms of climate, geomorphology, and soils. Ecosystems like mountains, major riverbeds or other geomorphologic features, which reflect azonal environmental conditions or landuse types, and which are atypical for the larger biome, have been avoided (but see the Observatory Numees [S20] as the only exception from this rule).

Every biome is characterised by its own range of land tenure and landuse types as defined by the environmental (climate and soil) and socio-economic frame conditions. The main landuse and tenure types within the biomes are represented in BIOTA's experimental design. Only in the northern Biome (Woodland Savanna) and the southern end (Fynbos Biome) of the BIOTA north-south transect is precipitation sufficient to allow for regular ploughing and cropping. Landuse in the more arid biomes along the transect relies primarily on grazing of rangeland (i.e. natural vegetation), by cattle, sheep, and goats or wildlife, depending on the carrying capacity of the land and on the particularly land tenure arrangement, which exists at a site. Nature conservation by the state, parastatal organisations or private land owners has become increasingly important in the region over the last two decades. Conservation as a landuse practice on private and state land typically aims to benefit economically from tourism.

Depending on the historic development and recent governance, different land tenure arrangements (mainly communal, privately owned, and state) and their respective land management systems co-exist in southern Africa. The Observatories have been placed in a way that the impacts of the biome-specific landuse and land tenure on the environment are documented and monitored.

Due to the different biome-specific natural conditions and ecological dynamics as well as land management and governance types, the biomes face different environmental challenges (see also Chapters III.5 and IV.1–IV.5). In the Woodland Savanna for instance deforestation through illegal logging causes rapid loss of natural resources and biodiversity. In the more arid Thornbush Savanna, however, the main challenge for sustainable land management emerges from the impact of bush encroachment that decreases grazing potential. The even more arid Nama Karoo, with its relatively low primary production potential, is prone to the loss of biomass and soil fertility caused by overgrazing and trampling. Large parts of the Namib Desert Biome are too arid and thus not subject to agriculture. However, unsustainable recreation activities, urban development, and an increase in mining activities form a severe threat to these fragile ecosystems. The Succulent Karoo Biome, on the other hand, is mainly threatened by overutilization through the impact of heavy stocking, which can lead to changes in plant species composition in favour of short-lived ephemeral plants thus increasing the risk for farmers during drought years. Finally, the Fynbos Biome receives enough rainfall to allow for crop farming with the effect that large parts of the lowlands within this biome are fragmented through ploughing. This in turn, can lead to the irreversible destruction of ecosystem and concomitant loss of biodiversity. Landscape fragmentation can even have a negative effect on ecosystem processes in the remaining, relatively intact "island".

The described management impacts have knock-on effects for a broad range of ecosystem components and functions, which may be further aggravated through projected climate change. The BIOTA Observatories (see below) have been developed and implemented as a standardised long-term biodiversity monitoring tool. The Observatories provide comparable data on the changes in inventories of the biota and their biotic and abiotic drivers over time.

Spatial design of the BIOTA Biodiversity Observatories

[N. Jürgens, U. Schmiedel, A. Gröngröft, A. Petersen, M. Finckh, D.H. Haarmeyer & J. Dengler]

The BIOTA Biodiversity Observatories have been designed as a standardised tool for spatially-explicit biodiversity monitoring at different spatial scales. (Schmiedel & Jürgens 2005; Jürgens 1998, 2006; Krug et al. 2006). They are large enough to be representative of a landuse and landscape type but comprise multiple smaller plots in order to cover the different habitat types and beta-diversity within the landscape. Due to the comparability of the biodiversity assessment and monitoring data among the different Observatories and researcher teams, the same disciplinary methodology has been applied at all sites. The disciplinary methods and sampling design are described in detail in Part II.1.3.

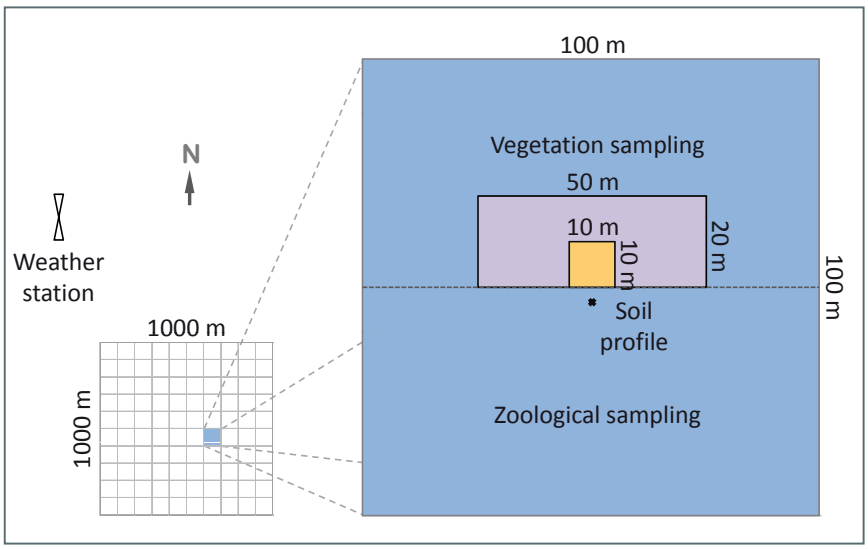

Fig. 5: Schematic layout of a BIOTA Observatory in southern Africa and arrangement of different sampling areas within one of the hectare plots.

A BIOTA Biodiversity Observatory encompasses an area of 1 km² (1000 m × 1000 m) with boundaries oriented along cardinal directions (Fig. 5). The 1-km² area is divided into 100 1-hectare plots of 100 m × 100 m. All corner points are geo-referenced by the use of a differential GPS and well marked with red painted metal poles. The hectare plots are numbered from 00 to 99 starting in the northwest corner and running from west to the east and southwards through the BIOTA Observatory. The numbers of the hectare plots are noted on small metal tags that are attached to the northwest corner post of each hectare. The hectare plots represent the largest replicated sampling unit within the BIOTA Observatory. The same layout and numbering of the hectare plots is applied for BIOTA Observatories in West Africa and Morocco, although the design is mirrored across the equator.

In general, the number of investigated hectare plots should be large enough to allow a statistically robust description of the BIOTA Observatory for the respective organism group. For a multidisciplinary team, however, it is critical that the activities of the involved disciplines are aligned spatially in order to achieve the best possible integration of data. On the other hand, such a spatial aligning of the different groups of an interdisciplinary team at the same hectare plots brings along the risk of disturbance, interference, and artefacts caused by the various scientific activities.

To reduce such problems, we assigned areas within each hectare plot for different purposes (see Fig. 5). Equatorwards of the centre of the hectare plot, the permanent botanical monitoring plots for lichens, biological soil crusts, and vascular plants was laid out whereas the zoological trapping (often involving digging or interference with plants) was assigned to the pole-ward half the hectare plot. The soil scientists placed their soil profiles 4 m pole-wards from the centre point of the hectare plot. Beyond this, experimental studies (as described for instance in Articles III.6.1–III.6.4) are allowed only outside the 1-km² boundary of the BIOTA Observatory and the researchers are asked to walk primarily along the lines from corner to corner of the hectare plots and leave its central parts undisturbed. Disturbance caused by local landusers as part of their usual practices were accepted, even within the Observatories. Study results concerning the impact of landuse on the diversity are described in Chapter III.5.

The spatial aligning of the sampling of an interdisciplinary team to the same hectare plots was guaranteed through our procedure for ranking and selecting the hectare plots. Some of the disciplines applied techniques that are too laborious to allow investigation of a larger number of hectare plots. This fact could result in spatial separation of activities and hence cause a lack of integration of these disciplines and their respective organism groups. To overcome this problem, all disciplines agreed to do their sampling work on hectare plots following a predefined sequence. This sequence was defined by a ranking procedure, which assigns to each hectare plot a rank from 1 to 100 (Fig. 6).

Complete randomization of plots in heterogeneous environments involves the risk of disregarding rare habitat types (Wildi 1986, Ruxton & Colegrave 2006, Roleček et al. 2007). To ensure a representative randomized sampling we employed a stratified sampling design (Wildi 1986) and developed a ranking method based on the d'Hondt divisor rules procedure (Balinski & Ramirez 1999, Palomares & Ramirez 2003, Taagepera & Shugart 1989). For this purpose, each hectare plot was characterized by a combination of its predominant vegetation and geomorphological structures, further referred to as "habitat type" (Fig. 6). The basic principle of the d'Hondt divisor method is to divide the number of hectare plots of each stratum (i.e. habitat type) by natural numbers ($N = 1, 2, 3, 4, ...$). The resulting quotients of all habitat types are then sorted in descending order. The highest quotient and therefore its habitat type would be allocated to rank number 1, the habitat type of the second quotient would be ranked second, and so on. With this method, a sequence of the habitat types can be compiled according to their real proportions.

We deviated from the original method of d'Hondt, by increasing the weighting for the proportion of rare habitat types by using the square root of habitat frequency as a basis for the determination of the ranking order. This modification had the effect of positioning the hectare plots of less common habitat types on higher ranks. This effect was desirable because it ensures a minimum of replicates even for rare habitat types in small sample sizes. Given the allocation of the habitat types, the rank number of the hectare plots was selected randomly within each of them. This resulted in a ranking of all hectare plots, each with a ranking number between 1 and 100. Fig. 6 shows an example of the grid structure and ranking order of a BIOTA Observatory. Besides achieving representativeness among the plots sampled, the application of this ranking method allowed for interdisciplinary studies as the same ranking, and therefore the same sequence of plots, was applied across all disciplines. Each discipline defined the number of hectare plots to be analyzed (x) and then carried out its research on the hectare plots of ranks 1 to x. Accordingly, the highest-ranked hectare plots were jointly sampled by all disciplines working on the BIOTA Observatory.

	0	1	2	3	4	5	6	7	8	9
0	54	24	40	67	**1**	**16**	80	91	**19**	56
1	72	95	28	49	31	33	34	51	62	88
2	84	78	100	26	98	41	43	94	99	27
3	71	85	37	**11**	75	46	69	**7**	68	90
4	66	**2**	77	81	23	**13**	82	**8**	65	96
5	57	70	30	**12**	74	22	55	**15**	97	**4**
6	73	47	29	**10**	79	**17**	**5**	64	59	93
7	76	83	32	50	**18**	36	45	92	52	**20**
8	35	21	89	53	39	44	**6**	87	58	**9**
9	48	61	38	86	25	**3**	60	63	**14**	42

1 Low open shrubland on stony plain
2 Low open shrubland on accumulation area
3 Low open shrubland on slope
4 Low open shrubland with intersection of river

Fig. 6: Example of the grid system of a BIOTA Observatory (S09, Niko South, Namibia, see Table 1) with ranking numbers. Line and row numbers are given at the left and top margins, respectively; the plot numbers are derived by the combination of the line number (first figure) and the row number (second figure). Different colours represent the four habitat types distinguished on this BIOTA Observatory. The numbers of the 20 highest ranked grids (those on which vascular plants are analysed) are printed in bold letters.

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S02 Mutompo: Berger, K., Büdel, B., Deckert, J., Deutschewitz, K., Dojani, S., Falk, T., Grohmann, C., Gröngröft, Haarmeyer, D.H., A., Haensler, A., Hecht, J., Hoffmann, A., Keil, M., Labitzky, T., Linsenmair, K.E., Luther-Mosebach, J., Mager, D., Mills, A., Petersen, A., Pröpper, M., Rambold, G., Strohbach, B.J., Weber, B., Wisch, U., Zedda, L.

S03 Sonop: Berger, K., Büdel, B., Darienko, T., Deckert, J., Deutschewitz, K., Dojani, S., Friedl, T., Gröngröft, A., Haarmeyer, D.H., Haensler, A., Hoffmann, A., Keil, M., Labitzky, T., Luther-Mosebach, J., Mager, D., Mills, A., Mohr, K., Petersen, A., Rambold, G., Strohbach, B.J., Weber, B., Wisch, U., Zedda, L.

S04 Toggekry: Berger, K., Classen, N., Deckert, J., Dorigo, W., Dreber, N., Grohmann, C., Gröngröft, A., Haarmeyer, D.H., Haensler, A., Hoffmann, A., Jürgens, N., Keil, M., Labitzky, T., Linsenmair, K.E., Luther-Mosebach, J., Mager, D., Mey, W., Mills, A., Oldeland, J., Petersen, A., Rambold, G., Wesuls, D., Wisch, U., Zedda, L.

S05 Otjiamongombe: Austermühle, R., Berger, K., Büdel, B., Darienko, T., Deckert, J., Deutschewitz, K., Dojani, S., Friedl, T., Graiff, A., Grohmann, C., Gröngröft, A., Haarmeyer, D.H., Haensler, A., Hoffmann, A., Keil, M., Labitzky, T., Linsenmair, K.E., Luther-Mosebach, J., Mager, D., Mey, W., Mills, A., Mohr, K., Petersen, A., Rambold, G., Strohbach, B.J., Weber, B., Wesuls, D., Wisch, U., Zedda, L.

S06 Okamboro: Berger, K., Falk, T., Gröngröft, A., Haarmeyer, D.H., Haensler, A., Keil, M., Labitzky, T., Luther-Mosebach, J., Mager, D., Oldeland, J., Petersen, A., Rambold, G., Schneiderat, U., Wesuls, D., Wisch, U., Zedda, L.

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S10 Gellap Ost: Berger, K., Deckert, J., Dengler, J., Domptail, S.E., Dorendorf, J., Dreber, N., Grohmann, C., Gröngröft, A., Grotehusmann, L., Haarmeyer, D.H., Haensler, A., Hoffmann, A., Keil, M., Labitzky, T., Linsenmair, K.E., Luther-Mosebach, J., Mager, D., Mey, W., Mills, A., Petersen, A., Rambold, G., Wisch, U., Zedda, L., Zeller, U.

S11 Nabaos: Bausch, J., Berger, K., Deckert, J., Dreber, N., Falk, T., Gibreel, T., Grohmann, C., Gröngröft, A., Haarmeyer, D.H., Haensler, A., Hoffmann, A., Keil, M., Labitzky, T., Linsenmair, K.E., Luther-Mosebach, J., Mager, D., Mills, A., Petersen, A.,

Rambold, G., Schneiderat, U., Wisch, U., Zedda, L.

S12 Karios: Berger, K., Büdel, B., Darienko, T., Deckert, J., Deutschewitz, K., Dojani, S., Friedl, T., Grohmann, C., Gröngröft, A., Haarmeyer, D.H., Haensler, A., Hoffmann, A., Jürgens, N., Kanzler, S.-E., Labitzky, T., Linsenmair, K.E., Luther-Mosebach, J., Mager, D., Mey, W., Mills, A., Mohr, K., Petersen, A., Rambold, G., Schmiedel, U., Weber, B., Wisch, U., Zedda, L.

S16 Wlotzkasbaken: Berger, K., Büdel, B., Darienko, T., Deckert, J., Deutschewitz, K., Dojani, S., Erb, E., Friedl, T., Gröngröft, A., Haarmeyer, D.H., Haensler, A., Hoffmann, A., Jürgens, N., Keil, M., Labitzky, T., Luther-Mosebach, J., Mager, D., Mey, W., Mills, A., Mohr, K., Petersen, A., Rambold, G., Weber, B., Wisch, U., Zedda, L.

S17 Alpha: Berger, K., Deckert, J., Gröngröft, A., Haarmeyer, D.H., Haensler, A., Hoffmann, A., Keil, M., Labitzky, T., Luther-Mosebach, J., Mager, D., Mills, A., Petersen, A., van Rooyen, M.W., Schmiedel, U., Wisch, U.

S18 Koeroegap Vlakte: Berger, K., Deckert, J., Dreber, N., Grohmann, C., Gröngröft, A., Haarmeyer, D.H., Haensler, A., Hoffmann, A., Jürgens, N., Keil, M., Labitzky, T., Linsenmair, K.E., Luther-Mosebach, J., Mager, D., Mey, W., Mills, A., Petersen, A., Schmiedel, U., Willer, J., Wisch, U.

S20 Numees: Berger, K., Deckert, J., Grohmann, C., Gröngröft, A., Haarmeyer, D.H., Haensler, A., Hoffmann, A., Jürgens, N., Keil, M., Labitzky, T., Linsenmair, K.E., Luther-Mosebach, J., Mager, D., Mey, W., Mills, A., Petersen, A., Rambold, G., Wisch, U., Zedda, L.

S21 Groot Derm: Berger, K., Büdel, B., Darienko, T., Deckert, J., Deutschewitz, K., Dojani, S., Dreber, N., Friedl, T., Gröngröft, A., Haarmeyer, D.H., Haensler, A., Hoffmann, A., Jürgens, N., Keil, M., Labitzky, T., Luther-Mosebach, J., Mager, D., Mey, W., Mills, A., Mohr, K., Petersen, A., Rambold, G., Schmiedel, U., Weber, B., Wisch, U., Zedda, L.

S22 Soebatsfontein: Berger, K., Büdel, B., Darienko, T., Deckert, J., Dengler, J., Deutschewitz, K., Dojani, S., Falk, T., Friedl, T., Grohmann, C., Gröngröft, A., Haarmeyer, D.H., Haensler, A., Hoffmann, A., Hoyer, P., Keil, M., Sop, K.T., Labitzky, T., Linke, T., Linsenmair, K.E., Luther-Mosebach, J., Mager, D., Mills, A., Mohr, K., Petersen, A., Rambold, G., Röwer, I.U., Schmiedel, U., Weber, B., Wisch, U., Zedda, L.

S24 Paulshoek: Berger, K., Büdel, B., Darienko, T., Deckert, J., Dengler, J., Deutschewitz, K., Dojani, S., Friedl, T., Gröngröft, A., Haarmeyer, D.H., Haensler, A., Hanke, W., Hoffmann, A., Keil, M., Labitzky, T., Luther-Mosebach, J., Mager, D., Mills, A., Mohr, K., Petersen, A., Rambold, G., van Rooyen, M.W., Schmiedel, U., Weber, B., Weber, J., Wisch, U., Zedda, L.

S25 Remhoogte: Berger, K., Büdel, B., Darienko, T., Deckert, J., Deutschewitz, K., Dojani, S., Friedl, T., Gröngröft, A., Haarmeyer, D.H., Haensler, A., Hanke, W., Hoffmann, A., Keil, M., Labitzky, T., Luther-Mosebach, J., Mager, D., Mills, A., Mohr, K., Petersen, A., Rambold, G., Weber, B., Wisch, U., Zedda, L.

S26 Goedehoop: Berger, K., Büdel, B., Darienko, T., Deckert, J., Deutschewitz, K., Dojani, S., Friedl, T., Gröngröft, A., Haarmeyer, D.H., Haensler, A., Hoffmann, A., Keil, M., Labitzky, T., Luther-Mosebach, J., Mager, D., Mills, A., Mohr, K., Petersen, A., Rambold, G., Schmiedel, U., Weber, B., Wisch, U., Zedda, L.

S27 Ratelgat: Berger, K., Bösing, B.M., Büdel, B., Darienko, T., Deckert, J., Dengler, J., Deutschewitz, K., Dojani, S., Etzold, S., Friedl, T., Gröngröft, A., Haarmeyer, D.H., Haensler, A., Hoffmann, A., Keil, M., Labitzky, T., Luther-Mosebach, J., Mager, D., Mills, A., Mohr, K., Petersen, A., Rambold, G., Schmiedel, U., Weber, B., Wisch, U., Zedda, L.

S28 Moedverloren: Berger, K., Deckert, J., Haarmeyer, D.H., Haensler, A., Hoffmann, A., Keil, M., Labitzky, T., Luther-Mosebach, J., Mills, A., Rambold, G., Schmiedel, U., Zedda, L.

S29 Rocherpan: Berger, K., Haarmeyer, D.H., Haensler, A., Keil, M., Kongor, R.Y., Labitzky, T., Luther-Mosebach, J.

S31 Riverlands: Berger, K., Esler, K.J., Haarmeyer, D.H., Haensler, A., Husted, L.B., Keil, M., Krug, C., Labitzky, T., Luther-Mosebach, J., Powrie, L.W., Rambold, G., Rutherford, M.C., Zedda, L.

S32 Elandsberg: Berger, K., Gröngröft, A., Haarmeyer, D.H., Haensler, A., Husted, L.B., Keil, M., Krug, C., Labitzky, T., Luther-Mosebach, J., Mager, D., Petersen, A., Powrie, L.W., Rambold, G., Rutherford, M.C., Wisch, U., Zedda, L.

S33 Cape of Good Hope: Berger, K., Gröngröft, A., Haarmeyer, D.H., Haensler, A., Husted, L.B., Keil, M., Labitzky, T., Luther-Mosebach, J., Mager, D., Petersen, A., Powrie, L.W., Rambold, G., Rutherford, M.C., Wisch, U., Zedda, L.

S34 Kleinberg: Berger, K., Büdel, B., Deutschewitz, K., Dojani, S., Grohmann, C., Haarmeyer, D.H., Haensler, A., Jürgens, N., Keil, M., Labitzky, T., Linsenmair, K.E., Luther-Mosebach, J., Rambold, G., Weber, B., Zedda, L.

S35 Gobabeb: Berger, K., Büdel, B., Deutschewitz, K., Dojani, S., Grohmann, C., Haarmeyer, D.H., Haensler, A., Jürgens, N., Keil, M., Labitzky, T., Linsenmair, K.E., Luther-Mosebach, J., Mey, W., Rambold, G., Weber, B., Zedda, L.

S36 Ganab: Berger, K., Deckert, J., Grohmann, C., Haarmeyer, D.H., Haensler, A., Hoffmann, A., Jürgens, N., Keil, M., Labitzky, T., Linsenmair, K.E., Luther-Mosebach, J., Mey, W., Mills, A., Rambold, G., Schmiedel, U., Zedda, L.

S37 Rooisand: Berger, K., Deckert, J., Grohmann, C., Haarmeyer, D.H., Haensler, A., Hoffmann, A., Keil, M., Labitzky, T., Linsenmair, K.E., Luther-Mosebach, J., Mey, W., Mills, A., Rambold, G., Strohbach, B.J., Zedda, L.

S38 Claratal: Berger, K., Deckert, J., Grohmann, C., Gröngröft, A., Haarmeyer, D.H., Haensler, A., Hoffmann, A., Keil, M., Labitzky, T., Linsenmair, K.E., Luther-Mosebach, J., Mager, D., Mey, W., Mills, A., Petersen, A., Rambold, G., Strohbach, B.J., Wisch, U., Zedda, L.

S39 Narais: Berger, K., Büdel, B., Darienko, T., Deckert, J., Dengler, J., Deutschewitz, K., Dojani, S., Dorigo, W., Friedl, T., Grohmann, C., Gröngröft, A., Haarmeyer, D.H., Haensler, A., Hoffmann, A., Jürgens, N., Keil, M., Labitzky, T., Lieckfeld, L.A.B., Limpricht, C., Linsenmair, K.E., Luther-Mosebach, J., Mager,

D., Mills, A., Mohr, K., Naumann, C., Oldeland, J., Pellowski, M., Peters, J., Petersen, A., Rambold, G., Weber, B., Wesuls, D., Wisch, U., Zedda, L.

S40 Duruchaus: Berger, K., Büdel, B., Darienko, T., Deckert, J., Deutschewitz, K., Dojani, S., Friedl, T., Grohmann, C., Gröngröft, A., Haarmeyer, D.H., Haensler, A., Hoffmann, A., Keil, M., Labitzky, T., Lang, H., Limpricht, C., Linsenmair, K.E., Luther-Mosebach, J., Mager, D., Mills, A., Mohr, K., Naumann, C., Petersen, A., Rambold, G., Weber, B., Wesuls, D., Wisch, U., Zedda, L.

S41 Sandveld: Berger, K., Deckert, J., Gröngröft, A., Haarmeyer, D.H., Haensler, A., Hoffmann, A., Keil, M., Labitzky, T., Luther-Mosebach, J., Mager, D., Mey, W., Mills, A., Petersen, A., Rambold, G., September, Z.M., Strohbach, B.J., Wisch, U., Zedda, L.

S42 Ogongo: Berger, K., Gröngröft, A., Haarmeyer, D.H., Haensler, A., Kangombe, F.N., Keil, M., Labitzky, T., Luther-Mosebach, J., Mager, D., Petersen, A., Strohbach, B.J., Wisch, U.

S43 Omano go Ndjamba: Berger, K., Gröngröft, A., Haarmeyer, D.H., Haensler, A.,.Kangombe, F.N., Keil, M., Labitzky, T., Luther-Mosebach, J., Mager, D., Petersen, A., Strohbach, B.J., Wisch, U.

S45 Nieuwoudtville: Berger, K., Haarmeyer, D.H., Haensler, A., Luther-Mosebach, J., Oliver, T., Schmiedel, U.

Sampling and analytical methods used for the standardised description of the Observatories

Diversity measures

[J. Dengler]

Introduction

Biodiversity and the diversity of the abiotic environment are multi-faceted phenomena (van der Maarel 1997, Hubbell 2001, Gaston & Spicer 2004, Magurran 2004, Storch et al. 2007, Dengler 2009b). Most basically, biodiversity means "variety in biological items (features, object, types, whatever), whereby both the number of items and the quantitative relations between them are of importance" (van der Maarel 1997). Biodiversity indices referring to the mere number of items are sometimes called richness measures and indices taking into account their quantitative proportions heterogeneity measures (Magurran 2004). A further distinction is whether different items are considered as equal or whether the degree of distinctness between items is considered in the calculation of a specific diversity measure (van der Maarel 1997). For example, one could give less weight to two species from the same genus than to two species from different families. Nearly all aspects of diversity are scale-dependent, i.e. both the patterns occurring and the processes underlying these are strongly influenced by the spatial (and temporal) scale at which they are analysed (Storch et al. 2007, Dengler 2009b). Accordingly, it is crucial to accompany each diversity measure with the (spatial and temporal) scale at which it was determined. Closely related to spatial scale are the widely used concepts of ***α***-, ***β***-, and ***γ***-diversity (Whittaker 1972). While α- and γ-diversity refer to the diversity within spatially delimited units of different sizes (α: "habitat"; γ: "landscape"), and are known as inventory diversity, β-diversity quantifies the spatial turnover in diversity among the habitats of a certain landscape, and is known as differentiation diversity (Magurran 2004). Finally, biodiversity can be considered at three major organisational levels: genetic, organismal, and ecological diversity (UNEP 1992, Gaston & Spicer 2004). Each of these levels can be further subdivided according to the "items" examined, e.g. at the organisational level one can analyse species, genera, families, and so forth.

For each combination of the mentioned dimensions of diversity (e.g. α-diversity of species at the 100-m² scale) there are again different possible measures (indicators) of diversity. In conclusion, it is neither desirable nor possible to combine all the different aspects of diversity into one single index. Instead, a set of diversity measures are used in this book to encapsulate the different dimensions of diversity within the study area. These diversity measures are explained within a common framework below.

Richness measures

The most fundamental and most frequently used index of (bio-)diversity is **richness**, i.e. the number of different items (e.g. species, families, soil units). Accordingly, we speak of species richness (S), family richness, soil unit richness (at a certain level), and so forth. Species richness (S) has been called the "common currency" in biodiversity research (Gaston & Spicer 2004).

Depending on the spatial scale, richness values can be seen as measures either of γ-diversity (entire Observatory) or α-diversity (all smaller plots or samples). Richness values are only meaningful and comparable when they are based on identical sampling schemes, i.e. a certain number of traps exposed for a certain period of time in the case of animals, or sampling plots of defined area that are more or less comprehensively sampled in the case of plants. Species richness on defined areas is also called **species density**, although we use the term "species richness" throughout. Sometimes we speak of "species richness" when, in fact, we mean richness of terminal taxa, i.e. the lowest-ranked taxa accepted (e.g. species, subspecies, variety etc.; see specific methods sections below and Subchapter II.1.5). When there are richness records both for individual points in time and accumulated over a number of recording years, we call the latter **cumulative richness**.

Heterogeneity measures

The following heterogeneity indices of α-diversity (or γ-diversity) combine both species richness and the number of individuals (abundance) per species, where N_i is the abundance of species i and N is the total abundance of all species in the sample/plot.

The **Shannon index *H'*** (sometimes erroneously termed Shannon-Weaver index; Shannon & Weaver 1949, Magurran 2004) originated from information theory and aims at quantifying the information content of a species assemblage (or more generally an assemblage of different items). It is defined as

$$H' = -\sum_{i=1}^{S} p_i \ln p_i \text{ with } p_i = N_i / \sum_{i=1}^{S} N_i$$

Originally, the Shannon index was applied to proportional abundances as in the above formula, but it can be equally well applied to proportional coverages (i.e. cover values that are standardised in a way that they sum up to 1), as we do in this book (cover-based Shannon index). The Shannon index can take values between 0 and ln S, and is undefined for 0 species.

While the Shannon index is probably the most widely used diversity index apart from richness, it has the shortcoming

that it combines two different aspects, namely richness and equitability (evenness), into one figure. Furthermore, it strongly depends on plot or sample size. A way to overcome this problem is to split the Shannon index into its two components, i.e. use species richness as one index and evenness as a second complementary measure. **Shannon evenness *J'*** (Pielou 1969, Magurran 2004) is defined as:

$$J' = H' / H'_{max} = H' / \ln S$$

The Shannon evenness can take values between 0 (low diversity, very unequal proportions of species) and 1 (high diversity, all species are equally frequent), and is undefined for assemblages of 0 or 1 species.

A further widely used heterogeneity measure is the **Simpson diversity index D_{Si}** (van der Maarel 1997; note that the complementary form $1 - D_{Si}$ is sometimes used under the same name):

$$D_{Si} = 1 - \sum_{i=1}^{S} p_i^2$$

While the complementary form $1 - D_{Si}$ quantifies the probability that two randomly drawn individuals from a community belong to the same species when based on abundance (Magurran 2004), D_{Si} (here calculated based on cover values) is a diversity index ranging from 0 to 1.

Finally, **Fisher's *α*** (also termed **log series *α***) is a heterogeneity measure for the composition of species assemblages (Fisher et al. 1943, Rosenzweig 1995, Magurran 2004). It is defined as

$$\alpha = \frac{N(1-x)}{x}$$

with x being estimated by an iterative approach so that it meets the following equation:

$$S / N = [(1-x)/x] \cdot [-\ln(1-x)]$$

Fisher's α is based on the assumption of a log-series distribution of species abundances (Rosenzweig 1995, Magurran 2004), but it also works reasonably well when this assumption is not met (Rosenzweig 1995, Magurran 2004). Fisher's α is approximately equal to the number of species represented by single individuals (Magurran 2004).

Species-area relationships and *β*-diversity

The increase of species richness with increasing plot size is typically well described by a power-law species-area relationship (SAR) (Rosenzweig 1995, Drakare et al. 2006, Dengler 2009a). The formula of this model is

$$S = cA^z \Leftrightarrow \log_{10} S = \log_{10} c + z \log_{10} A$$

The exponent z in the linear representation is the slope in the log-log representation. For terrestrial vegetation at the spatial scales studied in this book, it typically has values within the range of 0.15–0.35 (Dolnik 2003, Fridley et al. 2005). As the z-values describe the relative increase in species richness with increasing area, they can readily be used as a measure of β-diversity. When there are species richness values available for many different spatial scales, the z-values are typically derived as parameter estimates from a regression (Dolnik 2003, Fridley et al. 2005, Dengler 2009a). For the Observatory descriptions, we calculated the z-values for the transition from 100 m² to 1000 m² directly using the following formula:

$$z_{100-1000m^2} = \log_{10}(S_{1000m^2}) - \log_{10}(S_{100m^2})$$

Remote sensing

[M. Keil, U. Gessner & C. Hüttich]

Remote sensing can contribute in two ways to the characterisation of Observatories and in assisting vegetation monitoring:

- ▷ Earth observation products at multi-scalar levels put the Observatories into the landscape context.
- ▷ Remotely sensed time series of vegetation indices like the NDVI ("Normalised Vegetation Index") or the EVI ("Enhanced Vegetation Index") can link field observations and trends of development at the Observatories with regional vegetation dynamics.

The Observatories within their environment in Landsat images

In order to illustrate the land cover/land use situation of the Observatories at the landscape level, subscenes of Landsat imagery of approximately 20 km by 20 km extent around the Observatories were prepared with a spatial resolution of 30 m by 30 m. Landsat data were made available by USGS and by CSIR SAC. Some characteristics of Landsat data products are shown in Table 2, together with the characteristics of other satellite data used, such as QuickBird, IKONOS, SPOT, and MODIS.

During the studies within the BIOTA project, a combination of Landsat band 3 (visible red – RED), band 4 (near infrared – NIR), and band 5 (short wave infrared – SWIR), data proved to be a valuable band combination for the visualisation and differentiation of vegetation cover (for the information content of multi-spectral bands, see Lillesand et al. 2004 and Vogel 2006). Bands 4, 5, and 3 are represented by RGB colour, meaning that the near infrared band NIR is shown in red, the short wave infrared band SWIR in green, and the visible red band in blue. On each Landsat subscene, the Observatory (and, in case of Observatory pairs, the adjacent second Observatory) is presented with its extension of 1 km × 1 km. In most cases, Landsat data from the end of the wet season were used as it delivered better differentiation of the vegetation cover; the acquisition date of each subscene is provided in the caption of each satellite subscene. Table 3 summarises the land cover types represented by the colours in the false colour composite images of bands 4, 5, and 3 (RGB).

Very high resolution images of the Observatories

"Very high resolution" (VHR) satellite imagery was partly available for more detailed representation of Observatories, as these VHR images were integrated in multi-scalar mapping approaches in several focus study areas, together with Landsat and MODIS data (see Article III.2.3). Some characteristics of the VHR images used are composed in Table 2.

Table 2: Overview of the earth observation data used for the representation of Observatories and their key characteristics (VIS = Visible bands, NIR = Near infrared, SWIR = Short wave infrared)

Satellite/ sensor	Spatial resolution	Spectral resolution	Swath (coverage)	Website
Quickbird	2.4 m multispectral 0.6 m panchromatic	3 VIS, 1 NIR	16 km x 16 km	http://www.digitalglobe.com/
IKONOS	4 m multispectral 1 m panchromatic	3 VIS, 1 NIR	11 km x 11 km	http://www.euspaceimaging.com
HYMAP	Aircraft System, spatial resolution dependent on flight altitude	128 bands VIS, NIR, SWIR	Coverage depending on flight altitude	http://www.hyvista.com
SPOT-5	10 m multispectral 5 m (2.5 m) panchromatic	2 VIS, 1 NIR, 1 SWIR	60 km x 60 km	http://www.spot.com/
Landsat-5 Thematic Mapper	120 m thermal 30 m multispectral	3 VIS, 1 NIR, 2 SWIR, Thermal	180 km x 180 km	http://landsat7.usgs.gov/ http://www.csir.co.za/SAC/
Landsat-7 Enhanced Thematic Mapper +	60 m thermal 30 m multispectral 15 m panchromatic	3 VIS, 1 NIR, 12SWIR, Thermal	180 km x 180 km	http://landsat7.usgs.gov/
TERRA (AQUA) MODIS	250 m (bands 1–2) 500 m (bands 3–7) 1 km (bands 8–36)	VIS, NIR, SWIR, Thermal	2330 km	http://modis.gsfc.nasa.gov/

VHR satellite image products normally consist of one panchromatic band (a black and white image, derived using the full visible spectral region) at a very high spatial resolution (i.e. 1 m for IKONOS) in addition to several multi-spectral bands in the visible and near infrared region with a reduced spatial resolution (i.e. 4 m for IKONOS). In order to obtain a false colour image at very high resolution, the panchromatic band is combined with the multispectral bands using a so-called "resolution merge" approach. This approach was applied on the Quickbird, IKONOS, and SPOT images using the HPF (high pass filter) technique (see ERDAS 1997).

Table 3: Information on the interpretation of the presented Landsat subscenes in terms of the general relations between colours and land cover types. The characterisation is based on the Landsat band combinations 4, 5, and 3 (NIR = Near Infrared, SWIR = Short Wave infrared, R = Visual Red – in RGB representation).

Colour	Land cover types
Light red	Very dense and green vegetation of (irrigated) agricultural fields with dense and green crop cover or gardens within settlements
Dark red/brown	Very dense and green woody vegetation, such as green shrub thickets and dense forests
Light green	Medium dense or less green vegetation, such as grass savannas
Dark green	Dense, but less green vegetation, such as dry bush and shrub vegetation
White	Bare soil or sparsely vegetated areas, often independent from the natural soil colour. Also gravel roads and tracks
Light blue	Rocks and very sparsely vegetated soils. Also sealed areas/buildings in settlements.
Dark blue	Water bodies, dams, and lakes without algae
Black	Freshly burnt areas or sparsely vegetated areas with very dark topsoils
Intermediate colours	"Mixed" pixels with information on several land cover classes of the above units

VHR images consist of false colour composites of NIR, Visible Red and Visible Green (RGB) which correspond to colour infrared airphotos used for vegetation mapping. In contrast to the Landsat images, the VHR images with spatial resolutions between 1 m and 5 m were able to show typical savanna patterns, with parts of the woody vegetation (larger trees and groups of shrubs) within the grassy matrix being visible. Green trees and groups of shrubs appeared in red tones, while grassy and herbaceous vegetation appeared in grey tones (grey-green to grey-blue) on the VHR images, with light grey to white tones corresponding to areas of bare soil.

In addition, hyperspectral data from the HYMAP system were available for the Narais (S39), Duruchaus (S40), Toggekry (S04), and Okamboro (S06) Observatories. The HYMAP system delivers 126 spectral bands from the visible to the short-wave spectral region, which enabled the derivation of a number of special characteristics concerning vegetation and soil surface conditions (Wouters et al. 2007). False colour images comparable to the other VHR images were derived by combining specific NIR, SWIR, and visible RED bands (in RGB representation)

for these four Observatories. The spatial resolution of the HYMAP images is approximately 5 m.

Derived maps of fractional cover

It is difficult to express remotely sensed spatial patterns appropriately using discrete classes in savannas as they are characterised by high spatial heterogeneity and gradual transitions between a wide range of tree, shrub, and herbaceous compositions. This is especially the case when the spatial resolution of remotely sensed data are greater than 30 m (Landsat), as one pixel integrates a lot of different information. Realising these shortcomings, researchers have worked with concepts of continuous land cover representation, where land cover characteristics are mapped as continuous distributions at the subpixel level of remotely sensed data. An approach was developed for savanna biomes within BIOTA, which delivered the subpixel percentage cover of woody vegetation (i.e. shrubs and trees), herbaceous vegetation, and non-vegetated land surfaces. The approach combined analyses of field surveys, higher-resolution IKONOS and QuickBird data, and Landsat data and enabled the transfer of data to the 250 m MODIS time series. Further details can be found in Gessner et al. (2008, 2009); examples of the MODIS level are also provided in Article III.2.3. The fractional cover of woody vegetation, herbaceous vegetation, and non-vegetated land surfaces are provided for five Observatories and their surroundings. The fractional cover datasets were derived from QuickBird data (S01/Mile46 and S02/Mutompo) and IKONOS data (S03/Sonop, S05/Otjiamongombe, and S41/Sandveld).

Information from MODIS Time Series Products

When the BIOTA AFRICA project was initiated in 2000, the first MODIS sensor on board the satellite TERRA started to deliver global time series of multi-spectral reflectance data followed in 2003 by the second MODIS sensor on board the AQUA satellite. Since the launch of TERRA MODIS, vegetation indices such as NDVI, EVI, and other land surface products such as the Leaf Area Index (LAI) were made available on a regular basis (USGS LP-DAAC 2010). MODIS vegetation indices are available at a spatial resolution of 250 m by 250 m and can be downloaded as daily products or as preprocessed 16-day composites, each covering a time interval of 16 days. These vegetation indices provide information on vegetation density and productivity. The "Enhanced Vegetation Index" EVI was used more extensively in the BIOTA project as it characterises the vegetation and at the same time reduces the influence of varying soil type and brightness (Justice et al. 1998). The Leaf Area Index (LAI) is a proxy for the standing biomass of vegetation. The LAI variable defines the number of equivalent leaf layers relative to a unit of ground area and is available at a spatial resolution of 1 km × 1 km (USGS LP-DAAC 2010).

For the MODIS EVI time series around the Observatories, the 16-day composites were stacked to create a time series over a period of nearly 10 years starting in March 2000 (when the first MODIS products became available) and ending in September 2009 (the latest available processed products as of February 2010). Despite additional preprocessing, single artificial peaks and partial overlays caused by disturbances could not be avoided in the database.

The MODIS EVI time series depicted intra-annual variation influenced by the phenological cycle, and inter-annual variation, such as differences caused by the variation of annual precipitation levels. In addition to periodical dynamics, EVI time series could also be used to indicate change processes triggered by special events such as wildfires or clearing activities.

Parameters derived from MODIS

As an extract of the MODIS time-series information, the parameters provided in Table 4 were integrated into the infobox on basic remote sensing and landscape information.

Table 4: Parameters integrated into the infobox on basic remote sensing and landscape information

MODIS derived parameter	Explanation
EVI long-term mean (period 2000 to 2009)	The long-term mean of the Enhanced Vegetation Index (EVI) for the period 2000 to 2009 indicates the spatial distribution of the average photosynthetic activity of vegetation as a proxy for the average production of plant biomass.
Averaged EVI minimum (period 2000 to 2009)	The yearly minimum EVI values between 2000 and 2009 were averaged in order to describe the situation during the dry season at the Observatories.
Averaged EVI maximum (period 2000 to 2009)	The yearly maximum EVI values between 2000 and 2009 were averaged in order to describe the situation during the wet season at the Observatories.
EVI absolute minimum (incl. year of absolute minimum)	The EVI absolute minimum is the lowest EVI value reached during the period 2000 to 2009 at a particular Observatory. The year of this absolute minimum is included as an example of a very dry year
EVI absolute maximum (incl. year of absolute maximum)	The EVI absolute maximum is the highest EVI value reached during the period 2000 to 2009 at a particular Observatory. The year of this absolute maximum is included as an example of a very wet year.
LAI long-term mean (period 2000 to 2006)	The Leaf Area Index (LAI) variable defines the number of equivalent leaf layers relative to a unit of ground area. It is a parameter for calculating surface photosynthesis. The long-term mean over nearly 7 full vegetation cycles (2000 to 2006) enables the comparison of the different levels of photosynetically active biomass between the Observatories. LAI shows similar dynamics to EVI on an annual basis, and this is mainly coupled with vegetation phenology.

Climate

[J. Luther-Mosebach, K. Berger & J. Dengler]

BIOTA weather stations

Automatic weather stations (MC Systems, Steenberg, South Africa) were installed at 21 Observatories (Table 5) in southern Africa. These stations were equipped with the following sensors (see also Photo 1):

Relative humidity: MCS 174 Relative Humidity Sensor, 2 m above soil surface, shaded. Humidity sensors are prone to "shifts", and measurements of values above 100% therefore occur. For the calculation of means, values > 100% were "trimmed" using the maximum value of the weather station during the study period: new value = (value > 100%/maximum value of the 12 closest months) · 100. Note that this is only an approximative correction and the presented values on relative humidity are therefore not precise.

Air temperature: sensor MCS 152, 2 m above soil surface, shaded.

Solar radiation: pyranometer MCS 155, 2 m above soil surface. Solar radiation is defined as the total amount of radiation that strikes a horizontal surface. It is composed of the direct solar radiation and the diffuse radiation, which is scattered by dust and clouds. The sensor does not cover the full range of the solar spectrum; however, the error introduced is of the order of only 5%, under most conditions of natural daylight.

Wind speed: MCS 177 Wind Speed Sensor, 2 m above soil surface.

Wind direction: MCS 176 Wind Direction Sensor, 2 m above soil surface.

Precipitation: 150 cm above soil surface, tipping bucket, measuring 0.2-mm units.

Leaf wetness (data not shown).

The climate data collection periods at each Observatory are provided in Table 5. Climate data do not cover the full month periods for the first and last months of the data collection periods at each Observatory. Measurement gaps occurred (Table 5) for various reasons. Measurement gaps were treated differently, depending on the meteorological value and the kind of analysis. Details are provided in the Section "Preparation of diagrams" below.

Photo 1: Para-ecologist Wynand Pieters opening the logger box in order to download the data from the BIOTA weather station at Moedverloren (Observatory S28). The weather station is equipped with an automatic raingauge (black funnel in the background), wind direction and speed sensors, relative air humidity and temperature sensors in a shaded white metal shield, a leaf-wetness sensor (orientated horizontally on the right), and a pyranometer on top of the pole. Vertical wires on top of the pole prevent birds from sitting on the pyranometer. Photo: U. Schmiedel.

Data derived from the BIOTA weather stations

Apart from the directly measured parameters (relative humity, air temperature, solar radiation, wind speed, wind direction, and precipitation), we calculated climate parameters to characterise and compare the climatic conditions of the Observatories:

Mean annual potential evapotranspiration:
we defined the mean annual potential evapotranspiration (PET) according to Turc's method (see Dufour-Dror & Ertas 2004):
$PET = (R_s + 50)\,(0.013\,n)\,[T/(T+15)]\,[1+((50-RH)/70]$ for $RH < 50\%$ and $(R_s + 50)\,(0.013\,n)\,[T/(T+15)]\,[1+((50-RH)/70]$ for $RH > 50\%$, where PET is the potential evapotranspiration in mm, R_s the solar radiation in cal cm^{-2} day^{-1}, n the number of days, T the average air temperature in °C, and RH the relative humidity in %.

Interannual precipitation variability:
we defined the interannual precipitation variability as the coefficient of variation (in %; i.e. standard deviation / mean) of the available precipitation values for individual years.

Aridity index (UNEP):
we applied the aridity index of UNEP (AI_{UNEP}; UNEP 1992), which is defined as $AI_{UNEP} = MAP/PET$, where MAP is the mean annual precipitation and PET the mean annual potential evapotranspiration. The values along the transects were assigned to the following categories according to UNEP (1992):

$AI_{UNEP} < 0.05$: hyperarid
$0.05 < AI_{UNEP} < 0.20$: arid
$0.20 < AI_{UNEP} < 0.50$: semi-arid
$0.50 < AI_{UNEP} < 0.65$: dry subhumid

Modelled climate data

In addition to the climate parameters based on our own measurements, we present data based on the widely applied global dataset WorldClim (Hijmans et al. 2005; see http://www.worldclim.org). This database comprises modelled data with a spatial resolution of 0.5' × 0.5' (approx. 1 km²) for the period 1950–2000, based on spatial interpolations between thousands of climate stations worldwide. For each grid cell, the database comprises 48 monthly parameters (including precipitation, and minimum, mean, and maximum temperature) as well as 19 derived bioclimatic parameters (Bioclim; BIO1–BIO19; see www.worldclim.org), of which the following were used:

Table 5: Climate data collection periods and data gaps for the BIOTA weather stations in southern Africa

Observatory	Evaluation period	Period with available data	Gaps (≥ 1 day)
S01 Mile 46	05.2001–08.2009	21.04.01–28.09.09	16.08.01–09.10.01 04.02.02–05.02.02 31.03.03–28.12.03 19.05.08–20.05.08
S03 Sonop	05.2001–07.2009	26.04.01–02.01.10	16.08.01–29.09.01 12.02.02–31.08.02 23.11.03–28.12.03 26.09.04–23.12.04 25.06.07–26.06.07 25.11.08–25.02.09 31.07.09–26.09.09
S04 Toggekry	05.2001–02.2009	17.04.01–26.03.09	16.08.01–28.09.01 01.06.04–16.10.04 30.11.05–07.04.06 03.08.06–07.02.07 04.04.07–03.08.07
S06 Okamboro	05.2001–02.2009	17.04.01–10.03.09	16.08.01–28.09.01 13.01.06–07.02.07 16.04.07–01.08.07 25.02.09–10.03.09
S10 Gellap Ost	09.2001–06.2009	13.08.01–21.07.09	
S12 Karios	09.2001–06.2009	14.08.01–22.07.09	08.06.03–07.03.04 09.03.07–12.03.07
S16 Wlotzkasbaken	10.2001–08.2009	07.07.01–20.09.09	16.08.01–03.10.01 24.11.05–18.02.06
S17 Alpha	10.2002–08.2009	21.09.02–15.09.09	20.12.02–24.12.02 28.03.03–22.05.04 22.12.05–06.03.06 20.10.06–22.10.06
S18 Koeroegap Vlakte	04.2001–11.2009	01.04.01–14.12.09	14.10.01–16.08.02 21.12.03–26.09.04 02.10.05–10.03.06 21.12.07–10.06.08
S20 Numees	12.2002–11.2009	03.11.02–13.12.09	
S21 Groot Derm	04.2001–11.2009	27.03.01–13.12.09	10.08.01–11.09.01 17.03.02–17.08.02 28.09.05–18.10.05
S22 Soebatsfontein	04.2001–10.2009	30.03.01–13.11.09	14.08.01–26.08.01 15.10.01–03.11.01 20.01.09–22.05.09
S24 Paulshoek	04.2001–04.2009	29.03.01–24.09.09	10.08.01–23.08.01 12.10.02–20.10.02 06.05.03–06.09.03 06.09.03– 22.09.03 16.05.08–24.05.08
S27 Ratelgat	05.2001–10.2009	03.04.01–10.11.09	10.08.01–22.08.01 05.05.04–18.08.04 28.04.07–16.08.07
S28 Moedverloren	05.2001–10.2009	03.04.01–23.11.09	10.08.01–18.08.01 21.08.03–13.10.03 19.06.09–30.08.09
S29 Rocherpan	05.2001–07.2009	05.04.01–30.08.09	10.08.01–28.08.01
S34 Kleinberg	08.2005–07.2009	04.07.05–20.09.09	15.01.06–13.06.07
S37 Rooisand	06.2006–08.2009	24.05.06–19.09.09	10.07.06–24.10.06
S38 Claratal	11.2005–03.2009	12.10.05–24.04.09	
S39 Narais	04.2004–08.2009	18.03.04–19.09.09	02.08.04–10.12.04 08.08.05–10.10.05 23.02.06–04.12.06 23.02.07–24.02.07 01.08.07–27.08.07
S41 Sandveld	08.2005–06.2009	04.07.05–12.07.09	02.09.06–15.11.06

Temperature:
annual mean temperature (BIO1), maximum temperature of warmest month (BIO5), and minimum temperature of coldest month (BIO6)

Mean annual temperature range:
difference in mean temperature between the coldest and warmest months. Note that this is a different measure to BIO7 (= maximum warmest month – minimum coldest month)

Mean diurnal temperature range:
BIO2 = mean diurnal range (= mean of monthly [max temp – min temp])

Precipitation:
BIO12 = annual precipitation

Precipitation seasonality:
BIO15 = precipitation seasonality (= coefficient of variation of the 12 monthly values)

Percentage winter precipitation:
the percentage winter precipitation was calculated as the proportion of winter precipitation (April–September) relative to the annual precipitation and was assigned to five categories (Bailey 1979, Rebelo et al. 2006):
80–100%: strong winter
60–79%: winter
40–59%: even
20–39%: summer
0–19%: strong summer

Length of dry season:
the lenght of dry season is defined as the number of months in which the mean precipitation (in mm) is below 1/2 of the mean temperature (in °C). This definition is equivalent to the delimitation of the dry season in Walther-Lieth climate diagrams (Walter & Lieth 1967, Walter & Breckle 1999).

Aridity index (De Martonne):
for the modelled data, we applied the aridity index of De Martonne ($AI_{DM;}$ Deniz et al. 2010), which is defined as $AI_{DM} = MAP / (MAT + 10)$, where MAP is the mean annual precipitation (in mm) and MAT the mean annual temperature (in °C).

The index was then assigned to the following classes (Deniz et al. 2010):
$AI_{DM} < 10$: dry
$10 \leq AI_{DM} < 20$: semi-dry
$20 \leq AI_{DM} < 24$: mediterranean

$24 \leq AI_{DM} < 28$: semi-humid
$28 \leq AI_{DM} < 35$: humid
$AI_{DM} \geq 35$: very humid

Preparation of diagrams

Time series diagrams of precipitation and air temperature

These diagrams show the monthly totals of precipitation and the monthly arithmetic means of air temperature calculated from hourly measurements. Measurement gaps of 1 week or more are shown as shaded areas. They have been assigned the arithmetic mean of the values for the same period of the years where valid data were available. The diagrams were prepared using Origin®.

Wind diagrams

The wind speed diagrams show the mean monthly values of the wind speed at three times of the day (morning: 8 h, midday: 14 h and evening: 20 h) averaged over all valid values of the corresponding month and the evaluation period. Measurement gaps were not filled.

Wind direction was measured in 2°-steps (0° = North, 2°, 4°, ... 90° = East and so on). The wind direction diagrams show the relative frequency (as a percentage) of the occurrence of the wind direction in each 2°-step separated by season (summer: December–February; autumn: March–May; winter: June–August; spring: September–November). Relative frequency was calculated as the number of valid values within a 2°-step of wind direction in a season divided by the number of valid values for the season. Valid values were those where both wind speed and wind direction values at a measurement time were valid. Measurement gaps were not filled. The wind diagrams were prepared using Origin®.

Climate diagrams

Climate diagrams for the climate data obtained from the BIOTA weather stations and the modelled data from WorldClim were created with the software package Climatol for the statistical environment R (R Development Core Team 2008). The climate diagrams follow the standard of Walter-Lieth diagrams, i.e. the axes of temperature and precipitation are scaled in such a way that the diagram allows for the rough determination of arid and humid periods during a year (Walter & Lieth 1967, Walter & Breckle 1999; also see "Length of dry season" in Section "Modelled climate data" above). Generally, when the temperature curve is below the precipitation curve (hatched part or the diagram), the climate is humid; when the temperature curve is above the precipitation curve (dotted part of the diagram), the climate is arid. In addition, the diagrams contain the absolute temperature minima and maxima over the evaluation period, and the period of the year when frost may occur. The latter is only available for our own measured data, as daily minima are not provided in the WorldClim dataset.

Soils

[U. Wisch, A. Petersen & A. Gröngröft]

Soil data are available for 27 Observatories.

Standard procedures for soil sampling and analysis

The position of the sampled soil profile was 4 m south of the centre of each hectare plot. A pit was dug using a spade and hoe, and a vertical profile was prepared. The total depth of the pit was based on the rooting depth, normally not more than 1 m. The individual sampling depth was based on the horizon boundaries. If there were no distinct boundaries in the topsoil, the boundary of the first horizon was 10 cm. The soil was described in terms of stratification, texture, rock fragments, colour, humus content, lime content, soil and surface structure, crusting, bulk density, penetration resistance, and the distribution of roots. In addition, a photograph of each profile and the surrounding habitat was also taken.

Disturbed soil samples were collected as mixed samples of approximately 300 g per horizon. For undisturbed samples, cores of 100 cm³ were collected (for the topsoil driven into the soil vertically, for other horizons horizontally) and carefully prepared to the exact core volume. Undisturbed samples containing large amounts of fragments were sieved to 2 mm and the ratio of fragments to fine earth was determined using an electronic scale (0.1 g sensitivity) in the field. All other samples were transported to the laboratory without further preparation. The methods for the applied analyses are listed in Table 6.

Soils were classified according to the World Reference Base for Soil Resources (IUSS Working Group WRB 2006) after laboratory analysis. The Reference Base distinguishes 32 **soil reference groups**, which are further subdivided into **soil types** by sets of qualifiers (a maximum of four, and a minimum of one for each). These soil types are indicated either by a prefix or by a suffix attached to the reference group name. Prefixes can be subdivided into typically associated qualifiers, which represent a key-characteristic of the soil reference group, and integrated qualifiers, which represent the transition from one soil reference group to another. Suffixes are qualifiers not typically associated with reference groups, and provide further information about the soils, colour, base status, and other properties.

Determinig pedodiversity

Pedodiversity

Three different approaches were applied to determine the diversity of soils (pedodiversity) at the Observatories:

- ▷ Taxonomic pedodiversity (i.e. richness) classified based on WRB units (IUSS Working Group WRB 2006)
- ▷ Parametric pedodiversity classified based on "soil eco-types"
- ▷ Parametric space ("environmental envelope") by calculation of the *n*-dimensional space of normalised soil properties

A short description and the advantages and disadvantages of each approach are also provided in Fig. 7. For further information about pedodiversity and the three approaches applied here, see Petersen

Table 6: Laboratory methods applied for the soil analyses

Parameter	Description	Reference(s)
Sample preparation in the lab	Field samples were air dried, crushed, and sieved to 2 mm (= fine earth fraction). A subsample was ground to < 0.06 mm with a vibration disc mill (Conrad TS 100). If necessary, samples were dried with 105°C in a drying oven.	Blake (1965)
Bulk density	100 cm^3-samples are dried at 105°C and subsequently weighed by an electronic balance (0.1 g sensitivity).	
Colour	Determined for the fine earth with Munsell Soil Colour Chart (2000), on wet and on dry material.	
pH	Two soil suspensions were prepared by addition of aquademin or 0.01 M $CaCl_2$ (10 g dry weight + 25 ml solution). Measurement is conducted with a pH-electrode after 1 hour with repeated stirring of the suspension.	Van Reeuwijk (2002), Deutsches Institut für Normung (2005)
Electrical conductivity (EC)	Measurement were taken from the aquademin-solution (see pH-value) with a conductivity sensor. In addition, a 1:5 solution is prepared and measured.	
Total amount of carbon (TC)	A fine-ground sample (about 0.7 g) was combusted at high temperatures (900°C) with oxygen. The CO_2 is measured by thermal conductivity (vario MAX, Elementar Analysensysteme).	US Department of Agriculture, National Soil Survey Center (1996)
Total amount of inorganic carbon (TIC)	If inorganic carbon occured (pre-test with HCl) 0.2 to 2 g of fine earth was weighted in a 50-ml glass bottle closed with a septum. 10 ml of HCl (10%) was injected, mixed, and the solution was stored at room temperature overnight. A gas sample was analysed gas-chromatographically.	
Total amount of nitrogen	A finely ground sample (about 0.7 g) was combusted at high temperatures (900°C) with oxygen, the released gases were separated and cleaned from water, and the NO_x is reduced to N_2. The N_2 was measured by thermal conductivity (vario MAX, Elementar Analysensysteme).	US Department of Agriculture (1996), Deutsches Institut für Normung (1998)
Particle-size distribution (PSD)	A pre-test on the PSD was conducted with a dried sample of fine earth. If the supernatant water of a soil/water suspension was clear, the analysis was conducted according to (a). All other sample were analysed according to (a) and (b). Pre-treatment procedures: • Addition of HCl to remove carbonates [in cases of pH (H_2O) > 7.4] • Addition of $Na_4P_2O_7$ to improve dispersion of particles • Ultrasonic treatment (a) 300 g pre-treated fine earth was washed from clay and silt particles by repeated addition of $Na_4P_2O_7$ and ultrasonic treatment until the supernatant was clear. The dried sample was sieved through a set of sieves (2000 µm, 630 µm, 200v, 125 µm, 63 µm). The weight of each fraction was measured on an electronic scale (0.01 g sensitivity). (b) 30 g of pre-treated fine earth was diluted in a 1-l sedimentation cylinder with $Na_4P_2O_7$ solution. The suspension was shaken overnight. Aliquots of 10 ml were removed At predetermined intervals using a pipette, with depth and time being based on Stokes' law. The aliquots (representing particle sizes < 63, < 20, < 6.3, < 2 µm) were dried (105°C) and weighed on an electronic scale (1 mg sensitivity).	Van Reeuwijk (2002)
Elemental composition (XRFA)	A mixture of 8 g fine-ground sample and 1.6 g of HWC-wax was placed into a mould of Ø 20 mm and pressed with 200 kN into a tablet. The tablet was then converted in an X-Ray fluorescence spectrometer (Philipps PW-1404). The total concentration of the elements Al, Ba, Ca, Cr, Cu, Fe, K, Mg, Mn, Na, Ni, P, Pb, S, Si, Ti, and Zn was determined by X-Ray spectroscopy.	Kikkert (1982)
Exchangeable cations and cation exchange capacity (CEC)	The exchangeable cations were removed with ammonium (5 g of air-dried soil, were extracted five times with 25 ml 1 M NH_4Cl each) and were quantified using atomic absorption and atomic emission spectroscopy (AAS). The ionic strength of ammonium was reduced to 0.01 M NH_4Cl and the adsorbed NH_4 extracted with 1 M KCl thereafter. The concentration of NH_4 was measured by photometry; the CEC was corrected for the dissolved proportion of NH_4.	
Ammonium acetate (AC) exchangeable cations	5 g of air-dried fine-earth was mixed with two measures of ammonium acetate (25 ml each, totalling 50 ml as the final volume). For each step of extraction, the sample was shaken (30 min) and placed on a centrifuge (2000 rpm for 10 min). The extracted cations were quantified by atomic absorption and atomic emission spectroscopy (AAS/AES).	Helmke & Sparks (1996)
Water soluble anions and cations	30 g of air-dried fine earth was mixed with 30 ml water, shaken for 1 h and centrifuged. The supernatant was decanted and fine-filtrated (0.45 µm cellulose-acetate filter). The filtrate was divided in two bottles. Concentrated HNO_3 was added to the bottle for cation analysis to prevent precipitation of salts. The cations were measured with AAS and AES, and the anions by anion chromatography (IC). The concentration of dissolved carbonate/bicarbonate was calculated from the ion balance.	Van Reeuwijk (2002)
Plant-available P and K	The nutrients P and K were extracted with calcium lactate (1:50) at a constant pH of 3.6 and P and K were quantified within one day (P photometric, K by AAS).	Verband Deutscher Landwirtschaftlicher Untersuchungs- und Forschungsanstalten (1991)

continued next page

Table 6 continued

Parameter	Description	Reference(s)
Calculated values		
Total amount of organic carbon (TOC)	TOC = TC – TIC	
Electric conductivity (EC) in saturation extract	Calculated from the EC 1:2.5 solution and the water capacity of the soil (Wc) (derived from the texture) 250*EC/Wc = ECs [mS]	Alaily (2000)
Exchangable sodium percentage (ESP)	Calculated with the exchangeable cations from CEC or AC method see natric horizon definition in the WRB	IUSS Working Group WRB (2006), van Reeuwijk (2002)
Sodium adsorption rate (SAR)	Calculated by the ions in the water extract (1:1) (alternative for ESP), see natric horizon definition in the WRB	IUSS Working Group WRB (2006), van Reeuwijk (2002)

Table 7: Ranges and median values of pedodiversity-indices along the BIOTA Southern Africa transects

	Taxonomic pedodiversity	Parametric pedodiversity	Parametric space
Range (transect)	2–22	1–21	0.58–4.96
Median	9	9.5	3.46

Table 8: Upper class limits for the parametric pedodiversity

Parameter	Class 1	Class 2	Class 3	Class 4
pH	4.0	6.0	8.0	10.0
EC [µS cm^{-1}]	100	500	2,500	40,000
SOC [%]	0.6	2.0	12.0	
Silt and clay [%]	7.5	35	70	100

(2008) and Petersen et al. (2010). The ranges of each pedodiversity index over the BIOTA Southern Africa transect are shown in Table 7 to give an impression of the variability of pedodiversity.

Taxonomic pedodiversity

All profiles were classified according to the IUSS Working Group WRB (2006). The taxonomic level was reduced to two qualifiers: firstly, the prefixes according to their order in the classification, and if there were less than two prefixes then suffixes were also integrated. The Shannon index and the Shannon evenness (for more details, see "Diversity measures" above) were calculated for each Observatory based on taxonomic richness (number of taxa at the Observatory) as the most common index of diversity at the reference group level as well as the soil unit level (reduced to two qualifiers).

The BIOTA Southern Africa north-south transect covers 12 of the 32 global WRB reference groups, which is an indication of the high pedodiversity along the transect.

Parametric pedodiversity

The basic principle of this method (Petersen 2008) was to select a number of ecologically important soil parameters and to define useful and preferably even sized classes for each parameter. The following parameters were chosen: pH value, electrical conductivity, content of silt and clay, and organic carbon content.

An arithmetic average calculation, weighted in terms of the horizon's thickness for each selected parameter and each profile (0–60 cm), was used to deal with multiple information across the different horizons. Each parameter was then classified into four classes. All classes were based on the minimum and maximum for each parameter. The pH class limits were defined in order to provide four equally sized classes. Electrical conductivity (EC) class limits were based on log scales. Four classes were defined for the fine earth content (silt and clay): sands, loamy substrates, loam substrates, and silt and loam dominated substrates. Since log-scaled classes for organic carbon (SOC) were too highly differentiating, three ecologically relevant classes were defined instead. The upper class limits for all four parameters are shown in Table 8.

Each parameter was classified with the class identifiers A (low) to C and D (high) based on these classes. Finally, the class identifiers for each parameter (A, B, C, D) were combined in order to create an ecotype identifier for each profile,

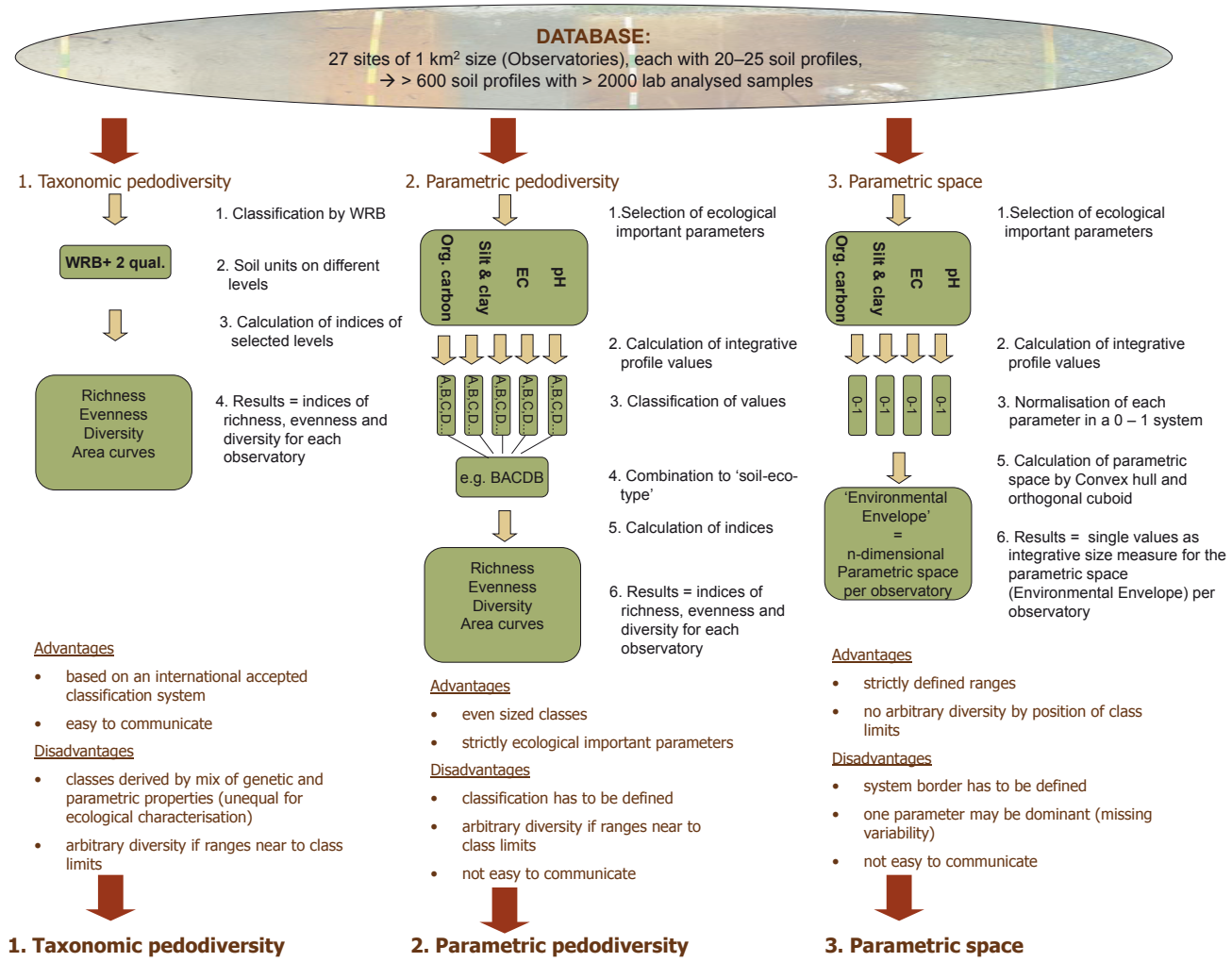


Fig. 7: Diagrammatical representation of the three approaches for determining pedodiversity.

e.g. "ACDA". This abbreviation can be used as a name for a **"soil ecotype"** that is strictly based on classified parametric values.

Parametric space

The parametric space is a multivariate mathematical approach that uses the basic numerical dataset to create a unique value representing the size of the "environmental envelope" for each area studied. The resulting values are the volume of *n*-dimensional spaces of all the soil properties involved.

The same four parameters as for parametric pedodiversity were used and normalised for further calculations:

$$x_i = (a_i - a_{\min})/(a_{\max} - a_{\min})$$

with x_i = normalised value; a_i = weighted mean of original values based on horizon thickness from 0 to 60 cm depth; $a_{\min}$ and $a_{\max}$ minimum and maximum of the entire dataset along the transect. For the calculation, electrical conductivity values were log-transformed to accommodate the non-normal distribution of the original data. The calculation of the minimal space of the 4-dimensional convex hull was solved using MATLAB 7.2 Software employing the Qhull algorithm (www.qhull.org, see also Barber et al. 1996) and the results were multiplied by 10,000,000 and $\log_{10}$ transformed.

Biological soil crusts

[B. Weber, T. Friedl & B. Büdel]

Biological soil crusts consists of soil-dwelling cyanobacteria (phylum Cyanobacteria), green algae (phylum Chlorophyta), lichens, and bryophytes (phyla Bryophyta, Marchantiophyta, and Anthocerotophyta). A standardised sampling technique was developed to assess the biological soil crust occurrence and diversity along the transects. At least three hectar plots were studied, beginning with the ranking number 1 (Photo 2), at each Observatory. Within these plots, five petridish-sized samples were taken from an area of 20 m × 50 m located south of the center of the respective hectar plots (Photo 3). Two of the five petridishes were used to isolate green algae and cyanobacteria, one was used for chlorophyll analysis, and two were used for the measurement of carbon and nitrogen content as well as isotope fractionation (not shown here). Dried samples were stored at room temperature in the dark before analysis. C-, N-, and chlorophyll analyses were conducted immediately after returning from the field in order to avoid sample degradation.

C- and N-content was determined and related to the total dry weight of the samples in order to obtain information on the biomass and nitrogen status of the soils. The samples were ovendried at 60°C and homogenised in a ball mill (MM2000, Retsch GmbH, Haan, Germany). 12.5 ml 0.1 N HCl was added for every gram of sample material to calcinate CO_2 from the samples. After incubation overnight, and subsequent drying (60°C) and homogenisation, aliquots of the dried and ground material (1–2 mg) were placed into tin capsules before analysis in a C-N-analyser.

Chlorophyll of the air-dried samples was extracted in 80% DMSO (dimethylsulfoxide, 50 times the volume of the sample) for 2 h at 65°C according to the method of Ronen & Galun (1984). A spatula tip of $Mg_2(OH)_2CO_3$ was added to each sample to avoid acidification and phaeophytinisation of chlorophyll. After spectrophotometry, the chlorophyll content was calculated according to the equations of Wellburn (1994).

The biological soil crusts were grouped into the following eight classes according to the occurrence and dominance of organism components (Table 9; see also Büdel et al. 2009).

For identification of cyanobacteria and green algae, microscopy of cultured isolates was combined with SSU rRNA gene sequencing to identify the maximum number of species in the soil samples. For the isolates, raw cultures established from soil samples were purified into unialgal culture strains applying standardised

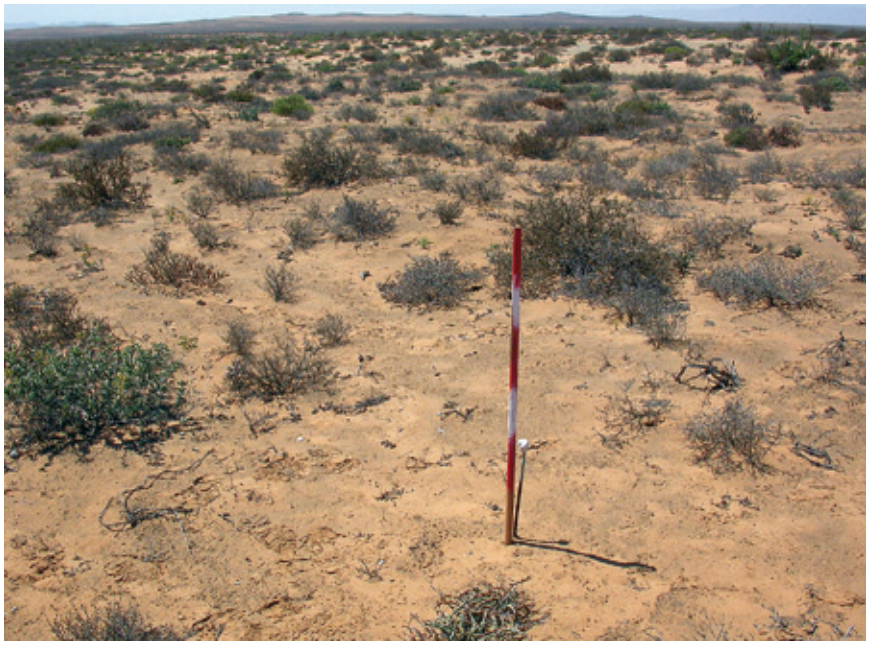


Photo 2: Center of the hectare plot, marked by a red and white striped pole. Samples were taken from an area of 20 m x 50 m located immediately south of the center. Photograph taken at the Groot Derm Observatory (S21), hectare plot H52.

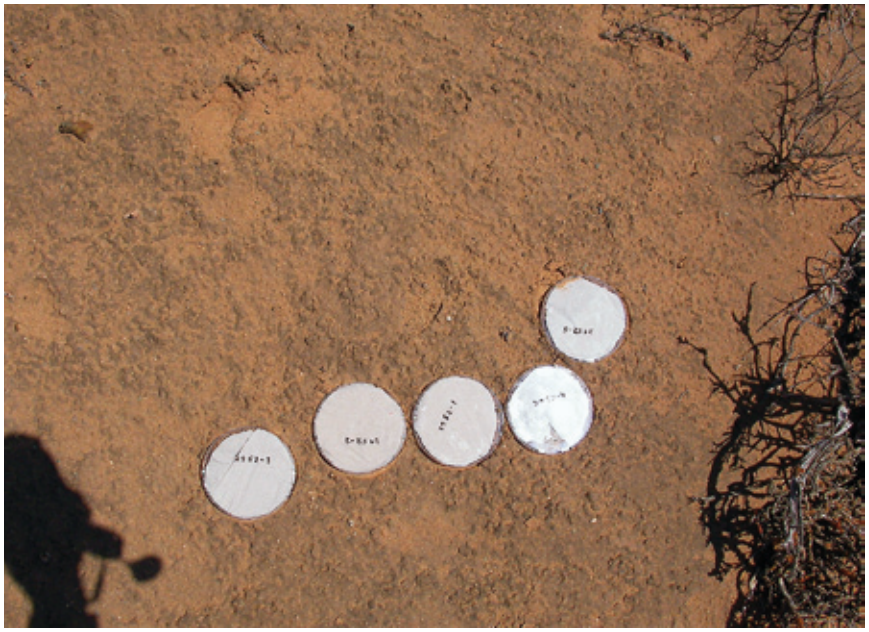


Photo 3: At each sampling site, five samples were taken with petridishes lined with tissue so as not to scratch the sample surface. The samples were carefully lifted with a trowel and the petridishes sealed with parafilm. Photograph taken at the Groot Derm Observatory (S21), hectare plot H52.

Table 9: Different types of biological soil crusts collected along the transect

Number	Crust type	Description
1	Light (initial) cyanobacterial crust	Patchy discoloration; thin crust that can only be removed in small pieces.
2	Well-established cyanobacterial crust	Dark coloured, thicker crust that can be removed in larger pieces.
3	Cyanobacterial crust with cyanolichens	Cyanolichens (such as *Collema*, *Heppia*, *Lichinella*, *Peccania*, *Peltula*) only sometimes visible with the naked eye as small black dots within the cyanobacterial cover.
4	Cyanobacterial crust with green-algal lichens	Contains green-algal lichens (such as *Acarospora*, *Placidium*, *Diploschistes*, *Psora*) and sometimes also cyanolichens; can be removed in large pieces.
5a	Crust with bryophytes, dominated by liverworts	Liverworts visible as grey to blackish y-shaped lobes when dry; can be removed in large pieces.
5b	Crust with bryophytes, dominated by mosses	Mosses visible as dark club-shaped structures or small dots when dry; can be removed in large pieces.
6	Hypolithic crust, dominated by cyanobacteria	Blue-green cover on the sides and underside of quartz gravels embedded in the soil. Algae, mosses, and lichens may occur besides cyanobacteria.
7	Namib Desert Lichen Fields	Composed of crustose, foliose and fruticose lichens (e.g. *Caloplaca*, *Lecidella*, *Ramalina*, *Teloschistes*, *Xanthomaculina*), covering large areas.

procedures (e.g. Waterbury & Stanier 1978, Büdel et al. 2004, Andersen & Kawachi 2005), using BG11 mineral medium for cyanobacteria (Waterbury & Stanier 1978, Büdel et al. 2004) and Bold Basal Medium with vitamins and triple nitrate (Starr & Zeikus 1993) for eukaryotic algae. The culture strains were kept in growth chambers at a 12:12 h light-dark regime and at temperatures of 20°C for raw cultures and 18°C for uni-algal isolates.

For cyanobacteria, full SSU rRNA gene sequences with the adjacent 16S-23S spacer region were amplified with PCR primers PCR1 and PCR18 (Wilmotte et al. 1993) following DNA extraction with the Invisorb Spin Plant Mini Kit (Invitek, Berlin, Germany). To amplify green algal 18S rRNA genes, the primers NS1 and 18L (Hamby et al. 1988) were used following DNA extraction with the same kit. Partial sequences (about 600–800 basepairs long) covering variable regions at the 5'-end of the SSU rRNA were sequenced for most isolates. The partial sequences were added to phylogenetic trees constructed from either 16S (cyanobacteria) or 18S (green algae) reference sequences in the ARB SSU rRNA gene sequence database (Ludwig et al. 2004).

From each clade of the 18S rRNA gene phylogeny for green algae, 2-10 strains were selected for further morphological examination. This was also necessary when no close neighbouring reference sequences were found for strains, and identification to genus level was therefore attempted by morphology.

Morphological identification of eukaryotic algae was based on Ettl (1999), Komárek & Fott (1983), Ettl & Gärtner (1995) and Andreeva (1998). Cyanobacteria were identified based on Geitler (1932) and Komárek & Anagnostidis (1998, 2005). Isolated cyanobacterial and algal strains were compared with well-identified strains from the culture collections at the University of Kaiserslautern (Department of Plant Ecology and Systematics) and the "Sammlung für Algenkulturen" (SAG) at the University of Göttingen.

Besides the standardised approach, the crust occurrence and distribution patterns were also assessed using a macroscopic approach to obtain a general overview of crust development at each site. The petridishes were examined macroscopically in the laboratory to determine the relevant soil and crust characteristics.

Biological soil crust data are available for 16 Observatories.

Lichens

[L. Zedda & G. Rambold]

Introduction

Lichens are symbioses of various fungi (regnum Fungi) with various blue-green algae (phylum Cyanobacteria) and/or green algae (phylum Chlorophyta). The lichen diversity at 31 Observatories was investigated during the three phases of the BIOTA Southern Africa project. A general floristic survey of each Observatory was carried out at all sites in order to examine the general diversity and composition of lichens. Particular attention was given to lichens forming biological soil crusts, since these were the research focus of the workpackage B2 (Phase III) and subproject S04 (Phases I–II). Epiphytic lichens (growing on plants) and saxicolous species (growing on rock), which have scarcely been lichenologically studied before, were examined at most of the Observatories. Soil-inhabiting lichens were investigated in more detail at the hectare-plot level using digital photography of the soil surface. A procedure for gathering and processing monitoring data were established for this purpose. Image analysis techniques suitable for measuring the soil surface cover of lichens and other biotic and abiotic elements were tested and object-based image analyses applied.

Photo 4: Soil surface scanner with an adjustable guide-rail on the top of the frame and digital camera. Photo: L. Zedda & G. Rambold.

Traditionally, the monitoring of soil lichens in arid to semi-arid regions is based on qualitative and/or quantitative assessments of lichen distributions in the field. The determination of lichen cover at the BIOTA Observatories was achieved by semi-quantitative estimation or by using a grid within permanent sampling plots (quadrats) of different sizes (20 cm x 50 cm or 1 cm x 1 cm), either selected randomly or along line transects (Eldridge 1996, Eldridge & Tozer 1997, Rogers & Lange 1971, Rosentreter et al. 2001). Examination of lichen soil communities was also carried out using traditional grid-based vegetation recording methods (Schieferstein & Loris 1992, Jürgens & Niebel-Lohmann 1995, Lalley & Viles 2005, Wirth & Heklau 2006, Wirth et al. 2007). The use of a digital photographic quadrat method was first proposed by Purvis et al. (2002), in order to monitor the growth and health status and diversity changes of epiphytic lichen communities in Great Britain. Kirschbaum et al. (2002) developed an application for the cover determination of lichen outlines drawn on a transparent film. Recently, two studies were published on the use of the object-based analysis of ground plot images for estimating vascular plant vegetation cover (Luscier et al. 2006, Laliberte et al. 2007). Until this project, processing of digital ground images of lichen crust plots had not been tested before.

Equipment and material

The following tools were used in the field: a SLR high resolution digital camera equipped with a macro lens (60 mm; 1:2.8) and a ring flash, a dark plastic shield or black umbrella, a square aluminium frame ('soil surface scanner') with an adjustable guide-rail, a GPS, a spirit-level, colour reference cards with tape measure (QPcards), small metal pegs, material for the collection of lichen specimens, and a notebook.

Digital ground photography

Sampling of soil-inhabiting lichen communities was carried out in most cases at the ten highest ranked hectare plots per Observatory, according to the conventions used in the greater project (Subchapter II.1.2). Additional lower priority hectare plots were also investigated if they were lichenologically interesting. Lichenological vegetation sampling using digital photography was carried out on a 1-m² plot immediately north of the centre point of the respective hectare plots (i.e. within the 100-m² plots used for vascular plant surveys). The photographed ground plots were marked with small metal pegs and a yellow ribbon, which was placed at the north-western corner of the plot.

Digital images were taken with a digital SLR camera equipped with a macro lens. This was fixed onto the top of the square aluminium frame construction ('soil scanner') (Photo 4). This allowed the capture of image sequences of the ground with the camera being fixed parallel to the soil surface using a spirit-level. In most cases, 24 or 36 (i.e. 6 × 4 or 6 × 6) images were taken, each covering about 15 cm × 10 cm of soil surface with a minimum overlap of 10%. The guide-rail was adjusted in order to move the camera at intervals of 10 cm along both axes of the frame. Sequences of images were taken from the left to the right. Subsequent sequences were taken along the next row, starting from the left (Photo 5), which corresponded in all cases to the NW corner of the sampling area. The method of image stitching was preferred instead of a single photograph of the plots as it provided sufficiently high resolution for the examination of the necessary detail structures (minimum: 118 px/cm = 300 dpi). For subsequent image colour calibration and scaling, a colour reference card with tape measure was placed in the first image of each row. Usually, soil surface photographs were taken at a distance of 60 cm. Strong insolation and the resulting shadows were compensated for by using a ring flash and shading the photograph area with a dark plastic shield or black umbrella. Sampling areas were marked and geographic coordinates were noted for future long-term monitoring. Additional images were taken at different scales for documenting the site

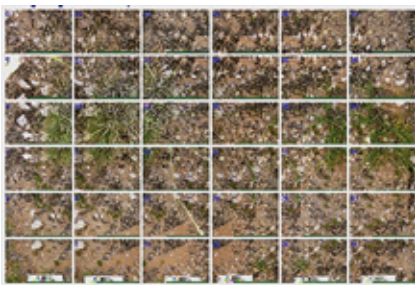


Photo 5: Sequences of 6 × 6 images each covering about 15 cm × 10 cm of soil surface taken from the left (NW corner) to the right (NE) of the sampling plot. Subsequent sequences were taken along the next row, starting from the left. Photo: L. Zedda & G. Rambold.

conditions. All images are accessible on the project website (Zedda et al. 2010).

Collection and identification of lichen specimens

Lichen specimens not identifiable in the field were collected in close proximity to the sampling area for later identification in the laboratory. Only specimens of taxa present in the photographed plot were identified. Identification was carried out using the literature as listed in Zedda & Rambold (2004) and Zedda et al. (2009), and using the LIASlight data set, of which the southern African subset was established in the context of the BIOTA project (Rambold et al. 2010). Taxonomical nomenclature follows LIAS names (http://liasnames.lias.net/) and Index Fungorum (http://www.indexfungorum.org). Collection data and Observatory species lists are accessible on the project website (Zedda et al. 2010).

Lichen morphological groups

Lichens can be grouped into morphological groups (MGs) on the basis of selected main characters, because of the frequent relation between morphology and function. This relation has often been revealed among phylogenetically unrelated taxa with comparable thallus structures and ecology, indicating a parallel morphological response to specific environmental conditions (Belnap et al. 2001, Zedda et al., in press). This concept has primarily been applied for vascular plants in order to identify morphological groups (i.e. plant functional types) based on a phenotypic, but non-phylogenetic, classification. In the context of the present subproject, the most common soil-inhabiting lichens occurring across the different biomes of the BIOTA transects were classified into MGs. The classification was based on the following traits: growth-from; photobiont type; and pigmentation of the upper surface of the thallus. Lichen morphological groups are more easily identifiable in the field as well as in digital images than lichen taxa. Furthermore, their identification does not require destructive lichen collection since lichens are only photographed after a study of lichen-mycota has been carried out. Collection and identification of lichen taxa is therefore only necessary at the beginning of an investigation of a new study site and has to be carried out by a lichen specialist. Non-specialist researchers may continue monitoring over time using repeat digital imagery of the sampling areas followed by image processing and analysis. Further information on morphological groups is provided by Zedda et al. (in press). Only a short description and images of the different MGs (Photo 6) are provided here:

Photo 6: Images of lichen species representing the different morphological groups. Photo: M. Schultz, L. Zedda & G. Rambold.

MG 01: species of the genus *Psora*; thallus squamulose, pinkish to pink-brownish (sometimes with white pruina), with green algae.

MG 02: species of the genera *Placidium*, *Eremastrella*, *Endocarpon*, *Anthracocarpon*, *Verrucaria*, *Sarcogyne*; thallus squamulose, brown with green algae.

MG 03: species of the genera *Collema*, *Peccania*, *Phloeopeccania*, *Lichinella*; thallus squamulose, subfoliose to subfruticose, black, with cyanobacteria.

MG 04: species of the genera *Buellia* and *Toninia*; thallus crustose to subsquamulose, whitish-grey, with green algae.

MG 05: species of the genera *Diploschistes*, *Caloplaca*, and *Lecidella*; thallus crustose, pale brown (beige), with green algae.

MG 06: species of the genera *Xanthoparmelia*; thallus foliose, yellowish-green, with green algae.

MG 07: species of the genus *Caloplaca*; thallus crustose, more or less distinct, pale brown-orange, with green algae.

MG 08: species of the genus *Toninia*;

thallus squamulose, brownish-grey, with green algae.

MG 09: species of the genus *Acarospora*; thallus crustose, yellow, with green algae.

MG 10: represented by dark coloured species of the genus *Xanthoparmelia* (formerly *Neofuscelia*); thallus foliose, dark brown to black, with green algae.

MG 11: species of the genera *Peltula* and *Heppia*; thallus peltate, olive brown, with cyanobacteria.

MG 12: species of the genus *Ramalina*; thallus fruticose, greenish-grey, with green algae.

MG 13: species of the genus *Teloschistes*; thallus fruticose, orange-red, with green algae.

MG 14: species of the genus *Cladonia*; primary thallus squamulose, podetia rarely present, greenish-grey, with green algae.

Image processing and classification

The methods applied for image processing and classification are briefly described below. Digital ground images were processed in order to obtain data on the percentage cover of lichen morphological groups, stones, bare soil, vascular plants, and cyanobacterial and bryophyte soil crusts. Digital images were stitched using Adobe Photoshop CS2, Version 9.0 (Adobe Systems Incorporated) in order to generate a single image of the photographed plot (Photo 7). Image calibration was carried out afterwards by adjusting brightness and colour values, in order to improve the visibility of objects and for the neutralisation of differences between the RGB values of single plot images. After image calibration, cut outs of 20 cm × 50 cm (= 1000 cm^2) were selected on the photographed surface area. After stitching and calibration, digital images were classified in order to quantify the percentage cover of the above listed objects. The object-oriented classification of images was carried out with the software eCognition professional 4.0, and based on the following steps: segmentation, definition of hierarchical network of segments, and proper classification.

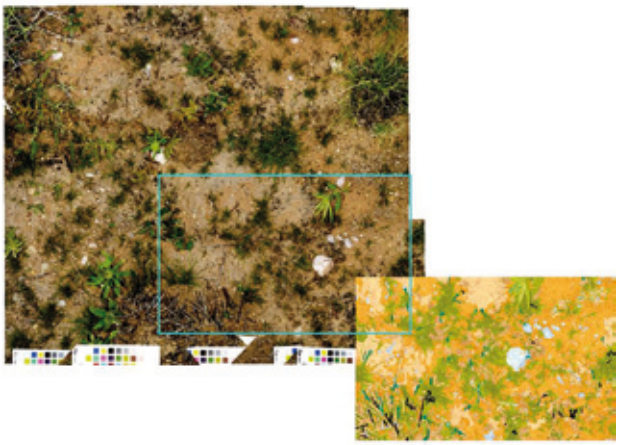


Photo 7: Example of stitched image and of cut out classification using the software eCognition (Observatory Duruchaus, S40, hectare plots H40 and H74). Photo: L. Zedda & G. Rambold.

During **segmentation** of images, pixels were grouped into homogeneous areas (objects or segments) based on three parameters: scale, colour (spectral information), and shape. The scale parameter represents the tolerated level of heterogeneity of the resulting segments. Colour and shape parameters determine how pixels in the digital image are to be grouped. For our analysis, images were segmented using the following parameters: scale = 100, shape = 0.25, and compactness = 0.75. The scale parameter was a weighable measure to define the mean size of the generated image objects. All parameters were kept constant for all classified images.

A **hierarchical network of segments** (= categories) was subsequently defined. Pixels were clustered using a local bottom-up merging process, which started with single pixel image objects. This pairwise clustering procedure was iteratively optimised according to weighable parameters, minimising values of heterogeneity defined as "$n \times h$" (n = image object size; h = an arbitrary value for heterogeneity). The clustering process of an image object was terminated when the least increase of heterogeneity exceeded a certain value. A priori knowledge was provided by the classification of soil lichen morphological groups. The class hierarchy also assigned appropriate class names and colours to the classified image objects.

Objects were then **classified** according to the definition of membership functions for easily separable segments and with a nearest-neighbour classification for less distinguishable classes. In subsequent steps, the weighting of feature values was adapted to the scene until misassigned objects or unclassified objects were assigned to the correct classes. This was done both visually with the "Feature View" tool and by using the "Feature Space Optimization" (FSO) dialog. The lichen shape was outlined using image objects and could be detected by shape specific features such as the pixel area covered by each image object, thus providing a measure of its size. The textural patterns of thalli were analysed using features. RGB layer values represented the mean of all pixels encompassed by imaged object borders. The issue was to define a set of features for each class to obtain intrinsic lichen characters as accurately as possible. Image analysis was based therefore not only on colour values (RGB), but also on other features. Altogether, 11 colour value parameters (RBG), 8 values of texture (GLCM = Gray Level Co-occurrence Matrix) and 7 object form values were selected for classification. The data output from eCognition contained the absolute counts of assigned pixels per class. Cover values of each object were therefore standardised as percentage values and summarised in Excel applications for further analysis with statistical programs.

Data analysis

The richness, abundance, and association of lichen species and of morphological

groups were analysed at the Observatory and transect levels (Zedda & Rambold 2004, 2009, Zedda et al., submitted). Lists of lichens occurring on specific substrata, species new to the study area and descriptions of new taxa have been published by Kantvilas et al. 2003, Diederich & Schultz 2009, Schultz et al. 2009, and Zedda et al. 2009. Lichenological data were correlated with climate and soil parameters in order to understand species and diversity patterns (Zedda et al. 2010, submitted).

Lichen data are available for 31 Observatories.

Photo 8: The para-ecologist Reginald Christiaan estimating cover on a 100-m² plot in Soebatsfontein (S22). Photo: U. Schmiedel.

Vascular plants

[J. Dengler, U. Schmiedel, D.H. Haarmeyer, J. Luther-Mosebach & G. Muche]

General sampling

Vascular plants comprise ferns (phylum Pteridophyta) and seed plants (angiosperms and gymnosperms, phylum Spermatophyta). Data on vascular plants were obtained at all 37 Observatories of BIOTA Southern Africa. The botanical sampling usually took place on the 20 hectare plots of highest rank (see Subchapter II.1.2), but see the info boxes of the individual Observatories for deviations from this rule.

Vegetation monitoring was conducted at each of the hectare plots on sets of three nested plots, with plot sizes following a geometric series (100 m², 1000 m², and 10,000 m²). The 100-m² and 10,000-m² plots were square, while the 1000-m² plots had a rectangular shape of 20 m × 50 m (see Subchapter II.1.2). These plot dimensions are frequently used in vegetation and biodiversity studies worldwide (Shmida 1984, Peet et al. 1998, Stohlgren 2007) and are regularly applied for vegetation mapping in Namibia (Strohbach 2001, Hüttich et al. 2009). The type of sampled data differed between the different plot sizes (see Table 10). The vegetation was divided into vertical strata according to standardised height categories (Photo 8) for the estimation of cover. Total species cover and the cover of each vertical layer was estimated as a percentage. Each plot was photographed in a standardised manner for visual documentation.

Table10: Types of vascular plant data sampled within the different plot sizes

Plot size	Presence	Cover	Abundance
100 m²	X	X	X*
1 000 m²	X	X	
10 000 m² = 1 ha	X		

* Only perennial plant species may be included, depending on limitations of data gathering. In a few BIOTA Observatories with relatively dense vegetation, graminoid species were excluded from abundance counts.

The two plots at smaller spatial scales (100 m² and 1000 m²) were sampled comprehensively and the documented diversity parameters should therefore be close to the true values. In contrast, the comprehensiveness of the species lists at the 1-ha scale differs between the Observatories, and in several cases, the reported values are significantly below the true values as the time allocated for sampling was not sufficient in some structure- and species-rich Observatories (Peters in prep., see also Site-specific study S39.01). For this reason, the 1-ha values are less reliable and only included in the Electronic Appendix, but not in the printed info boxes. A diversity value for the entire Observatory (1 km²) was derived by combining the species lists of all sampled hectare plots as well as additional species found outside the plots. Despite the lack of comprehensive sampling at the 1-km² scale, it appears that these values are more reliable than those for the 1-ha plots (see Article III.3.8) due to the stratified random selection of the hectare plots (see Subchapter II.1.2), which ensured good coverage of the variety of habitat types at each Observatory.

All vegetation monitoring was carried out during the phenological phase of maximum vegetative development. In general, all the above-mentioned sampling approaches were repeated annually; but see the info boxes of the individual Observatories for deviations.

Taxonomic basis and data handling

The taxonomy and nomenclature of the vascular plants follows Germishuizen & Meyer (2003), but is complemented by Craven (1999) for taxa only present in Namibia. However, the nomenclature of the subfamilies Ruschioideae and Mesembryanthemoideae (formerly: family Mesembryanthemaceae) follows Hartmann (2002a, b). The assignment of species to families follows Germishuizen & Meyer (2003), except for the family Mesembryanthemaceae, which are classified as Aizoaceae (Hartmann 2002a, b).

The calculation of "species richness" (and derived biodiversity measures) was generally based on terminal taxa, i.e. on the accepted taxa of lowest rank, which could be species, subspecies (subsp./ssp.), or varieties (var.). Distinctive taxa that were not yet formally described by science were also included in the counts, and they are provided with their "field name" accompanied by a collection number in the tables. Similarly, undetermined taxa (*Genus* sp.) were counted if it was plausible that they represented species other than those already recorded at a specific plot. Much effort was put into ensuring the consistent use of "field names" within Observatories and between plots and years. However, this may not always have been achieved completely, particularly when the surveyor changed between years, potentially leading to "inflated" richness values when species lists were cumulated over all years.

Each taxon was classified into a life form (i.e. major strategy types) according to field observations, following the life forms of Raunkiaer (1934) with the extension of Jürgens (1986, 1990). Raunkiaer classified vascular plants into strategy types according to the location of their buds and thus from where they start growing again after the annual frost/winter or dry season.

T = therophytes start anew every year from a seed, i.e. annuals.

G = geophytes have their buds below the soil surface, e.g. bulbs.

H = hemicryptophytes have their buds just above the soil surface, e.g. perennial grasses.

C = chamaephytes have their buds up to 50 cm above the soil surface.

P = phanerophytes have their buds above 50 cm from the soil surface.

T/per = therophytes that may survive more than one season if the weather conditions permit.

Jürgens (1986, 1991) further divided chamaephytes and phanerophytes into subclasses, which are provided in Table 11, see also Article III.3.9.

All data were entered and stored in the software BIOTABase (see Article III.8.6). BIOTABase also allowed the direct output of the majority of the parameters presented in the infoboxes of the Observatory descriptions.

Biodiversity parameters

We present indices of vascular plant diversity at the spatial scales of 100 m², 1000 m², and 1 km².

We calculated species richness at all three spatial scales and cover-based versions of Shannon evenness J' and the Simpson diversity index D_{Si} at the two smallest spatial scales with available cover data. Furthermore, we determined the z-values for the transition from 100 m² to 1000 m². All diversity indices except for the cumulative species richness and family richness at 1 km² were calculated for each plot × year combination according to the formulas in "Diversity measures" above and averaged thereafter. Finally, we calculated the mean annual change in species richness for the 1000-m² plots.

Vegetation classification

Our biome classification follows Rutherford et al. (2006) for South Africa and Mendelsohn et al. (2002) for Namibia. Due to its unique vegetation structure and climatic conditions, we treated the broad-leaved part of the tree- and shrub savanna, as delimited by Mendelsohn et al. (2002), as a biome on its own, namely the Woodland Savanna Biome (see also Article III.3.9). We also adjusted the delineation of the Namib Desert and the Succulent Karoo Biome in Namibia according to the patterns of distribution of floristic elements of the Succulent Karoo along the Namibian coast, described by Jürgens (1991). The biome delimitation used is shown in the biome map (Fig. 4 in Subchapter II.1.1).

For the vegetation classification within the Observatories, we used 1000-m² data from a specific year (given in brackets in the header of the respective vegetation table) with particularly well developed and recorded vegetation. During a case study in Namibia, we discovered that distinguishing ecologically meaningful units from the 1000-m² data performed slightly better than for the 100-m² data (Dorendorf 2010, Dorendorf et al. 2010; also see Site-specific study S10.04). In contrast, vegetation relevés or 100 m² plot sizes would most likely have been more suitable for the small-scale vegetation patterns exhibited in the Succulent Karoo and Namib Desert Observatories. In order to keep the results comparable between the Obseratories, we decided to stick to the same plot size for the classifications of all Observatories. It is important to note that the classification is only valid at this particular spatial scale (Dengler et al. 2009).

Table 11: Extended life form categories used in this book for C = chamaephytes and P = phanerophytes; sub = submerged, nan = nano, mic = micro, mes = meso

	Csub	Cnan	Cmic	Cmes	Pnan	Pmic	Pmes	Pmac
Height range [cm]	< 1	< 5	5–15	15–50	50–200	200–500	500–2000	> 2000

The classification of typically 20 1000-m² plots per Observatory was carried out using Modified TWINSPAN (Roleček et al. 2009). The decision of where to cut the TWINSPAN classification tree (dendrogram) in order to obtain meaningful units was made by the vegetation ecologist responsible for a particular Observatory. The TWINSPAN analysis was run using Whittaker's beta diversity as a distance measure except for Observatory S43, where the median Jaccard dissimilarity was used. Diagnostic species were identified using the phi coefficient of association (Chytrý et al. 2002). All groups of relevés were standardised to an equal group size to avoid unintended artifacts of unequal group size (cf. Tichý & Chytrý 2006), e.g. when there were four units it was assumed that each represented a fourth of the relevé. Species with phi ≥ 75 were considered as highly diagnostic, and species with phi ≥ 50 as diagnostic, provided their concentration was significant according to Fisher's exact test at $\alpha = 0.05$ (see similar approach of Chytrý [2007], though with different thresholds).

The classifications of the Observatories S03, S10, S11, and S22 were based on larger-scale classifications with many more relevés also containing the respective Observatory data. In these cases, the thresholds were set to phi ≥ 50 for highly diagnostic species and phi ≥ 25 for diagnostic species. Also, the diagnostic species were retained from the larger-scale classification (i.e. based also on relevés from outside the Observatory), but only the relevés from inside the Observatory are shown in the classification tables.

In all cases, only very few manual modifications from the TWINSPAN classifications were allowed by the responsible authors to assure comparability of the classifications between the Observatories. In some cases, a single relevé was moved to a different unit when this resulted in a substantially higher phi value for a respective diagnostic species.

The names of the communities were provided by the responsible authors. The communities are named informally after one or, in most cases, two species present. Normally either both species are (highly) diagnostic or the first-named species is highly diagnostic and the second is dominant (but not necessarily also diagnostic). While we consider our vegetation units more or less equivalent to phytosociological associations, we refrained from proposing formal association names according to the International Code of Phytosociological Nomenclature (ICPN; Weber et al. 2000) here. Such a formal description should be based on much more comprehensive relevé material including the areas outside the Observatories, and is an important task for the future, for which the informal descriptions in this book are a valuable basis.

Millipedes

[K. Vohland]

Introduction

Millipedes (class Diplopoda, phylum Arthropoda) are arthropods that typically have a high number of double-legged segments. They range in size from the tiny family Paradoxosomatidae measuring approximately 3 mm to the largest millipedes belonging to the family Spirostreptidae measuring approximately 30 cm. Millipedes feed mainly on decaying material and therefore have an important ecological function as decomposers.

The millipede fauna along the BIOTA Southern Africa transect is typically Afrotropical, mostly represented by the characteristic family Odontopygidae and the predominantly South African representative genus *Chaleponcus*. The family Harpagorphoridae is represented by the southern African genera *Harpagophora* and *Zinophora*. In the family Spirostreptidae mainly *Doratogonus rugifrons*, which also occurs in Botswana and South Africa (Hamer 2000), and the widespread, large-bodied *Spirostreptus heros* occur (Hoffman et al. 2001, Vohland, in press). Not all species known for the region were collected at the BIOTA Observatories.

Photo 9: Installed pitfall trap at Karios (S12) used to catch ground-dwelling arthropods. Pitfall traps are simple plastic cups or tins that are dug into the soil with the entrance level with the soil surface. Photo: J. Deckert.

Photo 10: Full pitfall traps at Soebatsfontein (S22), which have been dug out in order to be emptied. Photo: J. Deckert.

Methods

Most of the material was obtained by hand collecting during the period 2000–2002. Specimens were mostly located in more humid places such as in litter or under the bark of rotten trees.

Millipedes also entered pitfall traps (Photos 9 and 10) as bycatch from the research of other entomologists. However, these were often juveniles or females, which could not be identified, as the gonopods (sexual organs) of adult male specimens are examined for taxonomic determination. The monograph of Attems (1922) was used for identification and nomenclature. For more recent revisions on the families occurring along the BIOTA transects, more recent publications by Kraus (1966) (for the family Odontopygidae), Hamer (1998; 1999) (a checklist, and an illustrated key to the spirostreptidan millipedes, respectively), Redman & Hamer (2003) (revision of the southern African Harpagophoridae), and Nguen Duy-Jacquemin (2003; 2009) (for the family Polyxenidae) were accessed. A key for millipedes occurring in Namibia was compiled (Vohland, in press). The material sampled from the Observatories

is housed in the National Museum of Namibia, the Natal Museum in Pietermaritzburg, South Africa, and in the Museum of Natural History, Berlin.

Termites

[C. Grohmann & K.E. Linsenmair]

Collecting methods

Termites (Order Isoptera, class Insecta, phylum Arthropoda) were collected according to standardised sampling schemes at the Observatories S01 (Mile 46), S02 (Mutompo), S04 (Toggekry), S05 (Otjiamongombe), S10 (Gellap Ost), S11 (Nabaos), S34 (Kleinberg), S35 (Gobabeb), S36 (Ganab), S37 (Rooisand), S38 (Claratal), S39 (Narais), and S40 (Duruchaus). The schemes differed in their extent between field campaigns, but were conducted in the same manner within the twin Observatories along the north–south transect (i.e. S01/Mile 46 – S02/Mutompo, S04/Toggekry – S05/Otjiamongombe, S10/Gellap Ost – S11/Nabaos, S39/Narais – S40/Duruchaus) and within the Observatories along the west-east transect through the Namib Desert (i.e. S34/Kleinberg, S35/Gobabeb, S36/Ganab, S37/Rooisand, S38/Claratal).

At the twin Observatories, sampling took place during five field campaigns during February/March 2005, April/May 2005, September 2006, April/May 2007, and April/May 2009, except for the twin Observatories S01 (Mile 46) and S02 (Mutompo), where instead of the field campaign in February/March 2005 one was conducted in February/March 2006. Sampling at the Observatories along the west-east transect were conducted during February/March 2005, April/May 2005, and September 2006.

The sampling scheme comprised five different methods:

i) baiting: 14 pieces of wood and 14 toilet paper rolls were distributed on two different hectare plots each and checked after approximately 1–2 weeks and 2–3 months; the baits were arranged in a matrix of 4 x 7 pieces with a random sequence of the different types of baits,
ii) sections: 10–17 sections (2 m × 5 m plots in which sampling took place for 15 min),
iii) scrapes: eight soil scrapes in ten sections each (one scrape consisted of a 12 cm × 12 cm × 10 cm block of soil, which was searched for termites),
iv) pitfall trapping (see Photos 9 and 10): ten pitfall traps filled with 67% ethanol and left for 48 hours,
v) hand collection: two man-hours of direct sampling.

The methods i) to iv) covered a total of six different hectare plots at each Observatory, while the hand collection was conducted over the entire Observatory.

As mentioned above, the strategy was standardised within the Observatories of each transect but varied between years. For example, the elaborative baiting was only conducted during 2005, and the destructive pitfall trapping and scrapes were not conducted along the west-east transect with its fragile habitats.

Specimens were stored in 80% ethanol and identified according to the identification keys of Uys (2002) and Coaton & Sheasby (1972). Only the soldiers were identified, except for the species *Hodotermes mossambicus* with workers that can easily be distinguished from other species. The systematic treatment and nomenclature used in this book follows Uys (2002).

The list of taxa provided in the tables and the number of taxa per Observatory were complemented by those published by Vohland & Deckert (2005; note that the information was taken from the text of this publication and not from Table 1 of the same publication, as the latter contained errors). In this manner, *Schedorhinotermes lamanianus* was added to the list of the Observatory S02 (Mutompo), *Allodontermes* to the Observatory S04 (Toggekry), and *Baucaliotermes hainesi* to the Observatory S11 (Nabaos). The numbers and lists of taxa of the Observatories S18 (Koeroegap Vlakte), S12 (Kairos), S20 (Numees), and S22 (Soebatsfontein) were obtained solely from the above-mentioned publication.

Information on the species or genera provided in the text were mainly taken from Uys (2002), Coaton & Sheasby (1972, 1973a, 1973b, 1974, 1975), and Ruelle et al. (1975).

Parameters provided

Frequency index

The frequency index was used to indicate the distribution of each species within an Observatory. This index, which is provided in a table in the Termites Section, indicates firstly, in how many of the six hectare plots a taxon was collected during at least one field campaign and, secondly, during how many of the direct sampling events a taxon could be collected. Hence, the maximum frequency of a taxon was reached if it was found in all of the six hectare plots and during all of the direct sampling events (five at the twin Observatories and three along the west-east transect), providing a total of eleven scores at the twin Observatories and nine along the west-east transect. The frequency index is the percentage of occurrences per taxon during these eleven respectively nine observations. The frequency index does not include workers as only soldiers were identified (except for *Hodotermes mossambicus*, see Collecting methods above).

An "r" indicates that a certain species was not collected within the standardised scheme, but during additional collections, which were not standardised between the Observatories. This includes the species collected by Vohland & Deckert (2005).

Feeding substrate

The grouping of termite families and subfamilies according to their feeding substrate was accomplished after Eggleton & Tayasu (2001).

Abundance index

The abundance index as provided in the infobox in the Termites Section was used to express the general abundance of termites at the respective Observatories. The abundance of termites is important to assess the role termites play at the Observatories. There are two main differences to

the frequency index. Firstly, soldiers and workers were taken into consideration, and secondly, the occurrences during a single collection event counted, so that each bait, section, etc. at which at least one termite occurred was regarded independently of their location. The abundance index is provided as a total value and not as a percentage, but could still be compared between Observatories within the two transects. Scrapes and pitfall trapping were only carried out at the twin Observatories, as these methods were far less effective than the other methods. The presentation of the abundance index as a percentage would grossly underestimate the abundance of termites on the twin Observatories compared to those Observatories along the west-east transect.

Termite data are available for 17 Observatories.

Photo 11: Malaise traps at Otjiamongombe (S05) catches flying insects. Photo: J. Deckert.

True bugs

[J. Deckert]

Collecting methods

True bugs (suborder Heteroptera, order Hemiptera, class Insecta, phylum Arthropoda) are diverse in their biology and adaptations, therefore no single key method is available to collect them. However, the majority of the terrestrial heteropterans can be collected from plants directly by net sweeping and beating the plants. Ground living true bugs can be collected using pitfall traps, by sieving of the ground litter, or by hand collection. Malaise traps (Photo 11) and colour pan traps (Photo 12) are methods for collecting particular Diptera and Hymenoptera species, but also catch species of Heteroptera. Heteroptera are often active just after sundown or during the night and are attracted to light sources. Therefore an essential method to collect Heteroptera was the use of lights, particularly those that emit ultraviolet light.

A combination of these methods is recommended for obtaining an inventory of the local Heteroptera fauna. Collection should also be repeated several times a year, because the occurrence of Heteroptera varies between seasons, as is the case with other insects too. Many of them are adapted to survive on plants and they depend directly on the occurrence and condition of their host plants. During unsuitable periods of the year, the true bugs survive in dormancy or as eggs. Apart from seasonal differences, the local weather conditions (precipitation, humidity, wind, and temperature) have a strong influence on the emergence and activity of true bugs. Nights with strong wind or temperatures below 18°C strongly reduce the flight activity of Heteroptera and bring poor or no results with light trapping.

Photo 12: A colour pan trap is used to collect Diptera (flies etc.) and Hymenoptera (bees etc.) in particular, but also catches species of Heteroptera (true bugs). Photo: J. Deckert.

Photo 13: Light trap at Toggekry (S04). Photo: J. Deckert.

The diversity and abundances of Heteroptera at different localities was recorded with quantitative and standardised techniques using light and pitfall traps. We used automatic light traps (1 × 15 W with super actinic light tubes). The automatic light traps switched on automatically at sundown and worked for approximately four hours. In addition, battery operated light towers equipped with 2 x 15 Watt light tubes and a white sheet illuminated with a 160 Watt bulb powered by a generator (Photo 13) were also used during the same period of time. The non-automatic light traps were permanently manned or checked at least three times per hour. The Heteroptera were counted and selected by hand. The number of specimens (*N*) and species (*S*) collected during each trapping session was summarised for each Observatory. At least 10 pitfall traps (diameter 9 cm) were placed in a line, spaced approximately 5 m apart at each Observatory and left out for at least three days. A preservation agent (ethylene glycol, which is known as anti-freeze for cars) was placed in the traps.

Material

Most of the material was mounted with water-soluble glue onto small cards,

Photo 14: Collecting at a 160-W lamp light. Photo: W. Mey.

Photo 15: K. Ebert sorting out light trap samples in the shade of a car. Photo: W. Mey.

which is the traditional method for preserving medium-sized specimens. Larger Heteroptera (> 10 mm) were pinned with stainless steel pins through the right side of the scutellum. Large specimens were stored in ethyl alcohol (75%).

Identified material, including types, are housed at the Museum für Naturkunde, Berlin, the National Museum of Namibia, Windhoek, the South African Museum, Cape Town, and the Transvaal Museum, Pretoria.

True bug data are available for 15 Observatories.

Butterflies and moths

[W. Mey]

The order Lepidoptera, (class Insecta, phylum Arthropoda) contains the butterflies and moths. All available collecting methods can be used if an inventory of the local butterfly and moth fauna is the aim of the project. The application of a variety of methods should ensure that the entire fauna is covered and as many species as possible are collected. Day-flying moths and butterflies were collected using a hand net while night active moths were collected by operating with different light sources. There is no need for a strict sampling protocol. Such a protocol or defined procedure is, however, necessary if quantitative samples must be obtained.

Sampling protocol

Butterflies

Quantitative sampling of butterflies was carried out using the line transect method (Pollard & Yates 1993, Settele et al. 1999). Four transects measuring 250 m each were laid through an Observatory and formed a continuous line leading through different habitat types. Trails passing through or along the edge of the respective Observatories were used. The transects are described in detail in the Observatory chapters. While walking along the transects, all flying or resting individuals of butterflies were recorded and counted within a corridor of 5 m width. Individuals that could not be identified in the field were captured using a sweep net. As butterfly activity is highest in sunshine between 9:00 am and 3:00 pm, counting was performed during this time. Specimens were identified using the identification books of Pringle et al. (1994) and Woodhall (2005).

There is usually a strong seasonality in butterfly activity. Emergence takes place after the first rains (in Namibia usually in December or January). As many species fly only for a few weeks during this time, monitoring of butterflies should start at the beginning of this period. Later, the abundance of butterflies declines and counting becomes irrelevant. However, the onset of the rainy period is uncertain and can vary within two or three months or even fails to appear. This unpredictability can result in poor counts that do not reflect local diversity. Therefore, such counts were omitted and only days with optimal counts are presented.

Moths

Quantitative samples were obtained using three different trapping methods.

The first method used battery-operated automatic light traps. These traps were equipped with one 15 W superactinic light tube (Philips TLD) and a photoelectric switch. Chloroform was used as killing agent. Over a four-hour period after sunset, two to three traps were operated simultaneously at different sites on an Observatory. As this type of trap only attracts moths from short distances and the trapped specimens are usually of poor quality, additional quantitative data were gathered. This was accomplished

by systematically collecting and counting specimens from a fixed area of 0.5 m^2 on a white sheet, illuminated by a 160-W bulb (Photo 14). The lamp was powered by a Honda Exe generator. As a third method, a light tower with two 15 W super-actinic light tubes (company F. Weber, Stuttgart) was used (Photo 13). The tower was battery-powered (Panasonic, 12 V, 10 Ah) and operated simultaneously with the light traps. The tower is a mobile device, and was thus useful for collecting in remote or inaccessible habitats. Microlepidoptera in particular can be effectively collected with the light tower.

All individuals obtained from light traps and the light towers were counted and identified at the species level. The number of individuals (*N*) and the species richness (*S*) of the three trap types (3 light traps or 2 light traps + light tower) were pooled per day, resulting in a sample that was used for comparisons with samples from other Observatories. Fisher's alpha (see "Diversity measures" above) was used to characterise the diversity of the samples. Calculations were conducted with the computer program EstimateS (Colwell 2006). The analysis of the complete spectrum of Lepidoptera made use of four categories into which Lepidoptera are traditionally separated: Microlepidoptera, Pyraloidea, Macrolepidoptera (Heterocera), and butterflies. In addition, the Noctuidae (Macrolepidoptera), as the most species-rich family, were kept and documented separately.

Material

A part of the collected material was pinned or set on micro-pins in the field (Photo 15). One or two specimens of most micromoth species were fully prepared in small setting boxes whilst the remainder were stored in paper envelopes. The material was relaxed, pinned, labelled, and sorted into families at the museum. The identification of species required visits to the Natural History Museum in London (BMNH), the South African Museum in Cape Town (SAM), and the Transvaal Museum in Pretoria (TMSA). A number of specialists were involved in the determination and description of new species. Identified material including types was deposited in the above-mentioned museums and in the National Museum of Namibia in Windhoek and in the Museum für Naturkunde in Berlin (MFN).

Butterfly and moth data are available for 14 Observatories.

Vertebrates

[U. Schmiedel]

Vertebrates are members of the phylum Chordata. Species of the terrestrial vertebrate groups reptiles, birds, and large mammals were observed by researchers during their field work at the Observatories. The species lists are therefore neither comprehensive nor comparable among the Observatories. They should only complement the information on the faunal diversity and provide additional, anecdotal information for the interested reader. However, small mammals in Gellap Ost were recorded systematically. Methods are described in Article III.5.8.

Vertebrate data are available for the vertebrate groups reptiles (class Reptilia), birds (class Aves), and mammals (class Mammalia), for 26 Observatories.

Landuse and The people

Data on landuse and/or people are available for eight Observatories.

Mile 46 (S01) and Mutompo (S02)

[M. Pröpper]

Long-term anthropological field research was conducted in the five villages adjacent to the Observatories between 2003 and 2008 and concentrated on cultural aspects of landuse ranging from environmental knowledge and perceptions to the impact of different behaviours and landuse practices. A core method—an ethnographic census—was employed in 2005 to gain an exhaustive picture of population structure and reliable figures on the demography of the population utilising the area around the Observatories. Open and structured interviews were conducted on all aspects of the farming system. They were complemented with several surveys e.g. on field uses and agricultural input strategies, on gender related labour division, and on household consumption patterns. For more details of the methods, see also Chapter IV.1.

Okamboro (S06)

[U. Schneiderat]

Basic socio-economic data as well as information on the number and type of livestock were derived from semi-structured interviews carried out mostly with the heads of 26 households (of 29 households in total) during a socio-economic household survey in 2001. Livestock ownership was analysed within three wealth groups, which were defined according to the assets of the household and their economic activities. The best-off households were defined as the upper third of the calculated wealth points, the medium households as the middle group, and the poor households as the lower third.

The progeny-history technique (PHT) was applied to 48 female goats and evaluated the progeny history of 134 goat kids in the same year. This method, which was based on the memory of the livestock farmer or the employed herder, was applied to investigate livestock performance and the disposition of the offspring. Additionally, structured PHT interviews were conducted for 57 cows and evaluated the progeny history of 169 calves in 2003.

Rangeland assessments were carried out during October 2002 (dry season) and May 2003 (wet season), along five micro-transects, starting from the central watering point of the village. The length of the micro-transects were between 2.6 km and 5.0 km depending on the topographical conditions. The rangeland assessment was accomplished by taking a sample every 200 m along the micro-transects. Sampling was carried out every 100 m within 1 km from the water points. Each transect characterised a sector of a circle, representing the area between the micro-transects. This method detected

the present rangeland conditions and the presumably heterogeneous distribution of natural resources from the most degraded areas (near the water point) to the least degraded areas (in the peripheral areas) in a more realistic way than other sampling methods.

Grasses within a randomly positioned square meter were clipped by hand at approximately 2 cm above ground level in order to determine the amount of standing dry biomass of grazing resources ($g \cdot m^{-2}$). The mean values from these sampling points were used, relating to the cycle sectors, to extrapolate grazing amounts for the entire area available to a community. Available browsing resources were determined by measuring various spatial dimensions of tree and bush canopies. The computer software BecVol 2 (Biomass Estimates from Canopy VOLume), compiled by Smit (1996) for southern Africa, was applied for the calculation of browsing resources (leaf dry matter below 1.50 m height, in kg ha^{-1}, determined on 10 m × 20 m plots).

The content of crude protein and the energy content of mixed grass samples and of several leaf samples were analysed and calculated and then also extrapolated to obtain the amounts available for grazing and browsing resources within the entire area of a community. Requirements of mixed livestock herds were estimated, based on maintenance levels from literature, assuming a dry matter intake (DMI) rate of 2.5% of the body weight, adding 50% of the energy requirement for walking and grazing activities. Cattle and sheep were assumed to be 80% grazers and 20% browsers, goats to be 30% grazers and 70% browsers, while horses and donkeys were considered as 100% grazers.

Narais (S39) and Duruchaus (S40)

[C. Naumann]

Lang conducted a survey of 97 farms in the Rehoboth area during 1999/2000 (for information regarding the survey's sampling design see Lang 2005). The social anthropological study conducted between 2004 and 2006 within the BIOTA framework, was based on this former farm survey. 30 farms out of the 97 were resampled and their landusers interviewed again. Botanical characteristics were taken into account when selecting the 30 farms. According to Giess (1971), the Rehoboth area can be divided into three different vegetation zones; the highland savanna, the dwarf shrub savanna, and the mixed grass and tree savanna. The 97 survey farms were classified into one of these three zones using maps. Ten farms were chosen from each vegetation group according to the ethnographic sampling design (compare Werner & Bernard 1994). The aim of this sampling method was to collect a complete representation of the range of variation with regard to the research question. To achieve this, informants were chosen in terms of different characteristics. Within the social anthropological study, the aim was to consider the following farm and landuser characteristics in terms of variation:

- ▷ farm size (small, medium, and large farms)
- ▷ number of land owners (farms of single and multiple owners)
- ▷ age of landusers (young and old farmer)
- ▷ sex of landusers (men and women)
- ▷ full-time and part-time farmers

Data on the 30 sample farms and their landusers were gathered through participant observation and open, semi-structured and structured interviews (compare Bernard 2002).

Gellap Ost (S10)

[S.E. Domptail]

The study area was defined using homogeneity criteria in terms of economic and ecological characteristics. Ecological indicators were rainfall, soils, geology, and especially vegetation patterns, which were derived from soil and geological maps, discussions with experts on each of these topics, plant identification, rainfall data, and a final field tour. Only commercial farms were included. All farms were located within a 60 km wide belt around Keetmanshoop. The study area, which was 710,000 ha in size, included the town of Keetmanshoop and its communal town lands. Therefore, only about 530,000 ha of the study area were managed as private property.

The data were collected by S.E. Domptail on the farms during interviews with farmers and field trips. Interviews were conducted in English with most of the farmers or in Afrikaans with a translator when necessary. Data collection and verification took place from 2005 to 2006. The farm sample was designed in 2005 so as to include the diverse types of landuses and ranching systems in the study area. Twenty-two farmers were interviewed; their farms covered 45% of the commercial farmland of the study area. The sample may be biased as the purpose of the interview was announced on the telephone as being part of the BIOTA project for biodiversity research. Therefore, farmers with degraded farmland might have more frequently declined the interview than others.

Soebatsfontein (S22)

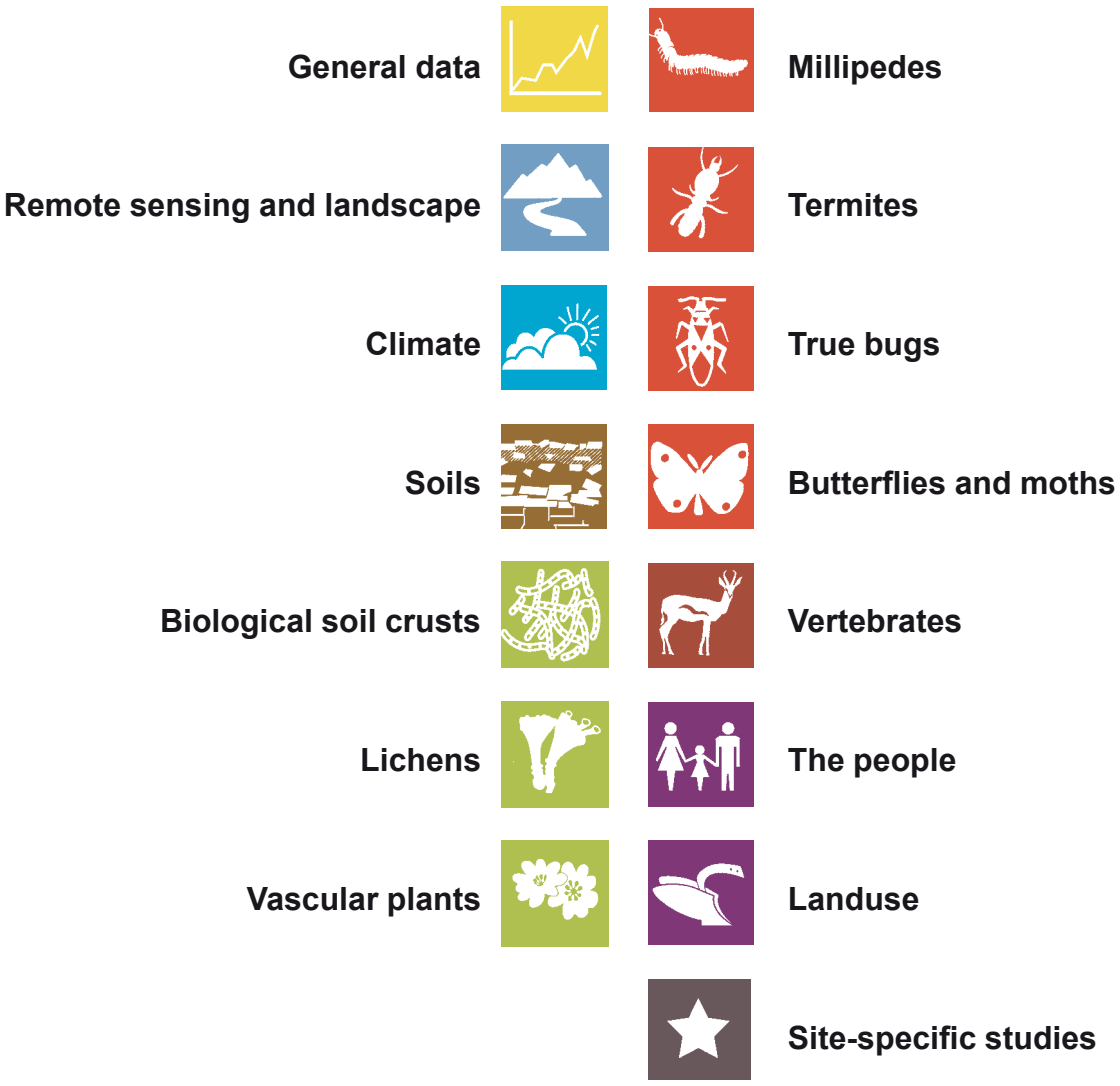
[T. Linke]

Linke conducted an ethnographic census in Soebatsfontein, gathered qualitative data on local knowledge and small stock farming, and monitored landuse activities over a period of five months. In her case study she analysed the links between features of the community and the pastoral land management system. For further details see Linke (2009) and Chapter IV.4.

How to read the Observatory descriptions

[J. Luther-Mosebach, D.H. Haarmeyer, U. Schmiedel, J. Dengler, J. Deckert, S.E. Domptail, C. Grohmann, A. Hoffmann, M. Keil, T. Linke, W. Mey, M. Pellowski, M. Pröpper, U. Schneiderat, K. Vohland, B. Weber, U. Wisch & L. Zedda]

The Observatory descriptions in Chapters II.2–II.7 have a highly standardised structure.
Each is subdivided into the following Sections (some of which may not be available for all Observatories):



Each of these Sections (apart from Site-specific studies) consists basically of a set of standardised infoboxes, tables, and figures, which allow the easy retrieval of information and comparison between Observatories, plus a description. In the following, we explain how to read and interpret these standardised elements using examples from different Observatories. For methodological details of data sampled by the BIOTA Southern Africa project, you are referred to Subchapter II.1.4.

The colour coding on the page margins refers to the biome the Observatory belongs to. Icons indicate which topics are presented on the respective page.

The CD-Symbol indicates where the printed and / or additional data are presented in the Electronic Appendix.

An overview of the facts presented in the infoboxes for all the investigated Observatories is provided for most sections (excluding "The people", "Landuse", and "Sitespecific studies") in the Electronic Appendix.

At the end of each section, the names of the author(s) responsible for the contents (text and/or data provision) of the section are given. For an overview see Subchapter II.1.3.

General data

Infobox

Number	Name	Alternative name(s)
S01	Mile 46	Alex Muranda LDC
Implementation	**Country**	**Province/ region**
2001	Namibia	Kavango
District/ constituency	**Locality**	**Farm name**
Rundu	near Cove	Alex Muranda LDC
Latitude	**Longitude**	**Altitude**
18.301826 S	19.247311 E	1180 m a.s.l.
Rainfall season	**Biome**	**WWF Ecoregion**
Summer	Woodland Savanna	AT0726 Zambezian Baikiaea woodlands
Agro-Ecological Zone	**Relative intensity of land use**	**Tenure**
KAL3-2	Low	State
Type and history of landuse	**Land owner**	
Research farming for cattle breeding	MAWF	

Category	Description
Number	Observatory number
Name	Observatory name
Alternative name(s)	Alternative Observatory name(s) (if applicable)
Implementation	Year in which the Observatory was established
Country	Country in which the Observatory is located
Province/ region	Province (for South Africa) or region (for Namibia) in which the Observatory is located.
District/ constituency	District (for South Africa) or constituency (for Namibia) in which the Observatory is located
Locality	Town or village closest to the Observatory
Farm name	Name of the farm where the Observatory is located
Latitude	Latitude of the north-west corner of the Observatory in decimal degrees according to World Geodetic System 1984 (WGS 84)
Longitude	Longitude of the north-west corner of the Observatory in decimal degrees according to World Geodetic System 1984 (WGS 84)
Altitude	Altitude in meters above sea level of the north-west corner of the Observatory
Rainfall season	Season (summer or winter) when most of the annual rainfall falls on average
Biome	Biome according to classification in this book (see Subchapter II.1.2)
WWF Ecoregion	Code number and name of the terrestrial ecoregion according to Olson et al. (2001; available at http://www.worldwildlife.org/wildworld/profiles/terrestrial_at.html) – This classification divides the Earth's land surface into eight terrestrial ecozones, containing 867 smaller ecoregions
Agro-Ecological Zone	Classification of the region in which the Observatory is located according to land resources including components of climate, soils and landform (de Pauw et al. 1998/1999). CPL2 Central Plateau, fringe plains CPL3-6 Central Plateau, strongly dissected inselberg plains, average growing period 41-60 days CPL3-7 Central Plateau, strongly dissected inselberg plains, average growing period 21-40 days CPL4-9 Central Plateau, strongly dissected plains on Karoo rocks, average growing period 11-20 days CPL7 Central Plateau, flat plains with dolerite outcrops and pans ESC2 Escarpment, high mountains on Basement Complex rocks ESC5 Escarpment, strongly dissected uplands bordering the highlands KAL3-2 Kalahari Sands Plateau, stabilized sand drift with few pans, average growing period 91-120 days

continued on next page

continued from last page

	KAL3-4 Kalahari Sands Plateau, stabilized sand drift with few pans, average growing period 61-90 days, very short dependable growing period KAL8 Kalahari Sands Plateau, 'omuramba'-dune association KAL9-4 Kalahari Sands Plateau, 'oshana' flood system, dependable growing period 61-90 days, very short dependable growing period NAM6 Namib Desert Plains, gravel and rock pavement
Relative intensity of landuse	Rough classification of landuse intensity None: almost no grazing by livestock or game Low: far below regional average and below recommended carrying capacity (e.g. conservation areas with game) Medium: stocking rates at recommended carrying capacity and regional average High: stocking rates above recommended carrying capacity and/or other very intensive land-use activities
Tenure	Type of ownership of the land (e.g. state, private, or communal)
Type and history of landuse	Current or recent landuse practice
Land owner	Owner of the land on which the Observatory is located

Remote sensing and landscape

Infobox

Geomorphology	Geological units	Lithological units
Degraded dunes and inter dunes of Kalahari dune veld	Kalahari Sands	Sands and Calcrete
Mean EVI	**EVI absolute range**	**Mean leaf area index**
0.244 (0.160−0.373)	0.124 (2005)−0.412 (2006)	0.76

Category	Description
Geomorphology	Geomorphology of the wider landscape (10 km × 10 km area around the Observatory)
Geological units	Geological units of the wider landscape (10 km × 10 km area around the Observatory) according to Mendelsohn et al. (2002) and van Eeden et al. (1970)
Lithological units	Lithological units of the wider landscape (10 km × 10 km area around the Observatory) according to Mendelsohn et al. (2002) and van Eeden et al. (1970)
Mean EVI	Long-term mean Enhanced Vegetation Index (EVI) for the period 2000 to 2009 (in brackets: characteristic range of values over the year, averaged EVI minimum to averaged EVI maximum)
EVI absolute range	Absolute range of the Enhanced Vegetation Index (EVI) for the period 2000 to 2009: absolute minimum (in brackets: year of minimum) to absolute maximum (in brackets: year of maximum)
Mean leaf area index	Mean leaf area index for the period 2000 to 2006 derived by remote sensing

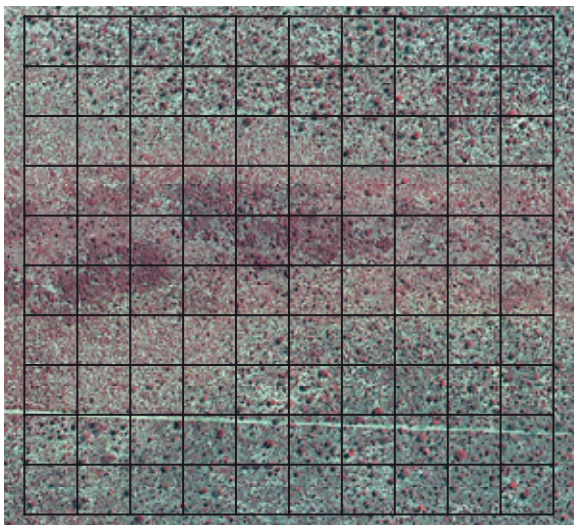
Grid map of Observatory

Left: Habitat types of the 1-ha plots according to our own ad-hoc classification within the Observatory (not directly comparable with other Observatories).

Right: Very high resolution satellite image QuickBird (IKONOS, SPOT-5, or HYMAP), with Near Infrared (NIR), Red, Green (RGB) bands with 100 m × 100 m grid; OR black-and-white air photo with 100 m × 100 m grid.

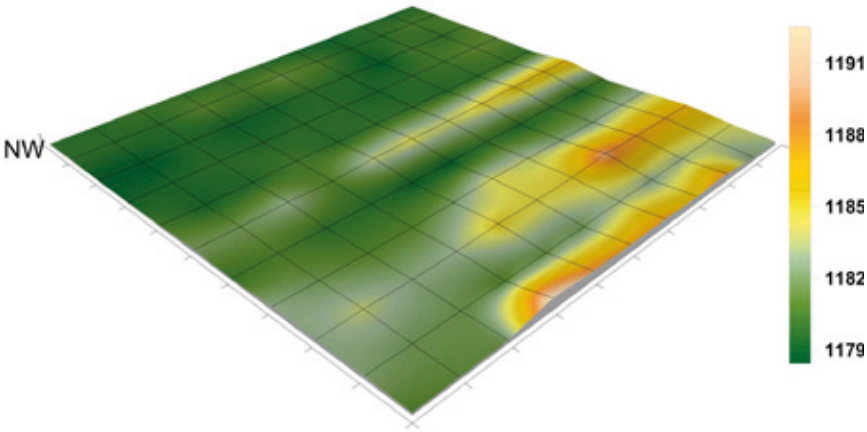
	0	1	2	3	4	5	6	7	8	9
0	15	72	90	3	25	1	70	98	37	7
1	44	81	27	94	4	56	91	95	12	79
2	57	60	31	9	29	11	47	53	24	33
3	71	46	42	23	52	34	17	78	75	6
4	49	16	5	40	28	35	68	39	85	63
5	58	66	20	2	73	61	55	77	67	97
6	13	80	83	50	26	59	76	74	41	92
7	38	21	10	43	32	64	30	8	54	62
8	51	82	88	36	87	19	93	14	86	18
9	84	48	22	89	100	69	99	96	65	45

1 Closed woodland savanna on degraded dune
2 Open woodland savanna on degraded dune
3 Woodland-thornbush transitional savanna on transission zone dune/interdune
4 Acacia thornbush savanna on interdune



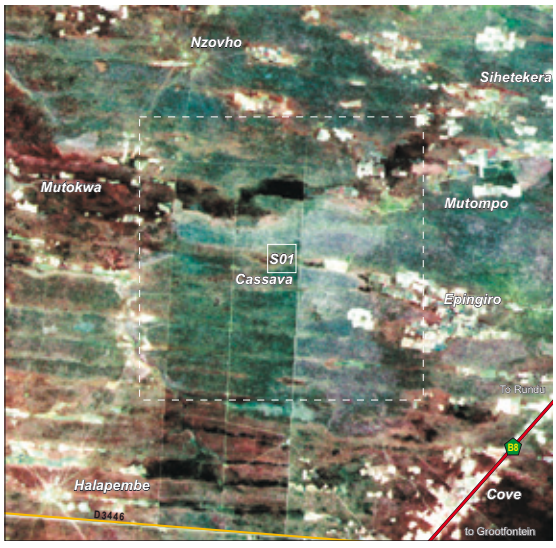
Elevation model of Observatory

Elevation model of the Observatory, generally based on 121 altitude readings with a differential GPS (Trimble) at the corners of the hectare plots interpolated with the "natural neighbor" algorithm using SURFER® 8.01.



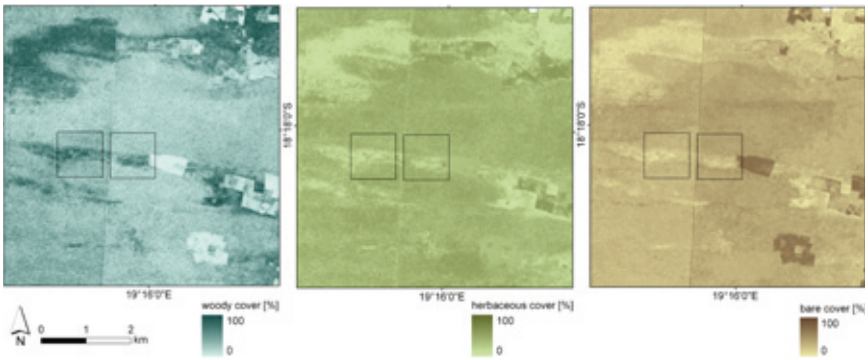
Landsat image

The Observatory and its surrounding (major roads, settlements etc.) as shown on a 20 km × 20 km size Landsat subscene. The text describes the structures detected on the central part (10 km × 10 km depicted by white dashed lines) of the Landsat image (bands NIR, MIR and Red in RGB). Scene number and acquisition date (i.e. date of production of image) are given below.



Fractional cover image

The fractional cover image describes the percentages of woody cover, herbaceous cover, and bare soil and is derived using QuickBird or IKONOS satellite data for the surroundings of the Observatory. The black quadrats indicate the location of the Observatory or the Observatory pair, respectively. By using IKONOS and QuickBird images and the derived fractional cover for calibration, the fractions can be derived also for larger Landsat and even for MODIS images (see Article III.2.3).



MODIS time series

Time series of MODIS Enhanced Vegetation Index (EVI) for the period 2000 to 2009, describing seasonal variability of green vegetation cover. For comparison, the temporal pattern of annual rainfall is included.

Blue bars: temporal patterns of annual rainfall (refer to right *y*-axis)

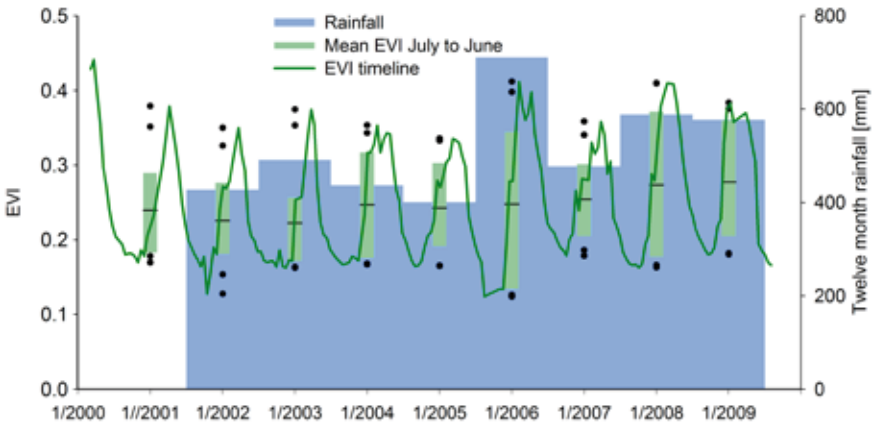
Green line: time series of green vegetation cover over the years expressed as EVI (refer to left *y*-axis)

Green boxes: inter-quartile range and mean (line) of annual EVI (July to June) (refer to left *y*-axis)

Black dots: extreme values of annual EVI (July to June) (refer to left *y*-axis)

Different characteristics of the specific seasonalities can be detected, with higher EVI values in the years 2006, 2008, and 2009 and lower EVI values in the years 2003 and 2007, indicating wetter conditions in 2006, 2008, and 2009 and drier conditions in 2003 and 2007. Besides that, differences in the beginning of the vegetation periods (compare 2002 and 2009) and in the duration of the vegetation period (compare 2005 and 2009) are visible.

Temporal patterns of annual rainfall, vegetation cover, and phenology



Climate

Infobox

Data from BIOTA weather station

Location	Recorded period	Mean temperature
Mile 46 (S01)	2001–2009	22.6 (-1.8–43.9) °C
Mean solar radiation	**Mean wind speed**	**Mean annual precipitation**
491 (263–754) $MJ \cdot m^{-2} \cdot month^{-1}$	1.1 (4.9) $m \cdot s^{-1}$	527 (348–816) mm
Mean annual potential evapotranspiration	**Interannual precipitation variability**	**Mean relative humidity**
1340 mm	131%	55% (23–84%)
Aridity index (UNEP)		
0.39 (semi-arid)		

Modelled data

Mean temperature	Mean annual temperature range	Mean diurnal temperature range
22.2 (6.6–34.0) °C	9.6 °C	15.7 °C
Mean annual precipitation	**Precipitation seasonality**	**Percentage winter precipitation**
536 mm	106%	8% (strong summer)
Climate type	**Length of dry season**	**Aridity index (De Martonne)**
BSh	7 months	16.6 (semi-dry)

Category	Description
Data from BIOTA weather station	These data are based on the recordings of the respective BIOTA weather station during the given period
Location	Name (in brackets: number) of the Observatory where the nearest BIOTA weather station is located.
Recorded period	Years during which climate data were recorded by the respective BIOTA weather station
Mean temperature	Mean annual temperature (in brackets: absolute minimum to absolute maximum)
Mean solar radiation	Mean value of solar radiation (in brackets: absolute monthly minimum to absolute maximum)
Mean wind speed	Mean wind speed (in brackets: mean of the annual maxima)
Mean annual precipitation	Mean annual precipitation (January – December) (in brackets: annual minimum to annual maximum)
Mean annual potential evapotranspiration	Mean annual potential evapotranspiration
Interannual precipitation variability	Variation of precipitation between the recorded years, expressed as coefficient of variation
Mean relative humidity	Mean relative humidity (in brackets: lowest to highest monthly means)
Aridity index (UNEP)	Aridity index according to UNEP (1992) as continuous value (in brackets: aridity index class according to UNEP [1992])
Modelled data	These data are based on global interpolations, mostly from *WorldClim* (Hijmans et al. 2005; see http://www.worldclim.org) for the period 1950–2000
Mean temperature	Mean annual temperature (in brackets mean daily minimum of the coldest month to mean daily maximum of the warmest month)
Mean annual temperature range	Difference in mean temperature between the coldest and the warmest month
Mean diurnal temperature range	Mean temperature range within a day
Mean annual precipitation	Mean annual precipitation
Precipitation seasonality	Variability of the precipitation among the means of the 12 months, expressed as coefficient of variation
Percentage winter precipitation	Mean percentage annual precipitation that occurs during the winter months (April to September) (in brackets: classification according to Bailey [1979])

continued on next page

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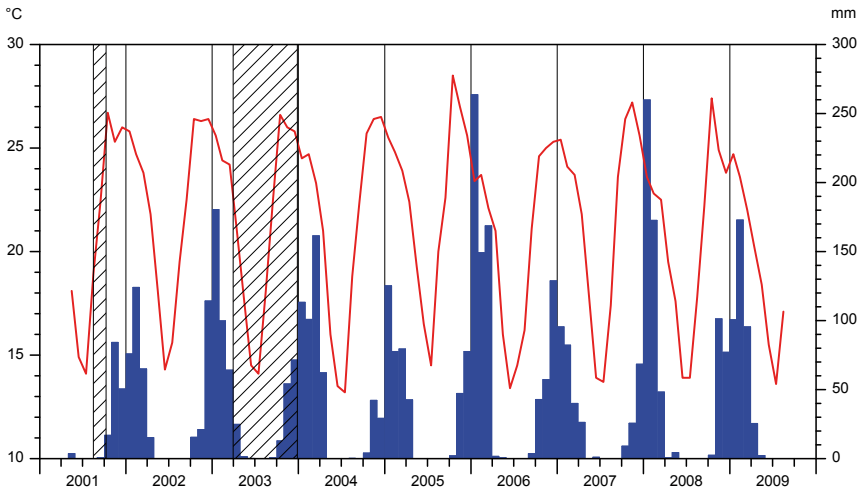
Climate type	Köppen-Geiger climate type after Kottek et al. (2006) – Note that this classification is not based on *WorldClim*	
	Main climate	B: arid
		C: warm temperate
	Precipitation	W: desert
		S: steppe
		s: summer dry
	Temperature	h: hot arid
		k: cold arid
		a: hot summer
		b: warm summer
Length of dry season	Number of months per year where the precipitation (in mm) is less than two times the temperature (in °C)	
Aridity index (De Martonne)	De Martonne's aridity index (in brackets: aridity index class according to Deniz et al. [in press])	

Time series: rainfall and temperature

Blue bars: monthly precipitation values recorded by the BIOTA weather station (refer to right y-axis).

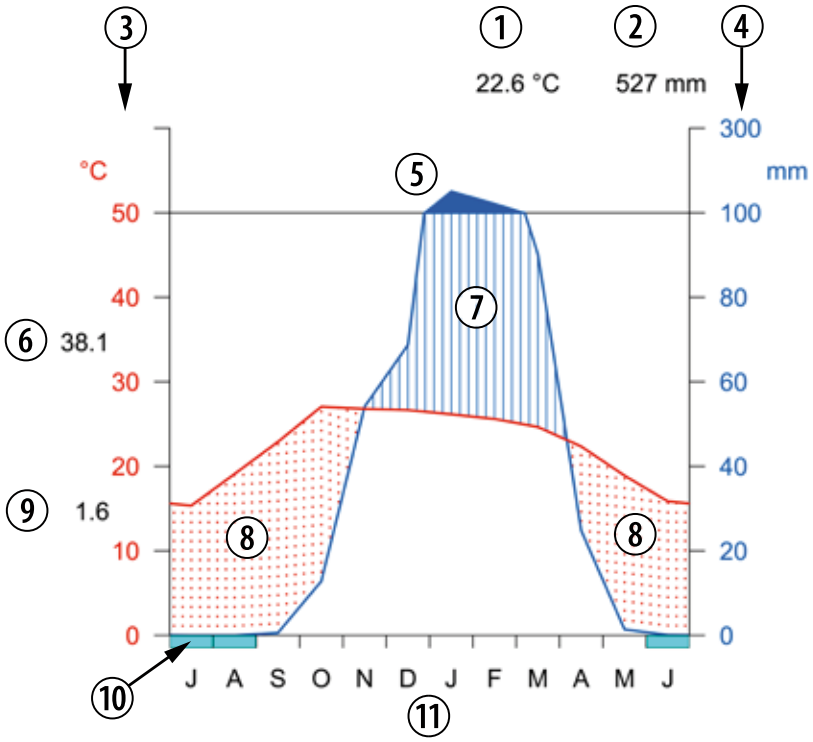
Red line: time series of temperatures. Monthly mean temperature as recorded by the BIOTA weather station (refer to left y-axis).

Hatched area: periods with interpolated data. Interpolated data are the mean values for the missing month calculated from all available values from other years for that particular month. Gaps shorter than one week are not shown.



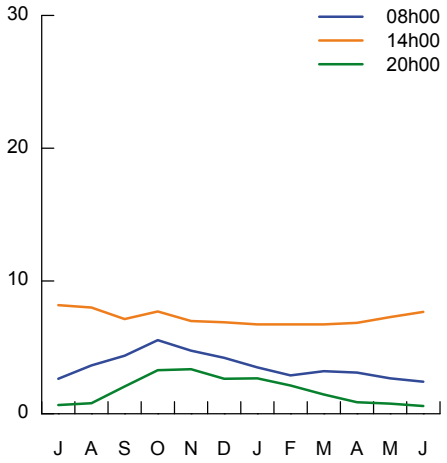
Climate diagrams

1: mean annual temperature
2: mean annual precipitation
3 (red): temperature in °C
4 (blue): mean monthly precipitation in mm
5 (dark blue): mean monthly precipitation above 100 mm
6: mean daily maximum temperatures of the warmest month for BIOTA weather station data and average monthly maximum temperature of the warmest month for modelled data
7: humid season
8: arid season
9: mean daily minimum temperatures of the coldest month for BIOTA weather station data and average monthly minimum temperature of the coldest month for modelled data
10: indication of periods in which frost can occur (not available for modelled data)
11: notation of months for the southern Hemisphere, starting with July

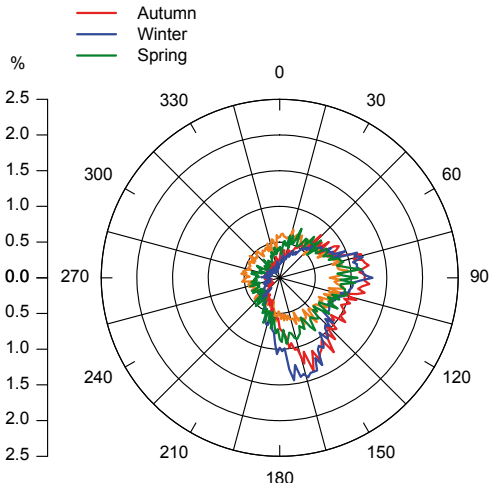


Wind diagrams

Wind speed in the morning, during midday, and in the evening over the year. Speed is indicated as km/h. Notation of month on the *x*-axis starts with July.



Percentage wind direction within the four seasons. Wind direction is displayed in 2° intervals. The percentage of wind direction was calculated as the number of values per season divided by the number of all valid values for the respective season. Seasons are summer (December to February), autumn (March to May), winter (June to August), and spring (September to November).



Soils

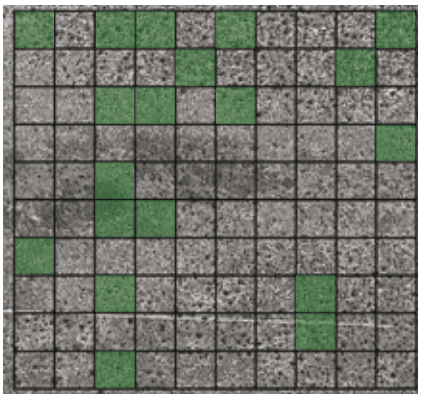
Infobox

Year of sampling	Hectare plots sampled	SOTER unit
2001	23 (R1–15, R19, R24, R25, R32, R76, R79, R88, R90)	NA17
Soilscape	**Dominant soil group(s)**	**Reference group richness**
Arenosols (AR)	Arenosol	1
Soil unit richness	**Soil unit evenness**	**Soil ecotype richness**
2	0.212	2
Parametric space	**pH**	**Electrical conductivity**
0.58	5.8 (4.8–7.0)	9 (4–20) µS·cm-1
Organic carbon		
0.42% (0.27–0.72%)		

Category	Explanation
Year of sampling	Year when soil studies were conducted.
Hectare plots sampled	Number (in brackets: ranks) of hectare plots analysed.
SOTER unit	Unit of classification according to FAO (1995)
Soilscape	Dominant soil at the landscape level (> 10 km^2) (Coetzee 2002)
Dominant soil group(s)	Dominant soil(s) on the Observatory classified according to IUSS Working Group WRB (2006)
Reference group richness	Number of different soil reference groups according to IUSS Working Group WRB (2006) represented on the Observatory
Soil unit richness	Number of different soil units represented on the Observatory, classified according to IUSS Working Group WRB (2006) with two qualifiers
Soil unit evenness	Evenness of soil units represented on the Observatory, classified according to IUSS Working Group WRB (2006) with two qualifiers
Soil ecotype richness	Richness of soil ecotypes represented on the Observatory, classified according to Petersen (2008)
Parametric space	Parametric space of soil properties derived from the analysed soil profiles on the Observatory
pH	Median (in brackets: range) of pH[$CaCl_2$]-values of first horizon
Electrical conductivity	Median (in brackets: range) of electrical conductivity of first horizon
Organic carbon	Median (in brackets: range) of organic carbon content of first horizon

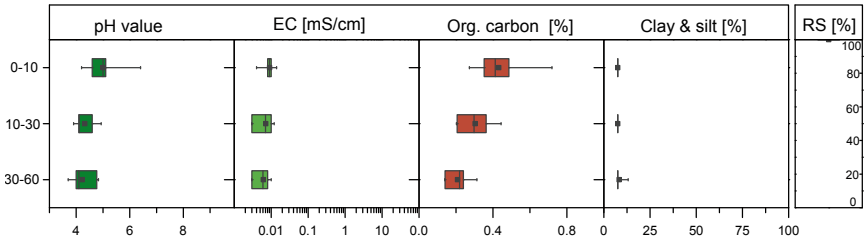
Map of soil profiles

Distribution of soil units [classification according to IUSS Working Group WRB (2006) with one qualifier]. The colours indicate the soil units found in the soil profiles, located 4 m south of the hectare centre points of the selected hectare plots.



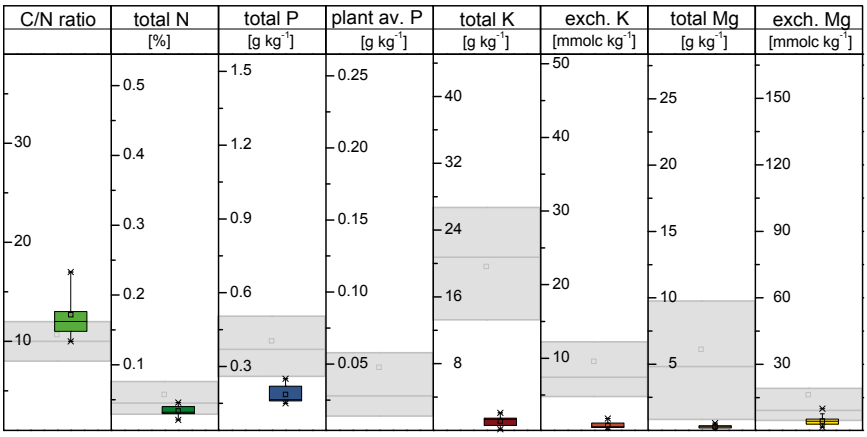
Soil characteristics

Variability of selected soil properties at three depth intervals (box = 25–75 percentile with median (line), and arithmetic mean (square); hinges = minimum/maximum. pH value measured in $CaCl_2$-solution; EC = electrical conductivity; RS = rooting space as a percentage of 100 cm depth).



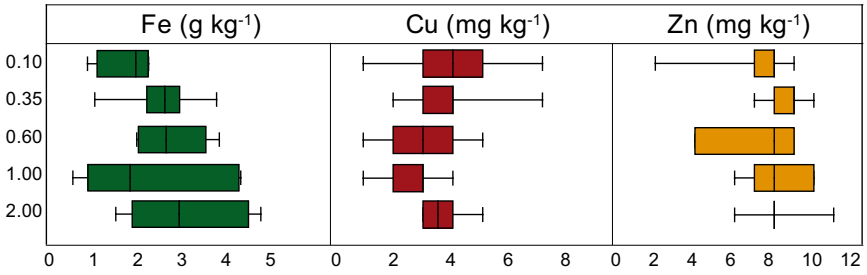
Soil nutrients

Variability of selected topsoil properties (Box = 25–75 percentile with median (line) and arithmetic mean (square), hinges = 5/95 percentile; asterisk = minimum/maximum). For comparison, the overall percentiles, medians, and means of the BIOTA Southern Africa transects are shown in grey.



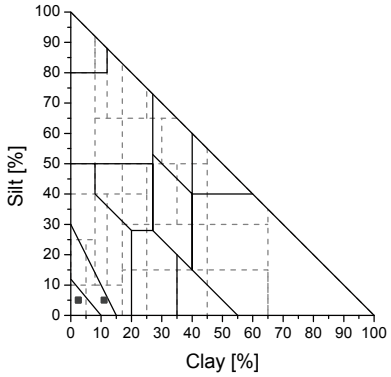
Soil micronutrients

Variability of selected soil micronutrient contents at five depth intervals (Box = 25–75 percentile with median (line); hinges = 5/95 percentile). Fe = iron; Cu = copper; Zn = Zinc.



Soil texture triangle

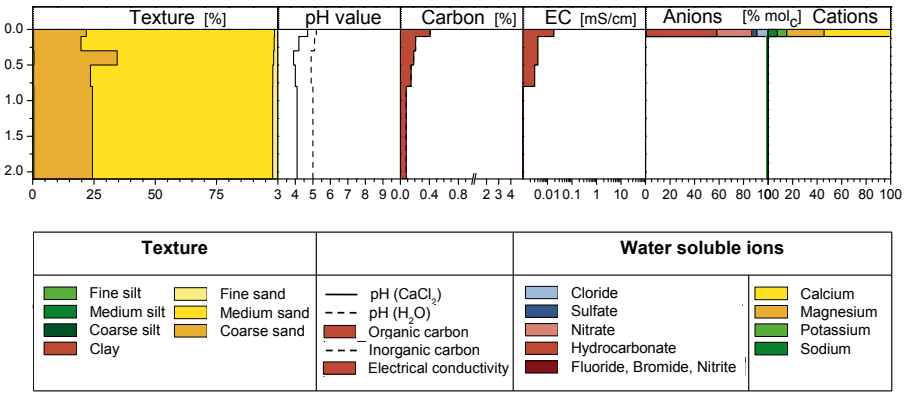
Results of texture analysis (squares = finger test, all samples; circles = laboratory analysis, selected samples; dashed lines = Texture according to German Classification KA5 (AG Boden 2005); solid line = Texture according to FAO (1990)).



Reference profile

Here, a soil profile from the Observatory is described in detail (photo, verbal description, figure) that is considered to be particularly typical. In the heading, the number of the respective hectare plot is given, while the soil type (according to IUSS Working Group WRB 2006) is named in the first sentence of the verbal description.

In the graph, the depth distribution (*y*-axis = depth in m) of selected soil properties is shown for the reference profile.



Biological soil crusts

Infobox

Sampling period(s)	Hectare plots sampled	Types of soil crusts
2003	2 (R1, R3)	1, 2
Crust thickness	**Cover**	**Carbon [weight %]**
< 3 mm	less than 1%	0.539
Nitrogen [weight %]	**Chlorophyll *a* [mg/m²]**	**Chlorophyll *a+b* [mg/m²]**
0.012	23	70

Category	Description
Sampling period(s)	Year(s) in which regular sampling of biological soil crusts took place
Hectare plots sampled	Number of hectare plots sampled (in brackets: rank numbers of these plots)
Types of soil crusts	Biological soil crusts are classified into 7 different types (compare Table 9 in Subchapter II.1.4)
Crust thickness	Mean thickness of crust measured with a caliper at 6 points on each crust sample collected from an Observatory
Cover	Mean percentage cover of biological soil crust within an Observatory
Carbon [weight %]	Mean gravimetric percentage of carbon of the soil crust samples collected within an Observatory
Nitrogen [weight %]	Mean gravimetric percentage of nitrogen of the soil crust samples collected within an Observatory
Chlorophyll *a* [mg/m²]	Mean chlorophyll *a* content of soil crust samples collected within an Observatory; given as milligrams per square meter of biological soil crust
Chlorophyll *a+b* [mg/m²]	Mean chlorophyll *a+b* content of soil crust samples collected within an Observatory; given as milligrams per square meter of biological soil crust

Biological soil crust characteristics

	H03	**H05**
Soil characteristics	Grey sand	Grey sand; several burnt wood particles
Crust characteristics	Dark grey clumps, only small fragile pieces; BSC not obvious	Only few fragile pieces, that cannot easily be identified as BSC
Chlorophyll *a* [mg/m²]	21.98	23.48
Chlorophyll *a+b* [mg/m²]	56.88	83.92
Carbon [weight %]	0.55	0.53
Nitrogen [weight %]	0.01	0.01

Soil characteristics: Description of texture, grain size, coloration, and characteristic particles within the soil samples per hectare plot

Crust characteristics: Description of texture, fragility and coloration of biological soil crust samples taken in the hectare plot

Chlorophyll *a* [mg/m²]: Chlorophyll a content of the soil crust within the sampled area within the hectare plot, given as milligrams per square meter of biological soil crust.

Chlorophyll *a+b* [mg/m²]: Chlorophyll a+b content of the soil crust of the sampled area within the hectare plot, given as milligrams per square meter of biological soil crust.

Carbon [weight %]: Gravimetric percentage of carbon within a soil crust sample of this hectare plot.

Nitrogen [weight %]: Gravimetric percentage of nitrogen within a soil crust sample of this hectare plot.

Growth forms: number of soil-inhabiting lin species representing a given growth form per Observatory (1 km²).

Lichens

Infobox

Sampling period(s)	Hectare plots sampled	Cover
2001, 2004	10 (R1–R10)	1% (0–7%)
Total species richness	**Species richness on soil [1 km²]**	**Species richness on rock [1 km²]**
4	2 (50%)	2 (50%)
Species richness on plants [1 km²]	**Species richness on soil [1000 cm²]**	
0	0.2 (0–1)	

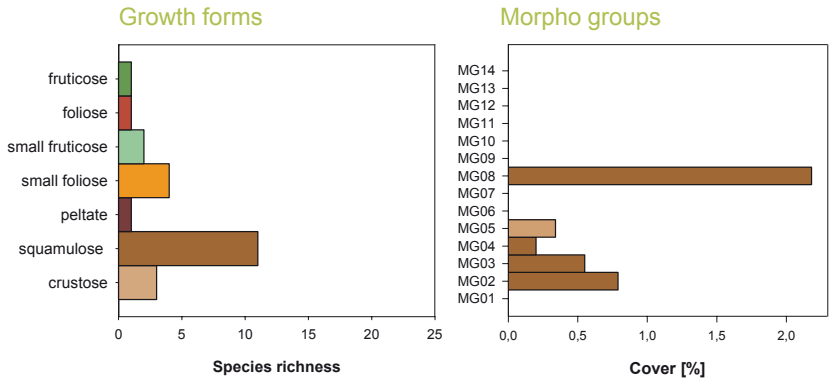
Category	Explanation
Sampling period(s)	Year(s) in which sampling of lichen data took place
Hectare plots sampled	Number (in brackets: ranks) of hectare plots sampled by standard methods
Cover	Mean cover of lichens at the 1000-cm² scale for all plots (in brackets: range of values)
Total species richness	Total richness of lichen species on the Observatory.
Species richness on soil [1 km²]	Number of lichen species growing on soil on the Observatory (in brackets: percentage of the total richness recorded)
Species richness on rock [1 km²]	Number of lichen species growing on rock on the Observatory (in brackets: percentage of the total richness recorded)
Species richness on plants [1 km²]	Number of lichen species growing on woody plants (shrubs and trees) on the Observatory (in brackets: percentage of the total richness recorded)
Species richness on soil [1000 cm²]	Number of lichen species growing on soil at the sampled plot (1000-cm² scale) (in brackets: range of values)

Growth forms – Morpho groups

Growth forms: number of soil-inhabiting lichen species representing a given growth form per Observatory (1 km²).

Morpho groups: dominance of lichen morphological groups at the sampling plots (1000-cm² scale). For an explanation of the morphological groups (MGs) see Subchapter II.1.4. Bars represent mean cover.

Max: maximum cover values of the respective morphological groups.



List of taxa

List of all lichen taxa recorded at the Observatory on different substrates (soil, rock, and woody plants).

Terricolous (on soil):	Saxicolous (on rock):	Epiphytic (on plants):
Collema coccophorum	Peccania sp.	No records
Peltula patellata	Peltula sp.	

Vascular plants

Infobox

Sampling period(s)	Hectare plots sampled	Biome
2001−2003, 2005−2009	20 (R1−R20)	Woodland Savanna
Vegetation unit (level 1)	**Vegetation unit (level 2)**	**Identification rate**
Tree Savanna and Woodland (Northern Kalahari)	n.a.	94% − 99% − 100%
Cumulative family richness	**Dominant families (cover)**	**Dominant families (richness)**
60	Bignoniaceae, Aizoaceae, Amaranthaceae	Fabaceae, Poaceae, Euphorbiaceae
Cumulative species richness (1 km²)	**Species richness (1000 m²)**	**Species richness (100 m²)**
322 − 149	43.8 (18−67)	22.2 (11−31)
***z*−value**	**Species richness change per year (1000 m²)**	**Evenness (1000 m²)**
0.295 (0.000−0.537)	0.58	0.818 (0.558−0.924)
Evenness (100 m²)	**Simpson (1000 m²)**	**Simpson (100 m²)**
0.921 (0.686−0.970)	0.921 (0.686−0.970)	0.842 (0.577−0.929)

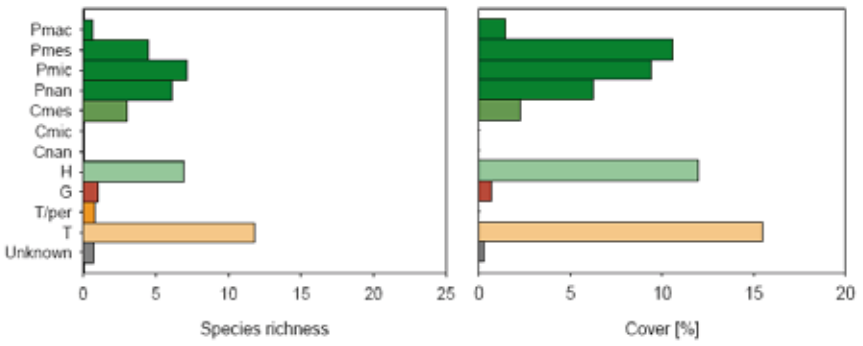
Category	Description
Sampling period(s)	Years in which regular sampling of vascular plant data took place
Hectare plots sampled	Number (in brackets: ranks) of hectare plots sampled
Biome	Biome according to classification in this book
Vegetation unit (level 1)	Namibia: vegetation unit according to Giess (1971); South Africa: higher-ranked vegetation unit according to Mucina & Rutherford 2006)
Vegetation unit (level 2)	Vegetation unit according to Mucina & Rutherford (2006) (only for South Africa)
Identification rate	Percentage of plant taxa that could be assigned to formally described taxa at the three spatial scales (1 km² - 1000 m² - 100 m²)
Cumulative family richness	Total number of vascular plant families recorded on the entire square kilometre during the study period
Dominant families (cover)	Vascular plant families that accounted for the highest cover at the 1000-m² scale in decreasing order (based on average values for all years and all plots)
Dominant families (richness)	Vascular plant families that accounted for the highest proportion of species at the 1000-m² scale in decreasing order (based on average values for all years and all plots)
Cumulative species richness (1 km²)	Total number of terminal vascular plant taxa encountered during the study period on the entire Observatory – number of terminal vascular plant taxa in one selected year (i.e. 2008 or, if not available, 2007)
Species richness (1000 m²)	Number of terminal vascular plant taxa on 1000 m², averaged over all plots and all years (in brackets: range of values)
Species richness (100 m²)	Number of terminal vascular plant taxa on 100 m², averaged over all plots and all years (in brackets: range of values).
***z*−value**	Slope of the species-area relationship (SAR) in the double-logarithmic space between 100 m² and 1000 m², averaged over all plots and all years (in brackets: range of values)
Species richness change per year (1000 m²)	Mean annual increase or decrease of richness of perennial species (C, P) over all years on 1000-m² plots calculated based on recordings from subsequent years.
Evenness (1000 m²)	Cover-based Shannon evenness of terminal vascular plant taxa at 1000 m², averaged over all plots and all years (in brackets: range of values)
Evenness (100 m²)	Cover-based Shannon evenness of terminal vascular plant taxa at 100 m², averaged over all plots and all years (in brackets: range of values).
Simpson (1000 m²)	Cover-based Simpson diversity index of terminal vascular plant taxa at 1000 m², averaged over all plots and all years (in brackets: range of values)
Simpson (100 m²)	Cover-based Simpson diversity index of terminal vascular plant taxa at 100 m², averaged over all plots and all years (in brackets: range of values)

Life forms

Relevance of different life forms according to species richness and cover. The life forms are Pmac = macrophanerophytes, Pmes = mesophanerophytes, Pmic = microphanerophytes, Pnan = nanophanerophytes, Cmes = mesochamaephytes, Cmic = microchamaephytes, Cnan = nanochamaephytes, H = hemicryptophytes, G = geophytes, T/per = therophytes that may survive more than one season if the weather condition permits, T = therophytes, Unknown = unclassified taxa.

Species richness: mean species richness per 1000 m².

Cover (%): mean cumulative cover of all species belonging to a certain life form.



Species richness

Left figure:

Brown and green box-whisker plots: inter- and intra-annual variability of vascular plant species richness (refer to left *y*-axis)

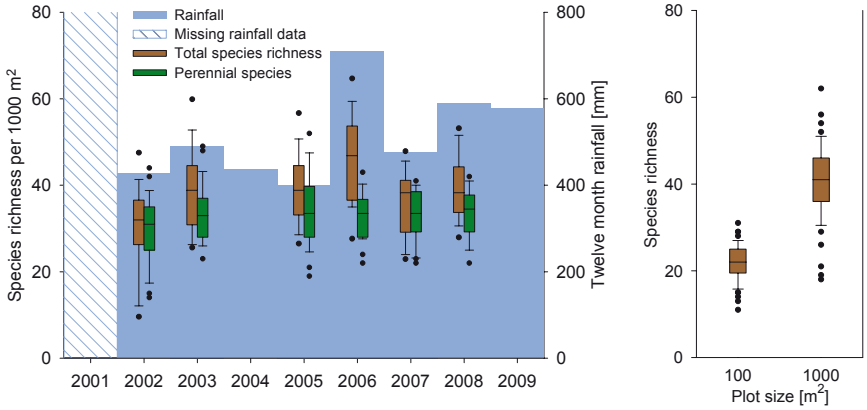
Blue columns: sum of rainfall recorded by the BIOTA weather station over 12 months; July to June in summer rainfall regions, January to December in winter rainfall regions (refer to right *y*-axis). Hatched parts: data gap or data that were not yet available for this analysis.

Right figure:

Plot-size-dependent species richness across all hectare plots and all recorded years

Both figures:

The box-whisker plots depict medians (lines), inter-quartile ranges (boxes), inter-decil ranges (hinges), and extreme values (dots).



Classification table

The classification is for 1000-m² plots and a selected year (given in brackets in the caption). In species-rich vegetation, it can extend over more than one page. The classification table consists of a **header** and a **species list**.

The **header** contains the obligatory lines 1–4 and further facultative lines. These facultative lines contain a selection of mean values of environmental or structural parameters for which the distinguished plant communities differed.

Obligatory lines of the header

1 **(Column):** name of the column ("All" or number of community)
2 **(Number of relevés):** number of relevés that are included in the respective column
3 **(Mean cover [%]):** mean cover of vascular plants
4 **(Mean species richness (1000 m²)):** mean species richness of 1000-m² plot

Facultative lines of the header

5 **(Inclination [°])**: slope of plot in degrees [°]
6 **(Mean soil pH):** mean soil pH of first horizon
7 **(Mean electrical conductivity [µS·cm^{-1}]):** mean soil electrical conductivity of first horizon
8 **(Organic carbon [%]):** mean organic carbon in percentage of first horizon
9 **(Nitrogen [%]):** mean nitrogen in percentage of first horizon
10 **(Fine material):** mean surface cover of the fraction size < 0.2 cm on 1000 m² plot
11 **(Gravel):** mean surface cover of the fraction size 0.2–2 cm
12 **(Stones 2–6 cm):** mean surface cover of stones between 2 and 6 cm in diameter ion
13 **(Stones 6–20 cm):** mean surface cover of stones between 6 and 20 cm in diameter
14 **(Stones 20–60 cm):** mean surface cover of stones between 20 and 60 cm in diameter
15 **(Blocks [%]):** mean surface cover of blocks > 60 cm in diameter
16 **(Rock outcrops [%]):** mean surface cover of rocky outcrops
17 **(Soft litter [%]):** mean cover of non-woody litter such as leaves
18 **(Biotic Crust [%]):** mean cover of biological soil crusts

Classification table

Column ①		Cover	All	1	2	3
Number of relevés ②			10	2	2	6
Mean cover [%] ③			22.9	13.8	29.6	23.7
Mean species richness (1000 m²) ④			70.2	57.0	83.5	70.2
Inclination [°] ⑤			6.4	14.0	5.0	4.0
Mean soil pH ⑥			6.29	4.21	6.97	6.85
Mean electrical conductivity [µS·cm^{-1}] ⑦			3005	743	5251	3011
Organic carbon [%] ⑧			0.76	1.40	0.57	0.58
Nitrogen [%] ⑨			0.08	0.10	0.07	0.07
Fine material [%] ⑩			47.7	4.0	35.5	70.0
Gravel [%] ⑪			33.4	41.5	40.0	27.6
Stones 2-6 cm [%] ⑫			15.2	50.0	13.0	2.2
Stones 6-20 cm [%] ⑬			0.8	1.5	1.5	0.2
Stones 20-60 cm [%] ⑭			0.1	0.5	0.0	0.0
Blocks [%] ⑮			0.0	0.0	0.0	0.0
Rock outcrops [%] ⑯			2.8	2.5	10.0	0.0
Soft litter [%] ⑰			1.6	0.5	6.0	0.3
Biotic crust [%] ⑱			27.3	5.5	5.0	45.0
Unit 1: Hirpicium alienatum-Ruschia burtoniae community						
Cmes	Microloma sagittatum	0.03	20	100	.	.
Cmes	Asparagus capensis	0.12	30	100	.	17
Cmes	Hirpicium alienatum	0.45	20	100	.	.
Unit 2: Tripteris hyosereoides-Ruschia burtoniae community						
T	Tripteris hyoseroides	0.06	20	.	100	.
Cnan	Peliostomum virgatum	0.02	20	.	100	.
T	Ehrharta triandra	0.18	20	.	100	.
T	Amsinckia retrorsa	0.02	20	.	100	.
Unit 3: Antimima solida-Cephalophyllum spissum community						
Pnan	Lampranthus otzenianus	0.54	60	.	.	100
Cmes	Galenia sarcophylla	0.35	60	.	.	100
T	Tetragonia microptera	0.10	50	.	.	100
Cnan	Antimima solida	0.31	70	.	50	83
G	Caulipsolon rapaceum	0.15	70	.	50	100
T	Tripteris clandestina	0.01	70	.	50	100

The **species list** is arranged according to the diagnostic value of the species. First, the diagnostic species of the first community are listed according to decreasing phi values, then those of the second community, and so forth. Finally, the most frequent companions are shown. They are sorted according to decreasing overall constancy and then according to their total cover. The printed list is cut at the end of the second page. Species with a constancy of 10% and lower are not shown. For the complete list, including a complete vegetation table of individual relevés, please refer to the respective Electronic Appendix.

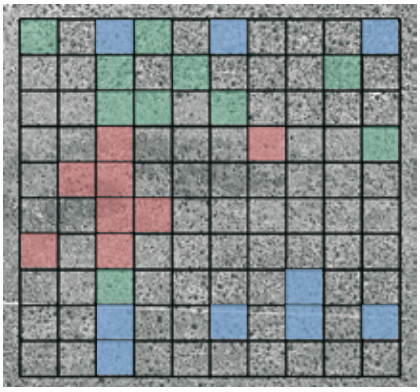
For each species, the following information is given from left to right:

Abbreviation of the life form (e.g. Cmes = mesochamaephyte)
Name of the taxon
Mean cover in all plots (in %)
Overall constancy in all analysed plots (in %)
Constancy in community No. 1 (in %)

The constancy values of diagnostic species of communities are highlighted in the respective colour of the community (see also Map of vegetation units and community photos). Two different intensities of the colour are used—deep for highly diagnostic species and light for diagnostic species

Map of vegetation units

The spatial distribution of the described vegetation units at an Observatory. Colour codes correspond to the colour codes used for the units in the vegetation table.



Millipedes

Infobox

Sampling period(s)	Species richness
2003/III	1

Category	Explanation
Sampling period(s)	Year and month of specimen collecting
Species richness	Total number of species (identified species + morphospecies) collected

List of species

List of all taxa recorded by hand collection or as bycatch in the pitfall traps at the Observatory:

Species: species name

Familiy: family name of the taxon

Relative frequency: non-quantitative estimation: frequent > 5 specimens/visit; seldom = 1 specimen

Feeding group: according to literature and own observation as in the case of *S. heros*

Species	Family	Relative frequency	Feeding group
Spirostreptus heros	Spirostreptidae	Frequent	Litter, fresh plant material

Termites

Infobox

Taxon richness	Abundance index	Dominant (sub-) family
9	28	Rhinotermitidae

Category	Description
Taxa richness	Measure of the number of different organisms: total number of distinct taxa, i.e. number of different species, morphospecies or genera, respectively, depending on the level up to which identification was possible
Abundance Index	Measure of the general abundance of termites
Dominant (sub-) family	Termite family or subfamily occurring most frequently during all sampling events, i.e. the termite (sub-) family with the highest Frequency Index

List of taxa

Taxon	(Sub-)family	Frequency Index	Feeding substrate
Psammotermes allocerus	Rhinotermitidae	0.82	w, d
Fulleritermes	Termitidae (Nasutitermitinae)	0.36	s, w, g, l, m
Trinervitermes	Termitidae (Nasutitermitinae)	0.36	s, w, g, l, m
Allodontermes	Termitidae (Macrotermitinae)	0.09	f (g, l, w)
Hodotermes mossambicus	Hodotermitidae	0.09	g
Microtermes	Termitidae (Macrotermitinae)	0.09	f (g, l, w)
Promirotermes	Termitidae (Termitinae)	0.09	s, w, g
Microcerotermes	Termitidae (Termitinae)	r	s, w, g
Odontotermes sp. 2	Termitidae (Macrotermitinae)	r	f (g, l, w)

Taxon: name of the termite (species, morphospecies or genus, depending on the level up to which identification was possible)

(Sub-)family: name of the family (subfamily) of the aforementioned taxon

Frequency Index: measure of the dominance of a taxon: percent occurrence of a taxon during all sampling events; r = rare occurrence of the taxon at the Observatory; i.e. the taxon was not found during the standardised sampling event, but during additional samplings or according to Vohland & Deckert (2005)

Feeding substrate: apparent feeding substrate of the subfamily following Eggleton & Tayasu (2001); d: detritus; f: fungus; g: grass; l: litter; m: microepiphytes; s: soil; w: wood

True bugs

Infobox

Sampling period(s)	Methods	Family richness
2001/IV, X; 2002/II, IV, V, VII, VIII, X; 2003/III, IV; 2008/IV, IX	Trapping (light, pitfall traps); beating of plants; hand collecting	23
Species richness	**Individuals sampled**	**Fisher's alpha diversity**
75	719	21.07

Category	Description
Sampling period(s)	Year and month of specimen collection
Methods	List of all methods used to collect Heteroptera on the Observatory
Family richness	Number of Heteroptera families found on the Observatory
Species richness	Total number of species (indentified species + morphospecies) verified and collected using all methods
Individuals sampled	Total number of collected specimens
Fisher's alpha diversity	Diversity of true bugs expressed by Fisher's *α*

Species richness in families

***S*:** recorded species richness of the particular family on the Observatory

Total: recorded species richness of all Heteroptera con the Observatory

Species richness of families

Family	*S*
Miridae	4
Pentatomidae	1
Lygaeidae	1
Reduviidae	1
Total	**7**

Species abundances

Species abundances: number of specimens of each species collected using trapping methods

Light traps / Pitfall traps: collecting method

Species: scientific name of the species

Family: family of the species

***N*:** number of collected individuals of the species

%: percentage of all collected individuals with the applied method

Others: species collected only as one or two specimens and <2% of all specimens. Small samples are listed completely

Total: all collected specimens (= 100%) collected with the applied method (e. g. light trap, pitfall traps)

Species abundances

Light traps

Species	Family	*N*	%
Nysius ericae	Lygaeidae	160	50
Micronecta spec.	Micronectidae	28	9
Euthetus leucostictus	Alydidae	19	6
Sigara meridionalis	Corixidae	19	6
Macroscytus brunneus	Cydnidae	11	3
Dicranocephalus schmitzi	Stenocephalidae	8	2
Miridae spec.	Miridae	6	2
Edocla quadrimaculata	Reduviidae	6	2
Aethus lautipennis	Cydnidae	5	2
Camptocoris rostratus	Lygaeidae	5	2
Dieuches herero	Rhyparochromidae	5	2
Hyalochilus scudderi	Rhyparochromidae	5	2
Others (23)		44	13
Total		**321**	**100**

Pitfall traps

Species	Family	*N*	%
Leptodemus irroratus	Oxycarenidae	41	37
Eupododus orbicularis	Pentatomidae	24	22
Thaumastella namaquensis	Thaumastellidae	10	9
Liorhyssus hessei	Rhopalidae	8	7
Spilostethus pandurus elegans	Lygaeidae	5	5
Geocoris phaeopterus	Geocoridae	5	5
Nysius ericae	Lygaeidae	4	4
Haemobaphus concinnus	Lygaeidae	3	3
Micrometacanthus spec.	Berytidae	2	2
Others (8)		8	7
Total		**110**	**100**

Butterflies and moths

Infobox

Sampling period(s)	Number of samples (moths)	Species richness (total)
2002/III; 2003/III; 2007/II	3	258
Species richness (butterflies)	**Species richness (all moths)**	**Species richness (Microlepidoptera)**
34	224	53
Species richness (Pyraloidea)	**Species richness (Macrolepidoptera)**	**Species richness (Noctuidae)**
56	43	72
Individuals sampled (moths)	**Fisher's alpha diversity (moths)**	
1299	77.9	

Category	Description
Sampling period(s)	Year of sampling/month in Roman numerals
Number of samples (moths)	Number of samples obtained using the standard methods for moth sampling. Each sample consists of three subsamples.
Species richness (total)	Number of all sampled Lepidoptera species
Species richness (butterflies)	Number of sampled butterfly species
Species richness (all moths)	Number of sampled moth species
Species richness (Microlepidoptera)	Number of sampled species of the moth group Microlepidoptera
Species richness (Pyraloidea)	Number of sampled species of the moth group Pyraloidea
Species richness (Macrolepidoptera)	Number of sampled species of the moth group Macrolepidoptera
Species richness (Noctuidae)	Number of sampled species of the moth group Noctuidae
Individuals sampled (moths)	Total number of sampled moth specimens
Fisher's alpha diversity (moths)	Diversity of moths expressed by Fisher's α

Transect analysis of butterflies

Butterfly species: species sampled by the transect method

***N*:** number of sampled specimens

Proportion: percentage of the total number of butterfly individuals sampled by this method

Abundance

Species	*N*	Proportion
Belenois aurota	357	95.9%
Pinacopteryx eriphia	6	1.6%
Eurema brigitta	3	0.5%
Junonia hirta	2	0.5%
Colotis doubledayi	2	0.5%

Butterfly species and main food plants

Left row: butterfly species sampled by the standard method, grouped by family (bold print)

Right row: plant genera of the butterfly's main food sources (in brackets: family of plants)

Butterfly species and main food plants

Lycaenidae	
Chilades trochylus	Indigofera, Heliotropium (Fabaceae)
Nymphalidae	
Cynthia cardui	Carduus, Arctotheca, Arctotis, Gazania (Asteraceae), Malva (Malvaceae)
Junonia hierta cebrene	Barberia, Ruellia (Acanthaceae)
Danaus chrysippus aegyptius	Asclepias, Stapelia, Cynanchum (Asclepiadaceae)
Pieridae	
Eurema brigitta brigitta	Hypericum (Clusiaceae), Chamaecrista (Fabaceae)
Pinacopteryx eriphia eriphia	Maerua, Boscia (Capparaceae)
Belenois aurota aurota	Maerua, Boscia, Capparis (Capparaceae)
Colotis doubledayi flavulus	Maerua (Capparaceae)
Colotis eris eris	Boscia (Capparaceae)
Colotis evippe omphale	Maerua, Boscia, Cadaba (Capparaceae)
Colotis evenina evenina	Boscia, Capparis, (Capparaceae)

Taxonomic spectrum of moths

Collection period: month/year of data collection

Family: sampled families arranged by traditional moth groups

***S*:** species richness of respective family

***N*:** number of collected individuals of the respective family

Taxonomic spectrum of moths
Collection period:
2001/IV, 2002/IV, 2003/III

Family	*S*	*N*
Nepticulidae	2	12
Tineidae	8	10
Yponomeutidae	1	1
Ethmiidae	1	1
Scythrididae	7	6
Oecophoridae	1	1
Cosmopterigidae	5	15
Gelechiidae	21	74
Pterophoridae	1	1
Tortricidae	4	21
Microlepidoptera	**51**	**142**
Pyralidae	25	143
Crambidae	10	99
Pyraloidea	**35**	**242**
Limacodidae	1	7
Cossidae	2	4
Metarbelidae	1	1
Lasiocampidae	2	15
Sphingidae	2	10
Geometridae	19	88
Arctiidae	1	2
Noctuidae	61	366
Nolidae	1	3
Macrolepidoptera	**90**	**496**
Total	**176**	**880**

Vertebrates

Infobox

Total species richness	Reptile species richness	Bird species richness
76	7	47
Large mammal species richness	Small mammal species richness	
13	9	

Category	Description
Total species richness	Total number of vertebrate species recorded during the sampling period for small mammal studies from 2001 to 2003 within 64 field days per plot
Reptile species richness	Number of reptile species recorded during the sampling period for small mammal studies from 2001 to 2003 within 64 field days per plot
Bird species richness	Number of bird species recorded during the sampling period for small mammal studies from 2001 to 2003 within 64 field days per plot
Large mammal species richness	Number of large mammal species recorded during the sampling period for small mammal studies from 2001 to 2003 within 64 field days per plot
Small mammal species richness	Number of small mammal species trapped on one 2-ha plot, where 90 Sherman live traps were set. In total, the study took place on 32 field days per plot

Reptiles – Birds – Large mammals – Small mammals

Lists of all vertebrate species observed and recorded during the sampling period for small mammal studies from 2001 to 2003 within 64 field days. The species are arranged into four separate lists, and within these, grouped by taxonomic orders.

Large mammals

Carnivora	**Carnivores**
Canis mesomelas	Black-backed jackal
Caracal caracal	Caracal
Cynictis penicillata	Yellow mongoose
Galerella sanguinea	Slender mongoose
Ictonyx striatus	Striped polecat
Otocyon megalotis	Bat-eared fox
Suricata suricatta	Meerkat
Vulpes chama	Cape fox
Artiodactyla	**Even-toed ungulates**
Raphicerus campestris	Steenbok
Sylvicapra grimmia	Bush duiker
Tragelaphus strepsiceros	Greater kudu
Tubulidentata	**Aardvarks**
Orycteropus afer	Aardvark

The people

Infobox

Study period	Size of study area	Population in study area
2004–2008	ca. 90 km²	737 people
Number of households	Mean household size	Population growth
107	6.1 people	1.5% (2006)
Total fertility rate	Cohort fertility	
6.5 children per woman	1920–1967: 6.1; 1968–1990: 6.0 children per woman	
Life expectancy	Sex ratio (m/f)	
41.7 years (2001)	0.85	

Categories are listed in alphabetic order. They only apply to the Observatories listed in the second column.

Category	Observatories to which the information applies	Description
Age structure	S06	Age structure of the inhabitants
Cohort fertility	S01, S02, S06, S22	Analysis of differing fertility of age-cohorts (data for S06 were provided by the Ministry of Health and apply to the entire Otjozondjupa Region)
Education of farmers	S10, S11, S22, S39, S40	Level of formal education reached by the farmers
Education of inhabitants	S06	Mean years of school education of the inhabitants (age > 16)
Employment	S11	Level of employment among the inhabitants
Ethnicity of farm owners	S06, S10, S11, S22, S39, S40	Ethnic group the farm owners belong to
Ethnicity of farm workers	S06, S10, S11, S22, S39, S40	Ethnic group the farm workers belong to
Female headed households	S06, S11	Households with a female head
Fertility	S10, S11	Number of children per mother
Life expectancy	S01, S02, S06	Average number of years to be lived by the respective group [data for S06 were provided by the Ministry of Health and apply to the entire Otjozondjupa Region].
Main sources of income	S06, S10, S11, S22	Most important sources of income for the interviewed household
Markets	S06, S10, S11, S39, S40	Markets on which the farmers sell their agricultural products
Mean age of farmers	S10, S11, S22, S39, S40	The mean age of the farmers (in brackets: the range of age, i.e. youngest and oldest)
Mean age of inhabitants	S06	Mean age of the inhabitants
Mean household size	S01, S02, S06, S11, S22	The average size of the households in the study area
Mortality rate	S06	UFMR (2002) = under five mortality rate out of 1,000 live births, i.e. number of deaths under five years of age per 1,000 in the year 2000). Data were provided by the Ministry of Health and Social Services and applied to the Otjozondjupa Region
Non-permanent household heads	S06	Share of absentee households or household heads who earn wages in the near urban centres
Number of households	S01, S02, S06, S11, S22	Total number of households in the study area

Landuse

Infobox

Study period	Size of Observatory farm	Recommended stocking rate
2004–2008	ca. 90 km²	1.5 ha·SSU^{-1} (50 kg·ha^{-1})
Actual stocking rate	Number of animals	
5 ha·SSU^{-1} (15 kg·ha^{-1})	Total: 437 (57,828 kg); cattle: 197; goats: 226; sheep: 12; donkeys: 2 (2001)	

Categories are listed in alphabetic order. They only apply to the Observatories listed in the second column.

Category	Observatories to which the information applies	Description
Actual stocking rate	S01, S02, S06, S10, S11, S22, S39, S40	Number of hectares available for one small stock unit
Agricultural products	S06, S11	Main agricultural products produced by farmers
Agricultural products	S10, S39, S40	Agricultural products predominantly produced in the investigated region
Density of farms	S10	Number of farms per square km
Farming activities	S06, S11, S22	Main economic activities of the farmers in the study area
Farming activities	S10, S39, S40	Agricultural activities undertaken by farmers in the study area
Households owing livestock	S06, S22	Percentage of household owing livestock within the study population
Mean borehole depth	S10	Mean depth of boreholes in meters for all surveyed farms
Mean camp size	S22	Mean size of the camps (communal land); with the range of camp sizes, i.e. smallest and largest in brackets
Mean camp size	S10	Mean size of the camps or paddocks, which are the basic land management unit
Mean farm family working units	S10	Mean farm family working unit: one working unit is 40 hours per week 48 weeks a year. Only time dedicated by the farm family is considered here, with minimum and maximum working units in brackets
Mean farm size	S10	Mean size of farms in the study area
Mean farm working units	S10	Mean farm working unit: one working unit is 40 hours per week 48 weeks a year. Time dedicated by all farm staff members (family and employed workers) is added up here to count the total labor of the farm, with the minimum and maximum working units in brackets
Mean number of boreholes per farm	S10, S39, S40	Mean number of functional boreholes on the surveyed farms of the study area, with the range of the number, i.e. minimum and maximum in brackets
Mean number of camps per farm	S10, S39, S40	Average number of fenced off camps per farm on the surveyed farms of the study area, with the range of the number, i.e. minimum and maximum in brackets
Mean number of farm worker households per farm	S10, S11, S39, S40	Mean number of farm worker households per farm on the surveyed farms with the range of the number, i.e. minimum and maximum, in brackets
Number of animals	S01, S02, S06, S11, S22	Animals counted on the commonage or on the farm
Number of boreholes / Number of boreholes on Observatory farm	S06, S10, S39, S40	Number of functional boreholes for water extraction located on one Observatory farm
Number of camps	S10, S22, S39, S40	Number of permanently fenced camps or paddocks the Observatory farm is divided into
Number of farm worker households	S39, S40	Number of farm worker households (including adults and children) living on the Observatory farm

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continued from last page

Category	Observatories to which the information applies	Description
Number of farm workers	S10	Number of full-time persons employed on the farm and who are not part of the farm family
Number of farmers managing camps	S22	Number of farmers who are actively engaged in livestock farming
Number of farms (total)	S39, S40	Total number of privately owned farms in the study area
Number of farms on commercial land (total)	S10	Estimated number of farms on the commercial land of the study area
Number of farms surveyed	S10, S39, S40	Number of farms of the study where an interview was conducted Number of farms surveyed in the study area
Number of windpumps	S22	Total number of windpumps on communal land
Observatory farm	6, S10, S39, S40	Name of farm on which the BIOTA Observatory is located
Recommended stocking rate	S01, S02, S06, S10, S11, S22, S39, S40	Recommended stocking rate corresponding to the carrying capacity of the land estimated by the Ministry of Agriculture, Water and Forestry of Namibia or Department of Agriculture in South Africa
Sampling period	S10, S39, S40	Period in which the investigation was conducted.
Size of commercial farmland	S10, S39, S40	Size of the privately owned farmland within the study area
Size of Observatory farm	S01, S02, S10, S39, S40	Size of the farm on which the BIOTA Observatory is located
Size of study area / Study area	S06, S10, S11, S22, S10, S39, S40	Size of the area, in which the research activities were conducted
Study period	S01, S02, S06, S22	Period in which the investigation was conducted

Site-specific studies

Besides the standardised monitoring that has been conducted on all or many of the Observatories, various additional studies have been conducted on and around only one or a few BIOTA Observatories. These studies are briefly presented in the Section Site-specific studies with references to respective publications or unpublished theses for further reading.

Photo: N. Classen

Woodland Savanna

Boundaries
- International Boundary
- Provincial Border

Hydrography
- River
- Periodical River
- Salt Pan
- Lake
- Wetland

Contour Levels
- up to 300 m
- up to 600 m
- up to 900 m
- up to 1200 m
- up to 1500 m
- up to 1800 m
- more than 1800 m

Communications
- Motorway
- Road
- Railway

Populated Places
- City
- Provincial Capital
- Capital

- Transect
- S32 Elandsberg — BIOTA Observatory

0 250 500 km

Uwe Ulrich Jäschke & Karen Langner • HTW - University of Applied Sciences Dresden

Wildlife on the premise of the Agricultural College Ogongo. Photo: N. Classen.

Woodland Savanna

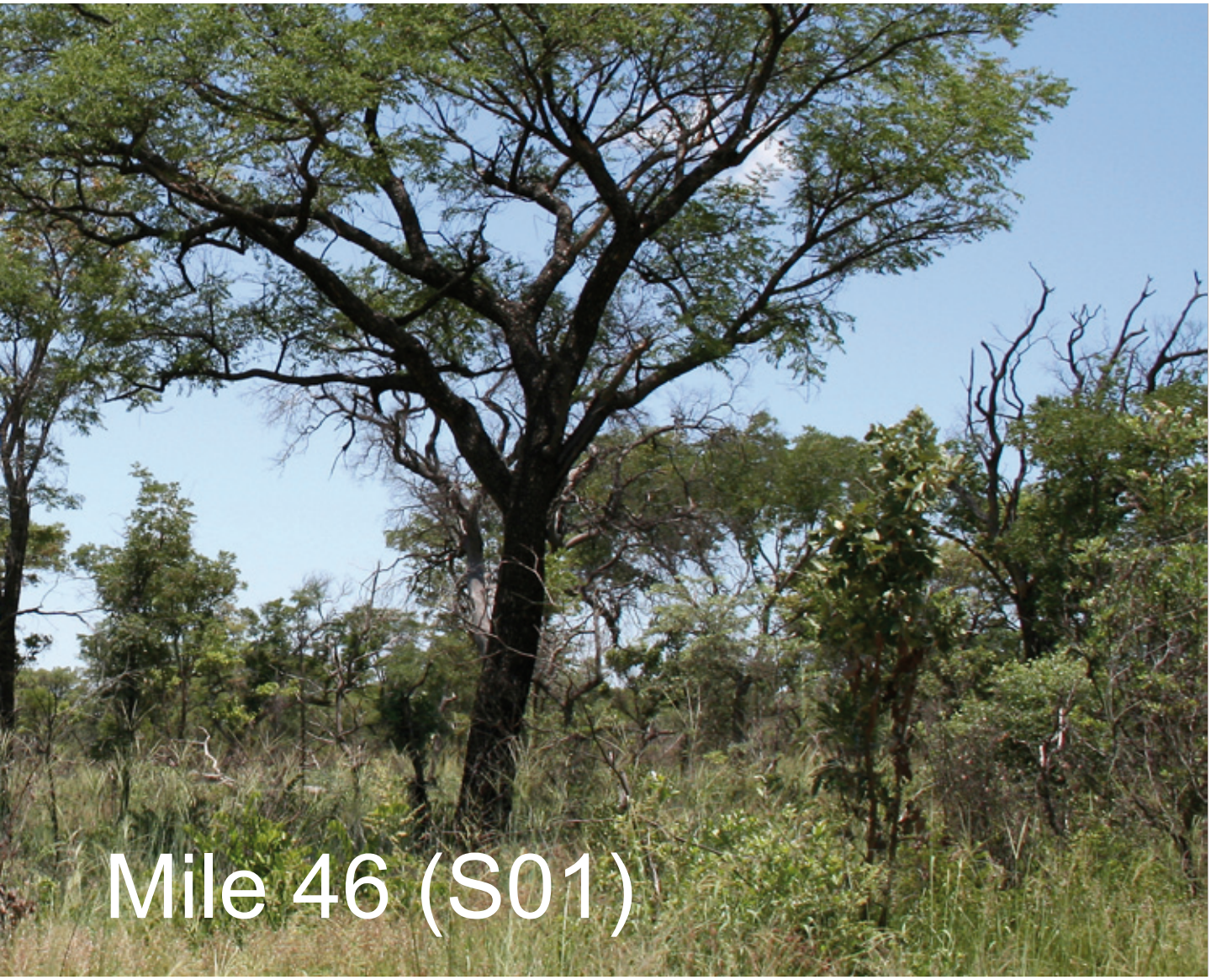
II.2.1 Mile 46 (S01) 70
II.2.2 Mutompo (S02) 92
II.2.3 Sonop (S03) 118
II.2.4 Ogongo (S42) 140
II.2.5 Omano go Ndjamba (S43) 152

The Woodland Savanna Biome is characterised by dry woodlands dominated by tall trees and relatively sparse under-storey vegetation. This biome covers large parts of the African continent. In Namibia it is situated in the north-east at the border of Angola and Botswana and receives much higher annual rainfall than the rest of the country. This higher rainfall allows for the typical, mainly non-commercial landuse structure in the area, which consists of rainfed subsistence cropping activities during high rainfall years. The Woodland Savanna Biome is comparatively densely populated by Namibian standards, with most of the people living in the rural settlements. Arable fields are situated on more fertile soils, which have developed in former inter-dune valleys or omirimbi (i.e. shallow dry rivers), within this biome.

Five BIOTA Observatories are located in this biome. The Observatory pairs Mutompo (S02) and Mile 46 (S01) near Rundu in the east, and Ogongo (S42) and Omano go Ndjamba (S43) in the west were established to compare the impacts of different landuse intensities between communal farming practices (Mutompo and Omano go Ndjamba) and the controlled, rotational cattle grazing systems of the Livestock Development Centre Alex Muranda (Mile 46) and the Ogongo Agricultural College (Ogongo). The Observatory Sonop (S03), further to the south, is also situated at an agricultural research station. [U. Schmiedel]

General data

Number	Name	Alternative name(s)
S01	Mile 46	Alex Muranda LDC
Implementation	**Country**	**Province/ region**
2001	Namibia	Kavango
District/ constituency	**Locality**	**Farm name**
Rundu	near Cove	Alex Muranda LDC
Latitude	**Longitude**	**Altitude**
18.301826 S	19.247311 E	1180 m a.s.l.
Rainfall season	**Biome**	**WWF Ecoregion**
Summer	Woodland Savanna	AT0726 Zambezian Baikiaea woodlands
Agro-Ecological Zone	**Relative intensity of land use**	**Tenure**
KAL3-2	Low	State
Type and history of landuse	**Land owner**	
Research farming for cattle breeding	MAWF	



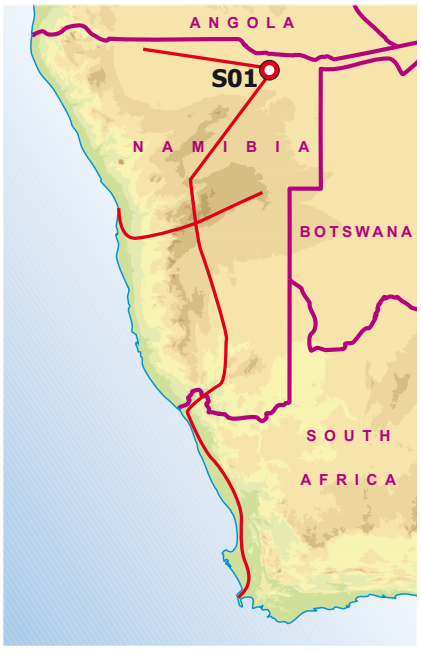
Mile 46 (S01)

Kavango woodlands at Mile 46 Observatory. Photo: J. Deckert.

The BIOTA Observatory Mile 46 (S01) is situated on the Alex Muranda Livestock Development Centre, ca. 60 km south-west of Rundu in the Kavango Region of Namibia. It falls within the extensive sand plateau of the Northern Kalahari, and possesses linear east-west orientated structures which are remnants of a pre-historic dune field (Thomas 1984), which was deposited ca. 18,000–13,000 years ago (Heine 1982). These dunes have since been eroded, sometimes to a level lower than the more loamy remnants in the adjacent inter-dune valleys. The deep sands of the Kalahari Plateau are stabilised by open broad-leafed woodland. The inter-dune areas are dominated by vegetation ranging from open bushland to dense thicket depending on the loam content of the soil. The vegetation on the Observatory is a typical example of the dry Woodland Savanna of the Northern Kalahari sensu Giess (1998). The average altitude is about 1180 m a.s.l. There is a typical summer rainfall climate, with an average annual rainfall of 536 mm.

The Alex Muranda Livestock Development Centre (LDC) belongs to the Ministry of Agriculture, Water and Forestry and is used for livestock breeding programmes. Here, a herd of Sanga cattle produce breeding stock for small-scale farmers and commercial farmers. The LDC was established in the 1980's as a demonstration farm.

This BIOTA Observatory was established to monitor potential variation of climate-change impacts within the dry



Woodland Savanna, especially regarding the predicted mobilisation of Kalahari dune systems due to global climate change (Thomas et al. 2005). This is done in comparison with the adjacent Observatory Mutompo (S02), and the more southern Observatories Sonop (S03), Sandveld (S41) and Alpha (S17). In addition to this, the installation of a fire break along the border of the LDC enables the investigation of the effects of fire exclusion, which can be studied in comparison to Mutompo Observatory.

Responsible authors: B.J. Strohbach & D.H. Haarmeyer

Remote sensing and landscape

Geomorphology	Geological units	Lithological units
Degraded dunes and interdunes of Kalahari dune veld	Kalahari Sands	Sands and Calcrete
Mean EVI	**EVI absolute range**	**Mean leaf area index**
0.244 (0.160–0.373)	0.124 (2005)–0.412 (2006)	0.76

Grid map of Observatory

	0	1	2	3	4	5	6	7	8	9
0	15	72	90	3	25	1	70	98	37	7
1	44	81	27	94	4	56	91	95	12	79
2	57	60	31	9	29	11	47	53	24	33
3	71	46	42	23	52	34	17	78	75	6
4	49	16	5	40	28	35	68	39	85	63
5	58	66	20	2	73	61	55	77	67	97
6	13	80	83	50	26	59	76	74	41	92
7	38	21	10	43	32	64	30	8	54	62
8	51	82	88	36	87	19	93	14	86	18
9	84	48	22	89	100	69	99	96	65	45

1 Closed woodland savanna on degraded dune

2 Open woodland savanna on degraded dune

3 Woodland-thornbush transitional savanna on transission zone dune/interdune

4 Acacia thornbush savanna on interdune

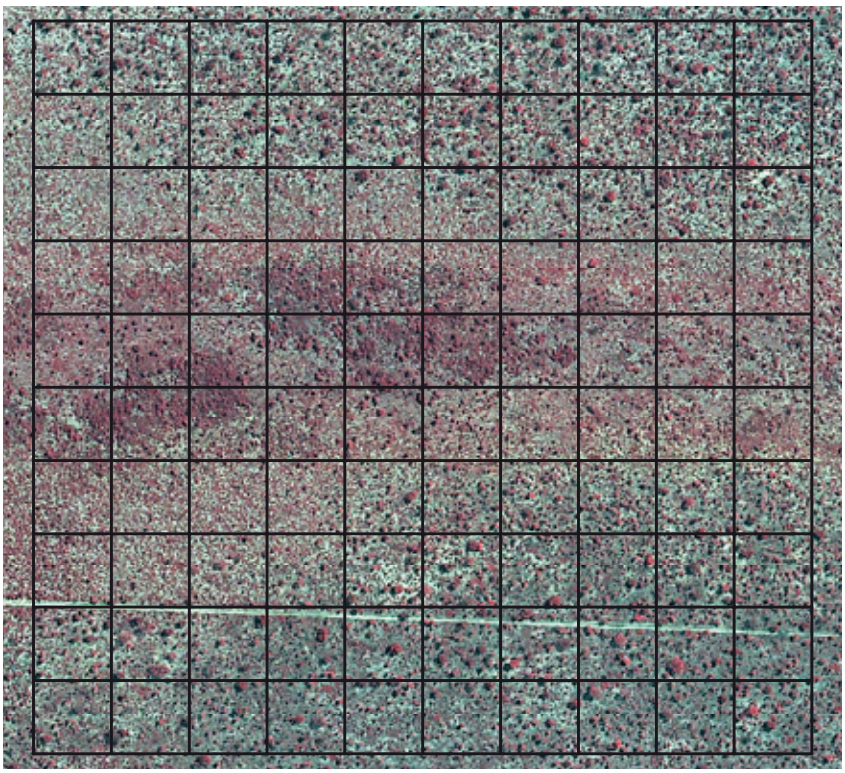
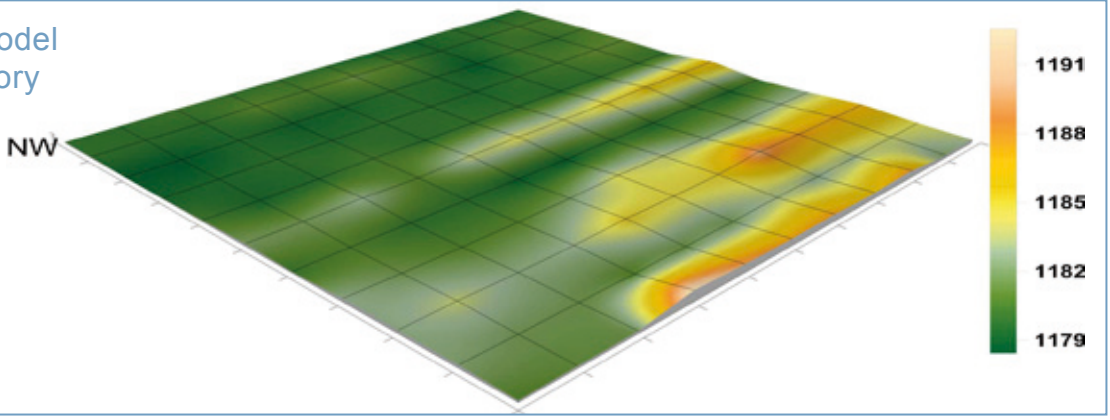


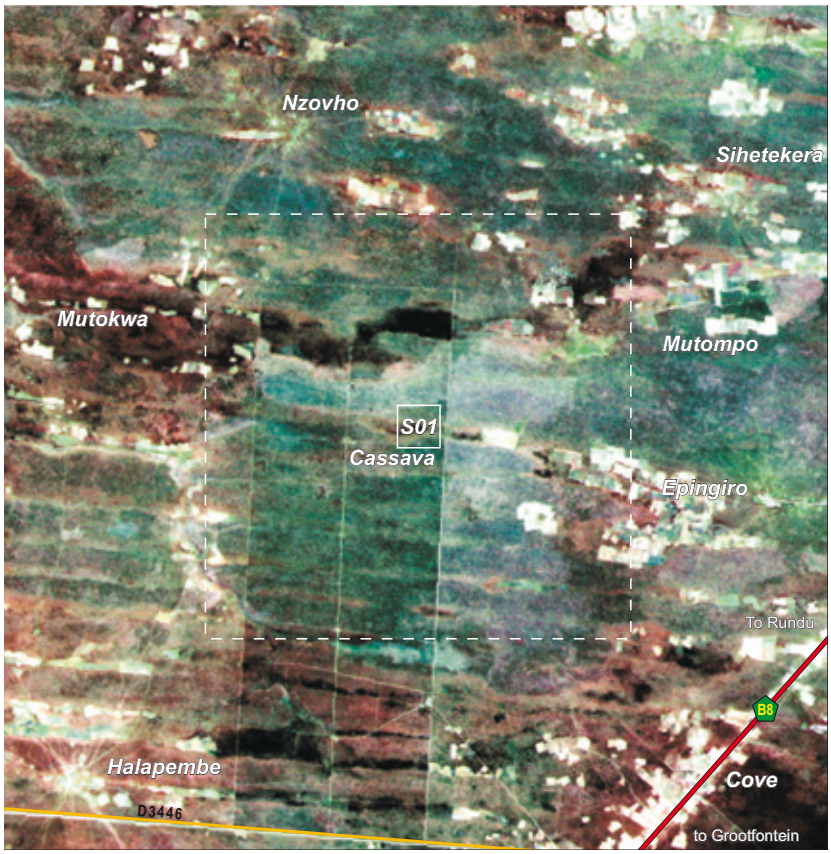
Image: QuickBird, 5 April 2007

Elevation model of Observatory



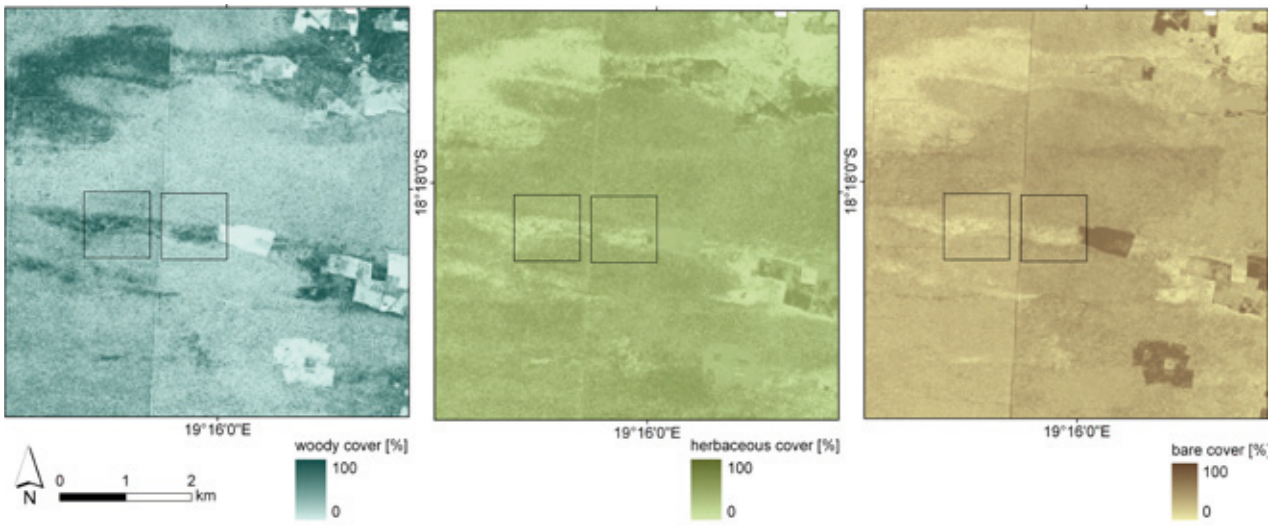
Landsat image

The dunes of the Kalahari, which were formed approximately 30,000 years ago by easterly winds, are east-west orientated. Some parts of the dune-ridges were eroded, whereas the finer particles in the valleys were able to resist the forces of wind. Therefore, the relief is relatively heterogeneous nowadays. The surface structure has a relative height difference of a maximum of 10 m, and the distance between neighbouring dune-ridges is generally between 800 m and 1000 m. The vegetation type is an open Woodland Savanna, with variable patterns of grasses and shrubs underlying the tree layer (normally greenish and light brown colours, but in this scene blue-grey and brownish colours resulting from the influence of bushfires in former years). The vegetation in the dune valleys is denser and often consists of dense Thornbush vegetation (displayed as dark red and brown tones).



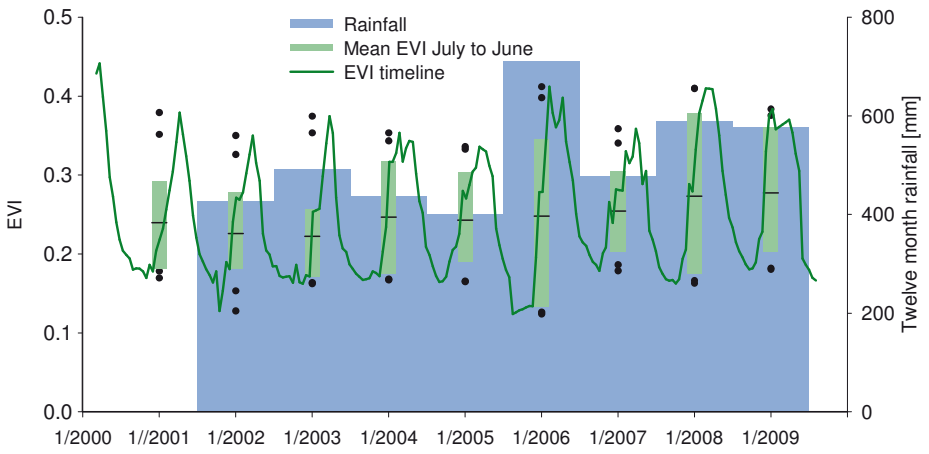
Scene: 177/73, acquisition date: 06 May 2007

Fractional cover image



MODIS time series

Temporal patterns of annual rainfall, vegetation cover, and phenology



Responsible authors: M. Keil & T. Labitzky

Climate

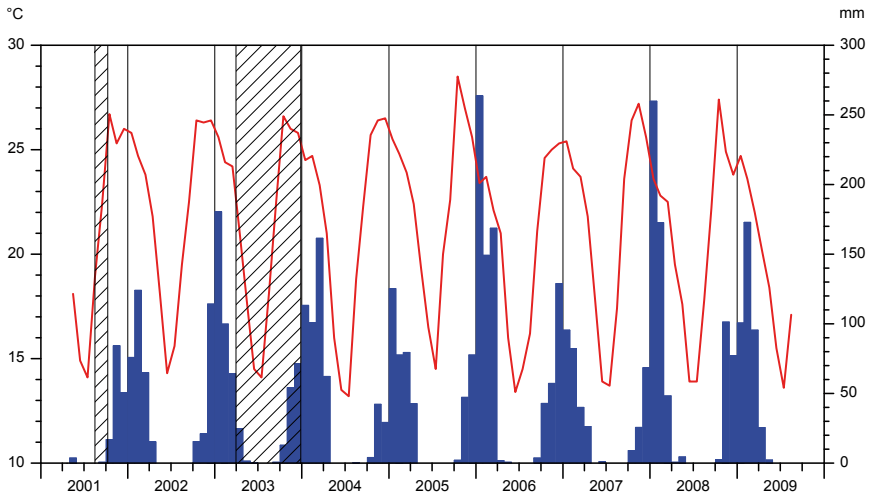
Data from BIOTA weather station

Location	Recorded period	Mean temperature
Mile 46 (S01)	2001–2009	22.6 (-1.8–43.9) °C
Mean solar radiation	**Mean wind speed**	**Mean annual precipitation**
491 (263–754) MJ·m^{-2}·month^{-1}	1.1 (4.9) m·s^{-1}	527 (348–816) mm
Mean annual potential evapotranspiration	**Interannual precipitation variability**	**Mean relative humidity**
1340 mm	131%	55% (23–84%)
Aridity index (UNEP)		
0.39 (semi-arid)		

Modelled data

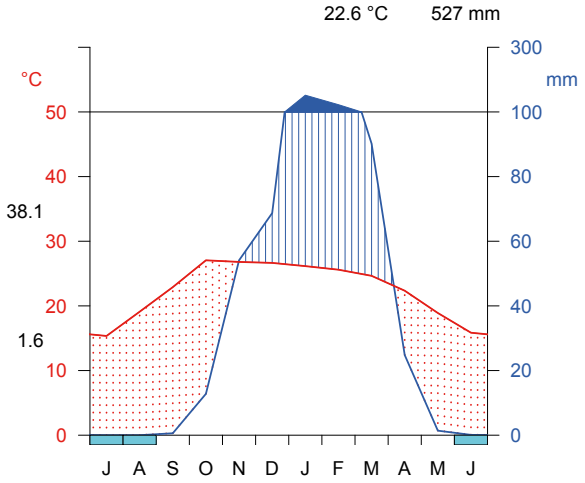
Mean temperature	Mean annual temperature range	Mean diurnal temperature range
22.2 (6.6–34.0) °C	9.6 °C	15.7 °C
Mean annual precipitation	**Precipitation seasonality**	**Percentage winter precipitation**
536 mm	106%	8% (strong summer)
Climate type	**Length of dry season**	**Aridity index (De Martonne)**
BSh	7 months	16.6 (semi-dry)

Time series: rainfall and temperature

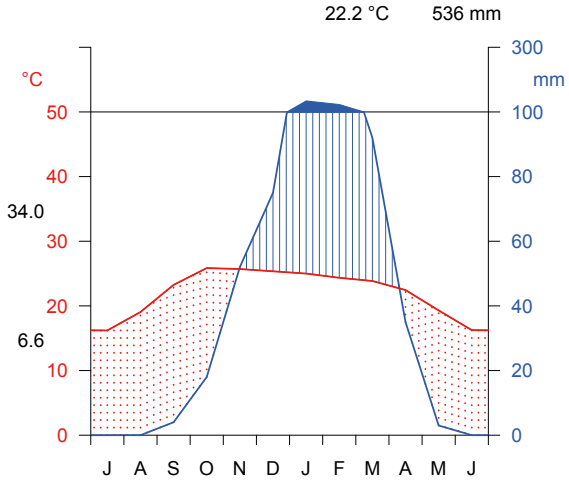


Climate diagrams

Recorded data (BIOTA)

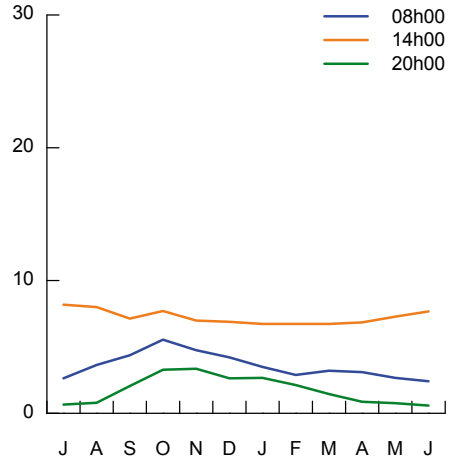


Modelled data (WorldClim)

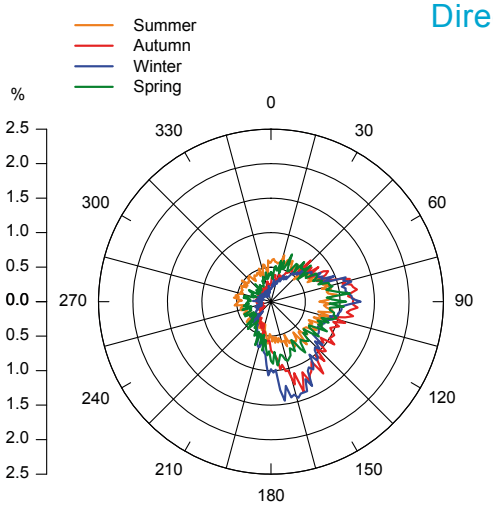


Wind diagrams

Speed



Directions



The climate at the Observatory is characterised by semi-arid conditions. Rainfall shows a strong seasonality with almost all rain falling during the summer season, peaking in January. Mean annual rainfall is about 527 mm, making Mile 46 and the neighbouring Observatory Mutompo (S02) the wettest Observatories within the Woodland Savanna. However, substantial interannual variability is evident. Near surface air temperature shows a moderate seasonal cycle. The observed mean annual temperature is 22.6°C and is therefore close to the average for the Observatories in this biome. The observed mean minimum temperature is above the freezing point, but there is still a possibility of the occurrence of frost during the months of June to August. Compared to the interpolated long-term data taken from the WorldClim dataset, only minor differences in mean annual temperature are evident. However, the data for extreme temperatures recorded at the station deviate substantially from the WorldClim data, showing warmer maximum and colder minimum temperatures. For precipitation, mean annual rainfall is slightly lower at the BIOTA weather station in comparison to the WorldClim dataset.

The observed near-surface winds at the Observatory are mainly constituted of easterly and south-easterly flows, with a slightly enhanced southerly component during the autumn and winter periods. Mean wind speed is highest during the early afternoons, reaching about 8 to 10 km/h. Winds during that time of the day stay fairly constant throughout the year, whereas a weak annual cycle is evident for the mean wind speed recorded during the mornings and evenings.

Responsible authors: K. Berger, A. Haensler & J. Luther-Mosebach

Soils

Year of sampling	Hectare plots sampled	SOTER unit
2001	23 (R1–15, R19, R24, R25, R32, R76, R79, R88, R90)	NA17
Soilscape	**Dominant soil group(s)**	**Reference group richness**
Arenosols (AR)	Arenosol	1
Soil unit richness	**Soil unit evenness**	**Soil ecotype richness**
2	0.212	2
Parametric space	**pH**	**Electrical conductivity**
0.58	5.8 (4.8–7.0)	9 (4–20) µS·cm-1
Organic carbon		
0.42% (0.27–0.72%)		

All profiles of this Observatory are classified as Arenosols and with low pedodiversity, only slight differences in the soils base saturation subdivide the soils by the suffixes 'Eutric' and 'Dystric', depending on their topographic position. But even when differences are slight, they result in distinct vegetation patterns (see Section Vascular plants).

Arenosols (Dystric) are the dominant soil types of the dry forest habitat on the eroded dunes. They consist of deep (> 2 m), greyish to pale brown medium sand. The topsoil shows a weak accumulation of humus and is covered with a thin layer of bleached sand. An organic layer consisting of windblown leafs of dry-forest trees can be found sporadically. Well developed, black biological soil crusts of a few millimetres in thickness are evident on some patches. The soil reaction is strongly acid to very strongly acid, the nutrient status and cation exchange capacity are very low. Many profiles show fragments of charcoal, which are commonly accumulated in the upper profile, but they can also be found scattered in deeper parts of the profile. Vertical chains of charcoal, which originally belonged to one single root, occur in some profiles. This demonstrates deep in-situ burning or carbonisation of organic components from the surface down into the profile during common fire events in this ecosystem. The high porosity of the sandy substrate and the dryness of the soil enable this process.

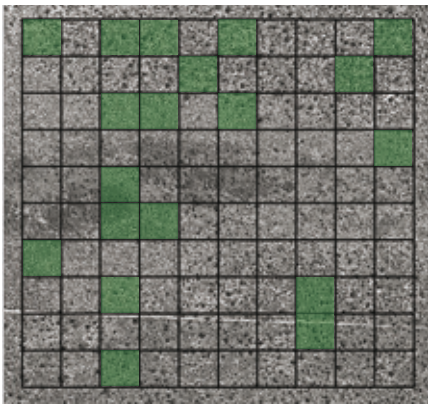
Arenosols (Eutric) are concentrated in the more open savanna habitats of the inter-dunes as well as the thicket sites in the central part of the Observatory. Compared to the Dystric Arenosols, prominent features of these soils are the darker colours across the entire profile and slightly higher clay contents. The soil reaction is slightly acid to neutral and the nutrient status and cation exchange capacity are slightly higher. The organic carbon content and pH values are slightly higher and remain slightly elevated in the subsoil. In the profile correspondent to hectare plot 64, calcrete was found at 1.75 m depth.

The two soil types differ only slightly in their properties, and these differences are all related to the topographic position. The prevailing low pH values and electric conductivity underline the nutrient poverty of these sands of very low fine earth content. Only in inter-dunes, soils are slightly loamier; however, the clay content is always below 10%. Organic carbon content shows a decrease with depth. The rooting space is 100% in all the profiles analysed where no limitations or variations within the Observatory occur.

Compared to other Observatories along the transect, topsoil nutrient content is very low. Especially the concentration of potassium (exchangeable and total) is below most values of other Observatories. This is due to the low clay content of the quartz-sand substrate, which is, if at all, increasing slightly only in the subsoil.

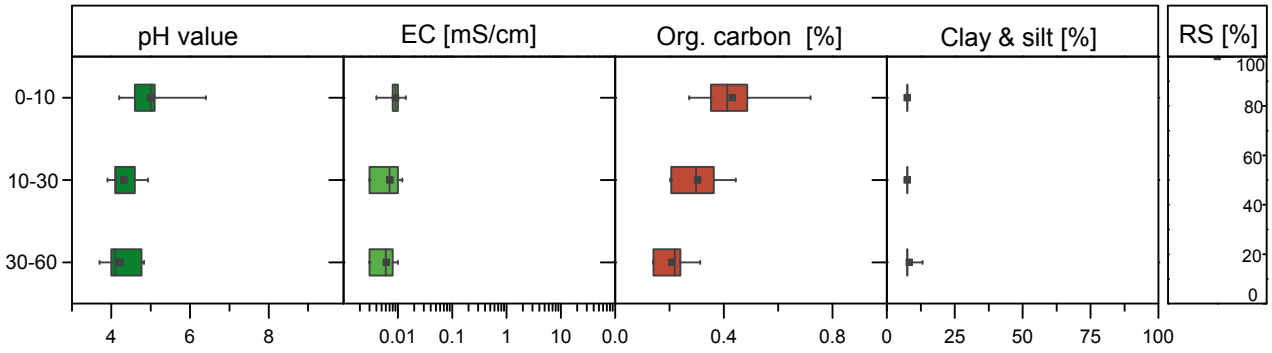
The main factor for the distinct vegetation pattern seems to be varying water supply, which is mainly driven by soil texture. Further, also the nutrient reserves and availability, though generally low, may play a role as they are slightly elevated in inter-dune areas.

Map of soil profiles

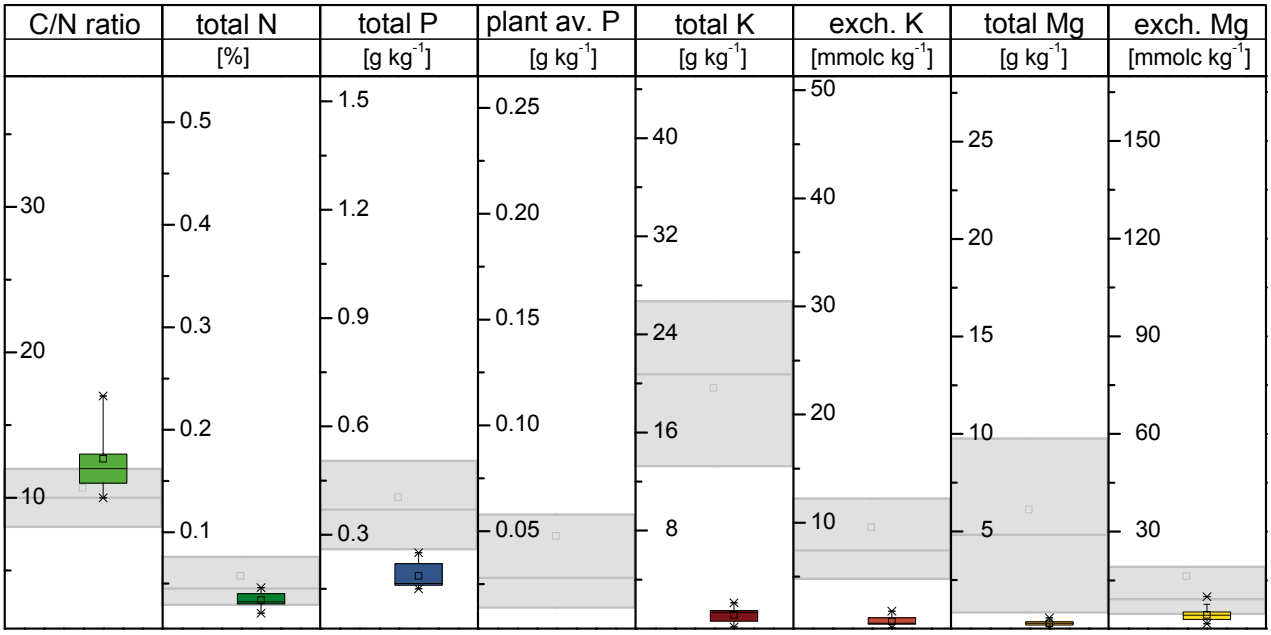


Ferralic Arenosol

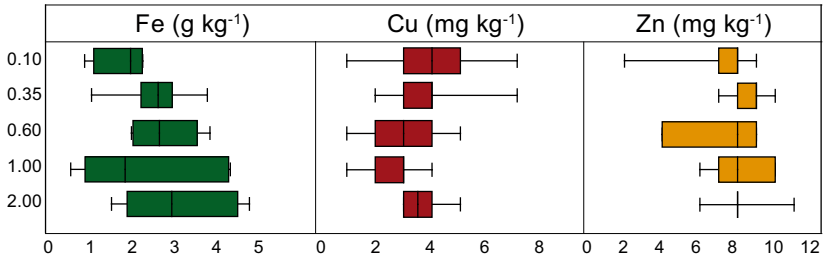
Soil characteristics



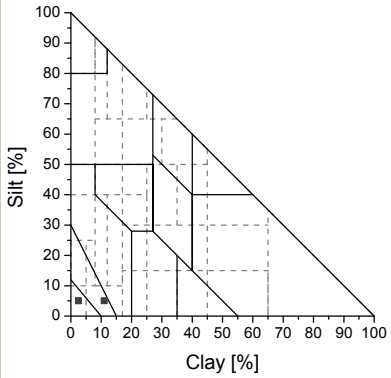
Soil nutrients



Soil micronutrients



Soil texture triangle

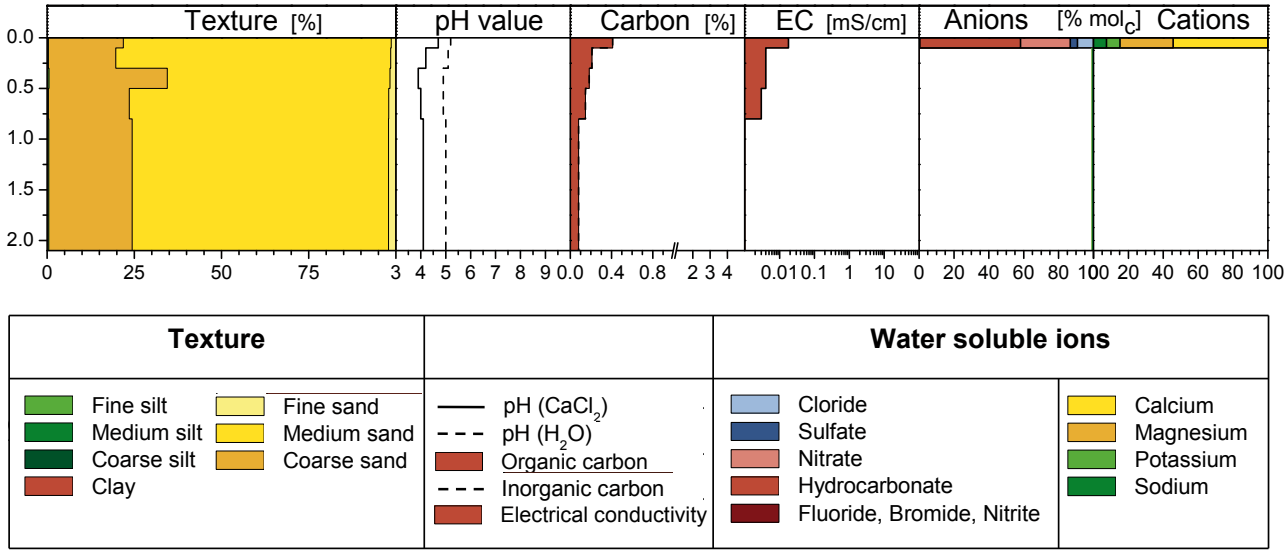


Reference profile (H06)

The **Ferralic Arenosol (Dystric, Greyic)** is a typical example of soils developed in the pure sands of dunes. The texture is dominated by medium sand (64–79%) and shows no significant changes or signs of layering over the entire profile. The extremely low pH values were relatively constant with depth. Organic carbon reaches about 0.4% in the topsoil and decreasing with depth. The electrical conductivity is very low with 18 µS cm^{-1} in the topsoil and < 5 µS cm^{-1} in the lower horizons. These values suggest both an input of rainwater with low ionisation and a deep drainage of the soil.

The soil has a single-grain structure and a low excavation difficulty. Root density is high, with 20–50 roots dm^{-2} in the topsoil and still 5–10 roots dm^{-2} at 80 cm depth. A layer of litter can be observed covering the soil with associated thick tree roots in the profile, related to the dry woodland of the area. Charcoal fragments are scattered across the whole profile even to a depth of 80 cm.

The quartz-rich dune sands are characterised by very low total content of elements (magnesium and potassium < 0.1 g kg^{-1}) with no significant changes across the entire profile. This results in a very low base reserve of about 4 $cmol_c\ kg^{-1}$ of the substrate. With values of 10 $mmol_c\ kg^{-1}$ in the topsoil and around 5 $mmol_c\ kg^{-1}$ in the deeper horizons the cation exchange capacity is also very small. The same is true for the water-soluble ions (2.7 $mmol_c\ kg^{-1}$). To summarise, this profile represents an extremely nutrient-poor soil with a deep drainage and distinct signs of acidification.



Responsible authors: U. Wisch, A. Petersen, A. Gröngröft & D. Mager

Biological soil crusts

Sampling period(s)	Hectare plots sampled	Types of soil crusts
2003	2 (R1, R3)	1, 2
Crust thickness	**Cover**	**Carbon [weight %]**
< 3 mm	less than 1%	0.539
Nitrogen [weight %]	**Chlorophyll *a* [mg/m²]**	**Chlorophyll *a+b* [mg/m²]**
0.012	23	70

Well-established cyanobacterial crusts, restricted to recently burnt areas. Photo: B. Büdel.

Similarly to the twin Observatory, S02 (Mutompo), biological soil crusts are restricted to recently burned areas (see Photo). Biological soil crusts do not occur inside the mature forest. The low species diversity and chlorophyll values as well as the significantly low carbon and nitrogen content are a direct indication of the low cover of early successional crusts.

Cyanobacteria
Calothrix cf. *elenkinii*
Leptolyngbya foveolarum
Phormidium cf. *nigrum*
Phormidium cf. *caerulescens*

Green algae
Chlorella cf. *sorokiniana*
Cylindrocystis brebissonii
Scenedesmus sp. 4
Scenedesmus cf. *rotundus*
Scenedesmus rotundus

Biological soil crust characteristics

	H03	**H05**
Soil characteristics	Grey sand	Grey sand; several burnt wood particles
Crust characteristics	Dark grey clumps, only small fragile pieces; BSC not obvious	Only few fragile pieces, that cannot easily be identified as BSC
Chlorophyll *a* [mg/m²]	21.98	23.48
Chlorophyll *a+b* [mg/m²]	56.88	83.92
Carbon [weight %]	0.55	0.53
Nitrogen [weight %]	0.01	0.01

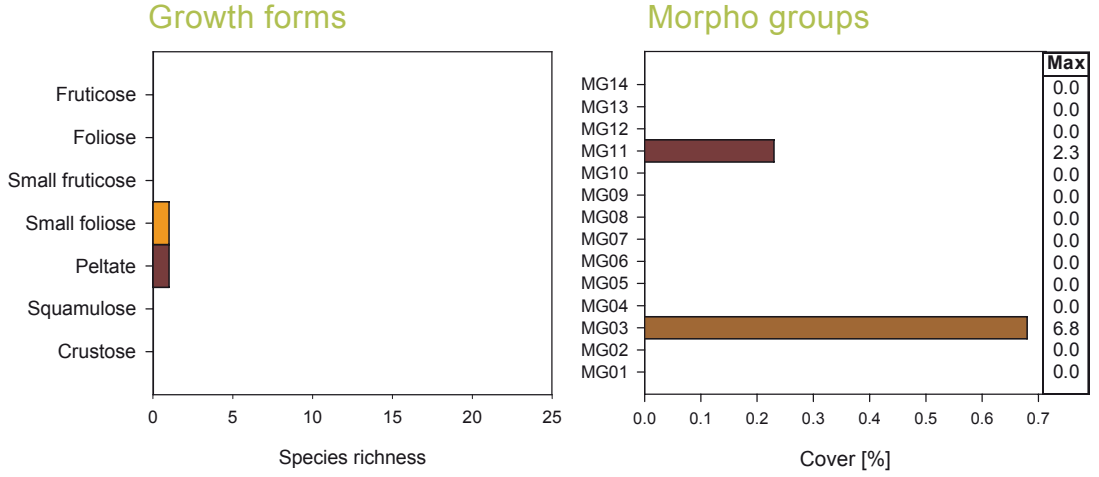
Responsible authors: B. Weber, K. Deutschewitz, S. Dojani, T. Friedl, T. Darienko, K. Mohr & B. Büdel

Lichens

Sampling period(s)	Hectare plots sampled	Cover
2001, 2004	10 (R1−R10)	1% (0−7%)
Total species richness	**Species richness on soil [1 km²]**	**Species richness on rock [1 km²]**
4	2 (50%)	2 (50%)
Species richness on plants [1 km²]	**Species richness on soil [1000 cm²]**	
0	0.2 (0−1)	

In spite of suitable macro-climatic conditions (i.e. relatively high rainfall) for lichen growth, this Observatory hosts only a low number of lichen species. Only two globally widespread cyanolichens colonise the soil, one squamulose and one small foliose species, and a few species are found on stones. The low richness of soil-inhabiting lichens is due to the presence of sandy, unstable, and acidic soils, with limited calcium carbonate contents. Also, disturbance is relevant at this Observatory mainly in the form of fire events, and this explains the generally low lichen richness and the absence of lichens on trees.

Lichen cover is extremely low on the investigated hectare plots, and only two morphological groups, MG03 and MG11, occur at hectare plots 23 and 53, while lichens are absent in the other plots. The low and patchy cover of lichens is most probably due to the negative impact of anthropogenic activities.



List of taxa

Terricolous (on soil):

Collema coccophorum

Peltula patellata

Saxicolous (on rock):

Peccania sp.

Peltula sp.

Epiphytic (on plants):

No records

Collema coccophorum.
Photo: L. Zedda & G. Rambold.

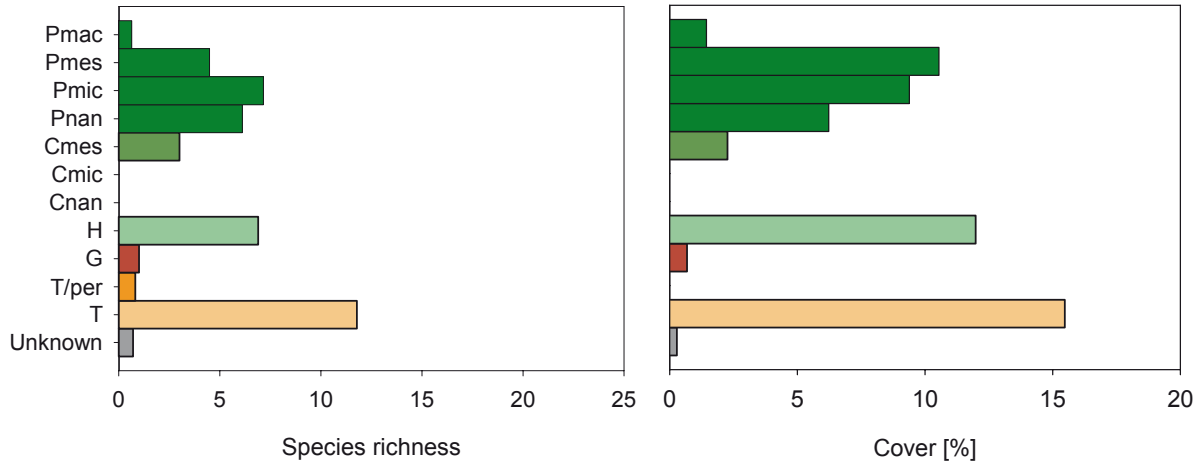
Peltula patellata. Photo:
M. Schultz, L. Zedda & G. Rambold.

Responsible authors:
L. Zedda & G. Rambold

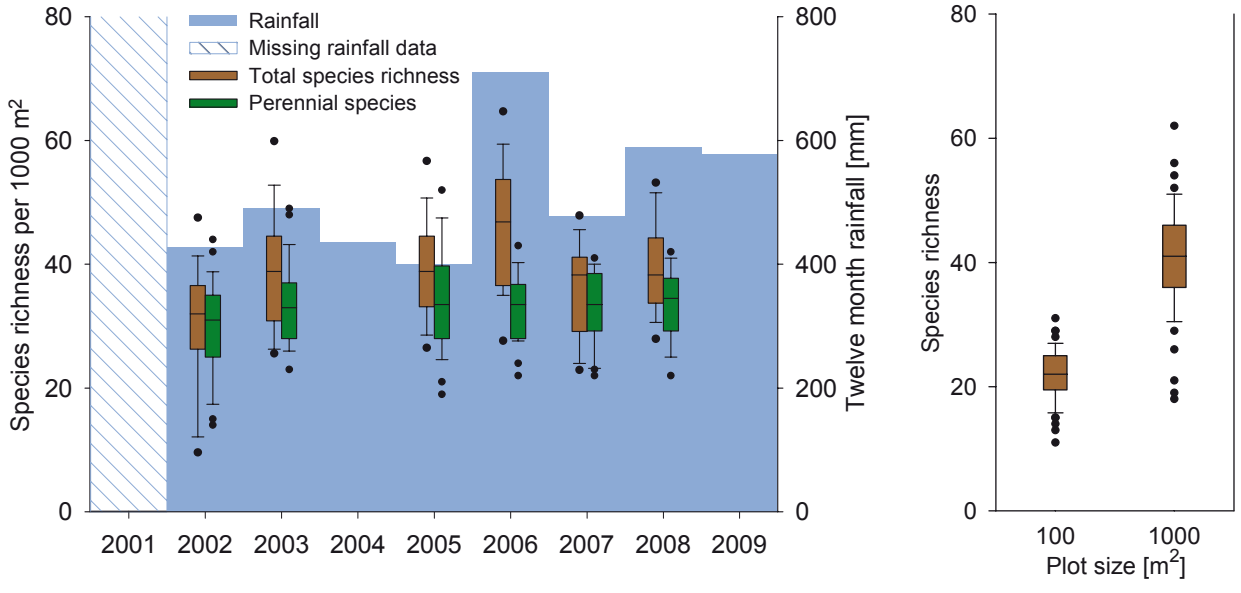
Vascular plants

Sampling period(s)	Hectare plots sampled	Biome
2001–2003, 2005–2009	20 (R1–R20)	Woodland Savanna
Vegetation unit (level 1)	**Vegetation unit (level 2)**	**Identification rate**
Tree Savanna and Woodland (Northern Kalahari)	n.a.	94% – 99% – 100%
Cumulative family richness	**Dominant families (cover)**	**Dominant families (richness)**
60	Fabaceae, Poaceae, Combretaceae	Fabaceae, Poaceae, Euphorbiaceae
Cumulative species richness (1 km²)	**Species richness (1000 m²)**	**Species richness (100 m²)**
322 – 149	43.8 (18–67)	22.2 (11–31)
***z*-value**	**Species richness change per year (1000 m²)**	**Evenness (1000 m²)**
0.295 (0.000–0.537)	0.58	0.818 (0.558–0.924)
Evenness (100 m²)	**Simpson (1000 m²)**	**Simpson (100 m²)**
0.921 (0.686–0.970)	0.921 (0.686–0.970)	0.842 (0.577–0.929)

Life forms



Species richness



The vegetation at the BIOTA Observatory Mile 46 (S01) consists of closed woodlands, open bushlands and thickets. These vegetation types are closely linked to the prevailing soil patterns—the deep, pure aeolian sands of the Kalahari support the typical Kavango woodlands, dominated by a range of broad-leafed trees and shrubs (P mic-P mac) associated with more mesic environments. The more loamy sands, which are associated with the old inter-dunal valleys and omiramba support dense Acacia-thickets. Omiramba (singular omuramba) are described by King (1963) as riverbeds that have been filled with sand or silt to the extent that local gradients have been lost. Various transitional forms and successional stages, also driven by fire dynamics, are visible. The Observatory is among the most diverse along the transect, with 60 plant families. Fabaceae and Poaceae represent the most important plant families in terms of cover and species richness. The Simpson's index was the highest of all Observatories along the BIOTA transect and is reflected in the dense cover of trees, shrubs, and grasses. Not surprisingly, beta diversity in this woodland is very low, with species evenness being the highest of all Observatories along the transect.

The Mile 46 (S01) Observatory posses a fare denser understorey bush layer than the neighbouring Mutompo (S02) Observatory, which occurs on exactly the same type of landscape. This is due to the presence of a fire break along the border of Mile 46 which prevents the spread of fires into the Observatory. Fires generally destroy low, small trees and shrubs provided there is sufficient grass fuel available. Large trees are generally not affected unless the fire spreads into the tree canopies and becomes a crown fire. The denser shrub layer at Mile 46 Observatory is especially evident in the transitional zones between the broad-leafed woodlands and the Acacia-thickets, with a variety of woody species encroaching.

The *Acacia luederitzii-Croton gratissimus* community (unit 1) is typically found on the loamy remnants of inter-dunal valleys (haplic Arenosols). This closed thicket is dominated by *Acacia*

Unit 1, 2003. Photo: B. Strohbach.

Unit 2, 2003. Photo: B. Strohbach.

Unit 3, 2003. Photo: B. Strohbach.

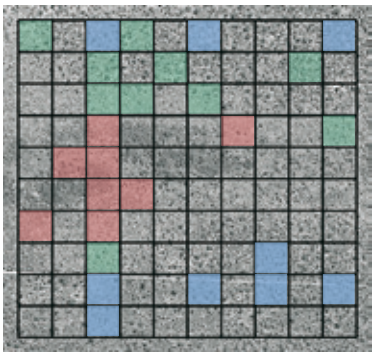
Unit 1, *Gloriosa superba*, 2003. Photo: B. Strohbach.

Unit 1, *Hydnora abyssinica*, 2003. Photo: B. Strohbach.

luederitzii (Kalahari Acacia) trees, in association with various other thicket-forming phanerophytes, e.g. *Dichrostachys cinerea* (Sicklethorn), *Acacia mellifera* subsp. *detinens* (Blackthorn), *Combretum hereroense* (Kierieklapper), *Mundulea sericea* (Visgif), *Ochna cinnabarina, Croton gratissimus* (Lavender Bush), and even *Acacia erioloba* (Camelthorn) trees. The average tree cover is 13%, average shrub cover is 60%, and the average grass cover is 20%. The lianous *Hippocratea parvifolia* as well as numerous shade-loving plants, e.g. *Pupalia lappacea* and *Sporobolus fimbriatus* (Dropseed), are also associated with this thicket community (Strohbach & Petersen 2007). This community possesses relatively high species diversity, due to the protection offered by the dense woody layer against fire and grazing, as well as the specialised niche habitats present in dense vegetation associated with nutrient-rich soils. However, because of the dense growth of woody species, this vegetation unit is mostly impenetrable and not an important grazing resource.

The *Acacia fleckii-Brachiaria nigropedata* community (unit 2) is a typical ecotonal association between the dense thickets of the *Acacia luederitzii-Croton gratissimus* community and the *Pterocarpus angolensis-Guibourtia coleosperma* community (unit 3) on the deep Kalahari sands. Strohbach & Petersen (2007) subdivided this community into two closely related types, the *Bauhinia petersiana-Acacia fleckii* shrublands and the *Eragrostis rigidior-Acacia fleckii* bushlands. The former is characterised by very dense stands of shrubby *Bauhinia petersiana* (Koffiebos), with an average shrub cover of 57%. The average tree cover is only 2%, whilst the average grass cover reaches 21%. The *Eragrostis rigidior-Acacia fleckii* bushlands are dominated by dispersed *Acacia erioloba* trees (on average 5% tree cover), with a far lower average shrub cover of only 40%. The grass cover reaches 28%, and is dominated by *Schmidtia pappophoroides* (Kalahari Sand Quick), *Digitaria seriata* (Kuruman Finger Grass), *Eragrostis rigidior* (Curly-leaved Plume Grass), *Stipagrostis uniplumis* (Silky

Map of vegetation units



Bushman Grass) and *Brachiaria nigropedata* (Swartvoetjie). These grasses provide a valuable grazing resource, but can also create high fuel loads for potential veld fires. The presence of the reedy grass *Tristachya superba* and individuals of various tree species, such as *Guibourtia coleosperma*, is conspicuous in the *Acacia fleckii-Brachiaria nigropedata* community at Mile 46, which is indicative of the lack of fire in this community.

The *Pterocarpus angolensis-Guibourtia coleosperma* community (unit 3) forms the well-known, landscape-dominating Kavango woodlands. Together with *Pterocarpus angolensis* (Teak) and *Guibourtia coleosperma* (False Mopane), other tree species such as *Baikiaea plurijuga* (Rhodesian Teak), *Burkea africana* (Sandsering), and *Schinziophyton rautanenii* (Mangetti), as well as the shrub/small tree species *Diplorynchos condylocarpon*, *Ochna pulchra* (Lekkerbreek), *Strychnos pungens*, and *Strychnos cocculoides* (Monkey Oranges) commonly occur within this community. The geoxylic suffrutices ("underground trees" sensu White 1976) *Diospyros chamaethamnus*, *Lannea gossweilerii*, and *Gardenia brachythamnus* as well as the dwarf shrub *Fadogia* cf. *thamnus* are also very conspicuous within this community. The grass sward of the Mile 46 Observatory has a higher proportion of perennial grasses, specifically *Digitaria seriata*, *Schmidtia pappophoroides*, *Brachiaria nigropedata*, and *Panicum kalahariense* (Kalahari Buffalo Grass), compared to the Mutompo Observatory. As a result

Classification table (2008)

Column			All	1	2	3
Number of relevés		**Cover**	**28**	**8**	**10**	**10**
Mean cover [%]			107.5	99.0	103.2	118.7
Mean species richness (1000 m²)			44.9	44.4	42.6	47.7
Mean soil pH			4.99	4.98	4.77	5.17
Mean electrical conductivity [µS·cm^{-1}]			10	10	10	11
Organic carbon [%]			0.44	0.40	0.43	0.46
Nitrogen [%]			0.03	0.04	0.03	0.04
Unit 1: Acacia luederitzii-Croton gratissimus community						
Pmic	Acacia ataxacantha	3.56	29	100	.	.
Pmic	Croton gratissimus	1.22	32	100	.	10
Pmic	Combretum engleri	3.44	25	88	.	.
Pmes	Acacia erioloba	4.27	39	100	10	20
Pmic	Grewia flava	2.00	32	88	10	10
Pnan	Indigofera trita	0.50	18	63	.	.
Cmes	Tragia okanyua	1.06	18	63	.	.
H	Eragrostis lehmanniana	3.13	50	100	30	30
Pmes	Dichrostachys cinerea	3.31	29	75	10	10
H	Eragrostis rigidior	2.20	21	63	10	.
Pnan	Ximenia americana	1.92	21	63	.	10
Pmes	Acacia luederitzii	3.63	14	50	.	.
H	Sporobolus fimbriatus	1.00	14	50	.	.
Pmes	Lonchocarpus nelsii	3.51	54	100	10	60
T	Cleome rubella	0.46	32	75	10	20
Pnan	Asparagus nelsii	1.50	57	100	20	60
Pnan	Commiphora angolensis	1.83	57	100	30	50
T	Jacquemontia tamnifolia	0.34	25	63	20	.
Cmes	Hermannia tomentosa	0.93	25	63	.	20
Pnan	Reissantia parviflora	0.67	11	38	.	.
Cmes	Helinus integrifolius	1.67	11	38	.	.
Pmic	Combretum hereroense	1.02	11	38	.	.
T	Tephrosia purpurea	0.50	36	75	20	20
Pnan	Asparagus cooperi	0.70	18	50	.	10
Unit 2: Acacia fleckii-Brachiaria nigropedata community						
T	Perotis patens	0.83	29	.	80	.
G	Diospyros chamaethamnus	1.25	29	.	80	.
T	Tricholaena monachne	1.44	29	.	80	.
Pnan	Lannea gossweileri ssp. gossweileri	1.13	43	.	90	30
T	Acrotome angustifolia	0.54	43	.	90	30
T	Aristida stipitata	5.47	54	.	100	50
n.a.	Hermannia eenii	3.38	57	13	100	50
H	Phyllanthus pentandrus	0.51	39	.	80	30
n.a.	Hibiscus marlothianus	0.55	39	.	80	30
H	Indigofera flavicans	0.66	68	38	100	60
Unit 3: Pterocarpus angolensis-Guibourtia coleosperma community						
Pmic	Securidaca longepedunculata	1.43	25	.	.	70
Cmes	Indigofera pechuelii	0.58	43	13	20	90
H	Brachiaria nigropedata	3.92	46	25	20	90
n.a.	Striga bilabiata	0.34	18	.	.	50
T	Stylosanthes fruticosa	0.70	18	.	.	50
Cmes	Polygala schinziana	0.46	32	25	.	70
H	Tristachya superba	1.17	43	13	30	80
Cmic	Dicoma schinzii	0.20	14	.	.	40
Pmac	Guibourtia coleosperma	4.46	50	.	60	80
H	Eragrostis cimicina	0.50	11	.	.	30
Pnan	Hemizygia bracteosa	0.37	11	.	.	30
n.a.	Spermacoce senensis	0.50	11	.	.	30

continued on next page

Classification table (continued)

Column			All	1	2	3
Number of relevés		**Cover**	**28**	**8**	**10**	**10**
Most frequent companions						
H	Digitaria seriata	5.98	96	100	100	90
H	Stipagrostis uniplumis	3.19	96	100	90	100
Pmes	Terminalia sericea	11.02	93	75	100	100
Pmic	Combretum collinum	5.56	93	88	90	100
H	Schmidtia pappophoroides	2.94	89	100	70	100
H	Urochloa brachyura	1.58	89	100	80	90
Pnan	Bauhinia petersiana	9.81	86	100	60	100
Pmic	Combretum psidioides	5.20	82	38	100	100
H	Limeum fenestratum	0.50	82	63	90	90
Pmic	Ochna pulchra	3.77	79	25	100	100
G	Acanthosicyos naudinianus	0.95	79	88	90	60
Pmes	Burkea africana	9.00	75	25	90	100
H	Eragrostis pallens	5.38	75	13	100	100
Pmic	Combretum zeyheri	2.86	75	38	90	90
Pmic	Diplorhynchus condylocarpon	1.43	75	38	80	100
Pnan	Clerodendrum ternatum	0.98	75	100	50	80
H	Commelina africana	0.50	75	63	70	90
T	Oxygonum alatum	0.51	71	50	90	70
Pmes	Baphia massaiensis ssp. obovata	5.95	68	100	40	70
Pmic	Ozoroa schinzii	1.29	61	63	40	80
Pmes	Rhus tenuinervis	1.06	61	75	50	60
Pmes	Pterocarpus angolensis	4.78	57	.	80	80
H	Panicum kalaharense	3.06	57	38	60	70
H	Rhynchosia venulosa	0.51	57	75	20	80
Pmic	Grewia flavescens	1.37	54	75	40	50
Cmic	Limeum myosotis	0.44	50	75	50	30
T	Melinis repens ssp. grandiflora	2.63	43	13	70	40
T	Pavonia clathrata	0.68	43	50	10	70
T	Vernonia poskeana ssp. botswanica	0.47	43	13	70	40
H	Evolvulus alsinoides	0.40	43	13	50	60
T	Melinis repens ssp. repens	1.82	39	25	40	50
Pmic	Strychnos pungens	1.23	39	.	70	40
T	Gisekia africana	0.46	39	25	30	60
Pmic	Acacia fleckii	2.05	36	63	10	40
Pnan	Commiphora africana	0.80	36	63	10	40
H	Indigofera filipes	0.56	36	13	40	50
G	Raphionacme velutina	0.50	36	13	30	60
n.a.	Kyllinga alata	0.26	36	13	60	30
T	Lophiocarpus tenuissimus	0.37	32	13	20	60
H	Triraphis schinzii	1.06	29	13	20	50
T	Chamaecrista absus	0.69	29	.	30	50
Pmes	Peltophorum africanum	1.43	25	25	.	50
Pnan	Ochna cinnabarina	0.71	25	13	30	30
H	Indigofera charlieriana	0.44	25	13	40	20
Pnan	Grewia avellana	2.33	21	.	30	30
T	Ipomoea chloroneura	0.50	21	.	30	30
H	Bulbostylis hispidula	0.37	21	50	10	10
Pmic	Strychnos cocculoides	1.00	18	.	20	30
T	Chamaecrista biensis	0.72	18	13	20	20
n.a.	Asparagus virgatus	0.50	18	38	10	10
n.a.	Vigna unguiculata	0.50	18	.	30	20
G	Gloriosa superba	0.34	18	38	.	20
Pnan	Grewia retinervis	1.75	14	.	10	30
G	Talinum arnotii	0.50	14	38	.	10
T	Ipomoea sinensis	0.50	14	25	.	20
T	Commelina benghalensis	0.50	14	13	30	.
T	Sida ovata	0.50	14	.	10	30
T	Sesamum triphyllum	0.40	14	38	10	.

of the lower fire intensity at Mile 46, there is a relatively high density of psammophoric (sand-loving) shrub species. These include species such as *Terminalia sericea* (Silver Terminalia) and various *Combretum* species such as *C. collinum*, *C. psidioides* and *C. engleri* (Variable Combretum, Peeling-twig Combretum and Sand Combretum, respectively), which often transform the structure of the community from a closed woodland to a thicket sensu Edwards (1983).

Responsible authors:
B.J. Strohbach & J. Luther-Mosebach

Millipedes

Sampling period(s)	Species richness
2003/III	1

List of species

Species	Family	Relative frequency	Feeding group
Spirostreptus heros	Spirostreptidae	Frequent	Litter, fresh plant material

Spirostreptus heros, one of the largest millipedes worldwide, was frequently found at this Observatory. This black millipede belongs to the family Spirostreptidae and grows to 30 cm in length. It feeds on decaying organic material but has also been observed feeding on fresh herbs (see Photo). *S. heros* is widely distributed in southern Africa, occurring from northern Namibia to the Kalahari.

An adult of the millipede species *Spirostreptus heros* feeding on fresh plant material. Photo: K. Vohland.

Responsible author: K. Vohland

Termites

Taxon richness	Abundance index	Dominant (sub-)family
9	28	Rhinotermitidae

In total, nine taxa were found at this Observatory. *Psammotermes allocerus* is by far the most abundant species here (see Observatory S11/Nabaos, for more information on this species). Together with *Hodotermes mossambicus*, *P. allocerus* belongs to the lower termites, which possess protozoa associated with bacteria, which assist in the breakdown of cellulose. The Nasutitermitinae genera *Fulleritermes* and *Trinervitermes* as well as the Termitinae genera *Promirotermes* and *Microcerotermes* belong to the Termitidae, which produce enzymes to break down cellulose. They possess very few protozoa which presumably do not play a role in the digestion of cellulose. *Microtermes*, *Odontotermes* and *Allodontermes* are genera of the Macrotermitinae, which cultivate fungi that digest cellulose and other plant material (see Observatory S04/Toggekry). It can be expected that two further taxa, *Amitermes* sp. and *Schedorhinotermes lamanianus* (Termitinae), which are found at the twin Observatory S02 (Mutompo), also occur here. Due to the denser vegetation and the larger amount of litter at Mile 46 compared to Mutompo, the effort spent on sampling probably was not sufficient for the detection of all species.

List of taxa

Taxon	(Sub-)family	Frequency Index	Feeding substrate
Psammotermes allocerus	Rhinotermitidae	0.82	w, d
Fulleritermes	Termitidae (Nasutitermitinae)	0.36	s, w, g, l, m
Trinervitermes	Termitidae (Nasutitermitinae)	0.36	s, w, g, l, m
Allodontermes	Termitidae (Macrotermitinae)	0.09	f (g, l, w)
Hodotermes mossambicus	Hodotermitidae	0.09	g
Microtermes	Termitidae (Macrotermitinae)	0.09	f (g, l, w)
Promirotermes	Termitidae (Termitinae)	0.09	s, w, g
Microcerotermes	Termitidae (Termitinae)	r	s, w, g
Odontotermes sp. 2	Termitidae (Macrotermitinae)	r	f (g, l, w)

Responsible authors: C. Grohmann & K.E. Linsenmair

Butterflies and moths

Sampling period(s)	Number of samples (moths)	Species richness (total)
2002/III; 2003/III; 2007/II	3	258
Species richness (butterflies)	**Species richness (all moths)**	**Species richness (Microlepidoptera)**
34	224	53
Species richness (Pyraloidea)	**Species richness (Macrolepidoptera)**	**Species richness (Noctuidae)**
56	43	72
Individuals sampled (moths)	**Fisher's alpha diversity (moths)**	
1299	77.9	

Butterflies

The observed butterflies are all abundant and widespread species with the exception of *Lepidochrysops michellae*, which is endemic to northern Namibia. The species composition is typical for woodland localities in that the families Nymphalidae and Hesperiidae are represented by several syntopically occurring species, and that only a few species of the genus *Colotis* occur. A characteristic woodland element is *Byblia ilithya*, which is a locally scarce species of open and dry savannas. It was found to be abundant during all visits to the Observatory.

Transect analysis of butterflies

Sampling period: 23 March 2003. The sampling was conducted after the rainy period and the counts yielded more species than in the preceding sampling years (2001–2002 and in 2007).
Description of transect: The transect of 1000 m length follows the eastern border of the Observatory and runs parallel to the sand road.
Species richness: 17, **Number of individuals:** 196

Abundance

Species	*N*	Proportion
Eurema brigitta brigitta	128	65.3%
Byblia ilithya	26	13.3%
Belenois aurota aurota	14	7.1%
Colotis evenina evenina	6	3.1%
Danaus chrysippus aegytius	5	2.6%

Moths

The woodlands in northern Namibia have the highest species diversity of moths in Namibia. The sample taken from the Observatory in March 2003 is an example of this high diversity, with the proportion of species represented by single individuals (singletons) being 47% (= 105 species). Leaf mining *Epicephala pyrrhogastra* (Gracillariidae) and *Deltophora typica* (Gelechiidae) are the most abundant Microlepidoptera species. The Pyraloidea are dominated by *Staudingeria* sp. (Pyralidae: Phycitinae) and *Achyra coelatalis* (Crambidae: Pyraustinae) (see Photo). Abundant macro-moths are *Palasea albimacula* (Lymantriidae) and *Antharmostes papilio* (Geometridae) (see Photo). The Noctuidae is the most species-rich family, with *Amyna punctum* and *Spodoptera exigua* being the most common species.

Achyra coelatalis. Photo: W. Mey.

Antharmostes papilio. Photo: W. Mey.

Butterfly species and main food plants

Hesperiidae	
Pelopidas thrax inconspicua	Imperata, Pennisetum (Poaceae)
Leucochitonea levubu	Grewia (Tiliaceae)
Sarangesa phidyle	Peristrophe, Barleria (Acanthaceae)
Spialia delagoae	n.a.
Spialia diomus ferax	Hermannia (Sterculiaceae), Hibiscus, Pavonia, Sida (Malvaceae)
Spialia mafa mafa	Hermannia, Hibiscus, Pavonia (Malvaceae)
Coeliades forestan forestan	Combretum (Combretaceae), Solanum (Solanaceae)
Coeliades pisistratus	Sphedamnocarpus, Triaspis, Indigofera (Fabaceae)
Lycaenidae	
Aloeides damarensis mashona	Aspalatus (Fabaceae)
Axiocerses amanga amanga	Ximenia (Olacaceae)
Axiocerses tjoane	Acacia (Fabaceae)
Azanus jesous jesous	Acacia (Fabaceae)
Lepidochrysops michellae	n.a.
Leptotes pirithous pirithous	Plumbago (Plumbaginaceae), Indigofera (Fabaceae), Burkea (Caesalpiniaceae)
Zintha hintza krooni	Zizyphus (Rhamnaceae)
Zizula hylax	Phaulopsis, Ruellia (Acanthaceae)
Chilades trochylus	Indigofera, Heliotropium (Fabaceae)
Nymphalidae	
Danaus chrysippus aegyptius	Asclepias, Stapelia, Cynanchum (Asclepiadaceae)
Charaxes jasius saturnus	Afzelia, Burkea, Bauhinia, Colophospermum (Caesalpiniaceae), Schotia (Fabaceae)
Charaxes achaemenes achaemenes	Pterocarpus, Dahlbergia, Xanthocercis (Fabaceae)
Acraea stenobea	n.a.
Hamanumida daedalus	Combretum, Terminalia (Combretaceae)
Byblia ilithya	Tragia, Dalechampia (Euphorbiaceae)
Hypolimnas misippus	Portulaca, Talinum (Portulacaceae)
Junonia hierta cebrene	Asystasia, Adhatoda, Barleria, Ruellia (Acanthaceae)
Junonia oenone oenone	Asystasia, Adhatoda, Barleria, Ruellia (Acanthaceae)
Pieridae	
Eurema brigitta brigitta	Hypericum (Hypericaceae), Chamaecrista (Caesalpiniaceae)
Pinacopteryx eriphia eriphia	Boscia, Maerua (Capparaceae)
Belenois aurota aurota	Boscia, Capparis, Maerua (Capparaceae)
Colotis eris eris	Boscia (Capparaceae)
Colotis evagore antigone	Capparis, Maerua (Capparaceae)
Colotis evenina evenina	Boscia, Capparis (Capparaceae)
Colotis ione	Boscia, Capparis (Capparaceae)
Mylothris agathina agathina	Tapinanthus, Erianthemum (Loranthaceae), Ximenia (Olacaceae)

Taxonomic spectrum of moths

Collection period: III/2003

Family	S	N
Nepticulidae	1	1
Tineidae	5	8
Bucculatricidae	2	4
Gracillariidae	4	65
Plutellidae	1	1
Coleophoridae	3	17
Elachistidae	1	55
Ethmiidae	2	8
Scythrididae	3	24
Lecithoceridae	1	3
Oecophoridae	1	1
Cosmopterigidae	6	14
Gelechiidae	17	124
Tortricidae	5	19
Thyrididae	1	2
Microlepidoptera	**53**	**346**
Pyralidae	30	126
Crambidae	26	116
Pyraloidea	**56**	**242**
Cossidae	1	1
Limacodidae	1	1
Lasiocampidae	2	20
Lymantriidae	2	65
Sphingidae	1	1
Notodontidae	1	1
Geometridae	35	91
Noctuidae	72	531
Macrolepidoptera	**115**	**711**
Total	**224**	**1299**

Responsible author: W. Mey

Vertebrates

Total species richness	Reptile species richness	Bird species richness
56	n.a.	56
Large mammal species richness	**Small mammal species richness**	
n.a.	n.a.	

Birds

Passeriformes	**Perching birds**	**Ciconiiformes**	**Herons and storks**
Anthoscopus minutus	Cape Penduline-Tit	Bubulcus ibis	Cattle Egret
Batis molitor	Chinspot Batis	Ciconia abdimii	Abdim's Stork
Bubalornis niger	Red-billed Buffalo-Weaver		
Calamonastes undosus stierlingi	Miombo Barred Warbler	**Coraciiformes**	**Kingfishers and relatives**
Cercotrichas leucophrys	White-browed Scrub-Robin	Coracias caudata	Lilac-breasted Roller
Cisticola chiniana	Rattling Cisticola	Halcyon chelicuti	Striped Kingfisher
Dicrurus adsimilis	Fork-tailed Drongo	Merops apiaster	European Bee-eater
Emberiza flaviventris	African golden-breasted Bunting	Merops hirundineus	Swallow-tailed Bee-eater
Eurocephalus anguitimens	White-crowned Shrike	Merops persicus	Blue-cheeked Bee-eater
Hirundo rustica	Barn Swallow	Tockus leucomelas	Southern yellow-billed Hornbill
Lamprotornis nitens	Cape Glossy Starling	Tockus nasutus	African Grey Hornbill
Laniarius atrococcineus	Crimson-breasted Gonolek	Tockus monteiri	Monteiro's Hornbill
Lanius minor	Lesser Grey Shrike	Upupa epops africana	African Hoopoe
Mirafra africanoides	Fawn-coloured Lark		
Muscicapa striata	Spotted Flycatcher		
Nectarinia senegalensis	Scarlet-chested Sunbird	**Caprimulgiformes**	**Nightjars**
Oriolus auratus	African Golden Oriole	Caprimulgus pectoralis	Fiery Necked Nightjar
Parus carpi	Carp's Black Tit		
Parus cinerascens	Ashy Tit	**Cuculiformes**	**Cuckoos and anis**
Phylloscopus trochilus	Willow Warbler	Corythaixoides concolor	Grey go-away-Bird
Plocepasser mahali	White-browed Sparrow-weaver		
Prinia flavicans	Black-chested Prinia	**Piciformes**	**Woodpeckers and relatives**
Psophocichla litsipsirupa	Groundscraper Trush	Tricholaema leucomelas	Acacia Pied Barbet
Pycnonotus barbatus	Common Bulbul	Dendropicos namaquus	Bearded Woodpecker
Pycnonotus nigricans	Black-fronted Bulbul		
Serinus mozambicus	Yellow-fronted Canary	**Galliformes**	**Fowl-like birds**
Sporopipes squamifrons	Scaly-fronted Weaver	Numida meleagris	Helmeted Guineafowl
Tchagra australis	Brown-crowned Tchagra	Francolinus adspersus	Red-billed Francolin
Uraeginthus granatinus	Violet-eared Waxbill		
Vidua regia	Shaft-tailed Whydah	**Falconiformes**	**Birds of prey**
Turdus litsitsirupa	Groundscraper Trush	Buteo buteo vulpinus	Steppe Buzzard
		Micronisus gabar	Gabar Goshawk
Accipitriformes	**Birds of prey**	**Columbiformes**	**Doves and pigeons**
Aquila rapax	Tawny Eagle	Stigmatopelia senegalensis	Laughing Dove
Terathopius ecaudatus	Bateleur	Streptopelia capicola	Ring-necked Dove
Melierax canorus	Pale chanting Goshawk	Turtur chalcospilos	Emerald Spotted Wood-Dove
Buteo buteo vulpinus	Steppe Buzzard		

Responsible authors: J. Deckert, A. Hoffmann & A. Mills

The people

Study period	Size of study area	Population in study area
2004–2008	ca. 90 km²	737 people
Number of households	Mean household size	Population growth
107	6.1 people	1.5% (2006)
Total fertility rate	Cohort fertility	
6.5 children per woman	1920–1967: 6.1; 1968–1990: 6.0 children per woman	
Life expectancy	Sex ratio (m/f)	
41.7 years (2001)	0.85	

Landuse

Study period	Size of Observatory farm	Recommended stocking rate
2004–2008	ca. 90 km²	1.5 ha·SSU^{-1} (50 kg·ha^{-1})
Actual stocking rate	Number of animals	
5 ha·SSU^{-1} (15 kg·ha^{-1})	Total: 437 (57,828 kg); cattle: 197; goats: 226; sheep: 12; donkeys: 2 (2001)	

Responsible authors: M. Pröpper & T. Falk

Vegetation of the Alex Muranda LDC and adjacent areas as example of the central Kavango woodlands (S01.01)

[B.J. Strohbach]

No detailed vegetation descriptions are available for the Kavango woodlands – recent descriptions have all been at the broad landscape level without describing any vegetation communities. With this paper, the vegetation associations found at and around the Alex Muranda Livestock Development Centre (LDC), including the villages of Mutompo and Epingiro are described. Two broad classes are recognised: the Acacietea are represented by three *Acacia* species-dominated associations on nutrient richer eutric Arenosols, whilst the Burkeo-Pterocarpetea are represented by three associations dominated by broad-leaved phanerophytic species on dystri-ferralic Arenosols. The *Pterocarpus angolensis-Guibourtia coleosperma* bushlands and thickets, which are typical for the Kavango woodlands, are further divided into four variants. The vegetation has been mapped using Landsat 7 ETM scene 177-073 (24 April 2000) with Definiens. Fire has been found to be an important factor in determining the structure of the vegetation—exclusion of fire on the LDC itself seems to lead to an increase in shrub (understory) density.

Strohbach, B.J., Petersen, A. (2007): Vegetation of the central Kavango woodlands in Namibia: an example from the Mile 46 Livestock Development Centre. – South African Journal of Botany **37**: 391–401.

Soil fertility and landuse in the Kavango Region (S01.02)

[U. Wisch]

The main objective of this study is to investigate soil fertility in the Kavango Region. As a typical example for an agricultural site of the Kavango Region, the territories of the villages Epingiro and Mutompo near the Observatories S01 and S02 were chosen as investigation area.

The soil characteristics in the region mainly vary dependent on their position within the "linear" dune system. Nutrient contents in the soil and in crop leaves are low, especially that of phosphorus and magnesium. The supply with nitrogen seemed to be sufficient under the current management.

To investigate the influence of land use on soil properties, a parallel sampling of uncultivated sites and of sites of different cropping and fallowing periods was conducted. The results showed a massive decrease of organic carbon contents due to cultivation correlated with a decrease in the general soil fertility. The fallowing practice in the region is not suitable for sustainable cropping; no recovery in organic carbon was detectable in fallows of ages up to 12 years.

Conclusions of this study are that the two main factors of soil fertility in the region are the soil clay and organic carbon contents. The former can only be influenced by the choice of land for cultivation, strictly staying in interdunal streets. The latter can be influenced by farm management. With these measures, sustainable farming might be possible without further increasing area consumption.

► *See also* **'Crop soils: water, nutrients' in Subchapter IV.1.5.**

Wisch, U. (2008): Soil fertility of dryland farming systems in the Kavango region, Namibia. – Diplom thesis in Soil Science. Hamburg: University of Hamburg.

Further studies

Falk, T. (2008): Communal farmers' natural resource use and biodiversity preservation. A new institutional economic analysis from case studies in Namibia and South Africa. – Göttingen: Cuvillier.

Falk, T., Bock, B., Kirk, M. (2009). Polycentrism and poverty: experiences of rural water supply reform in Namibia. – Water Alternatives **2**: 115–137.

Hecht, J. (submitted): Decision making of rural farm households in Namibia: lessons learned from multi-annual programming optimisation models. – Dissertation, submitted. Giessen: Institute of Agricultural Policy and Market Research, Justus-Liebig-University of Giessen.

Pröpper, M. (2009a): Culture and biodiversity in central Kavango, Namibia. – Berlin: Reimer.

Pröpper, M. (2009b): Sawing Kavango timber commons: levels of action and agency upon local natural capital. – In: Greiner, C., Kokot, W. (eds.): Networks, resources and economic action. Ethnographic case studies in honor of Hartmut Lang: 171–188. Berlin: Reimer.

Pröpper, M. (2008): Trust, sharing and cooperation in the central Kavango Region, North-East Namibia. Linking the results of experimental economics with ethnographic research. – In: Limpricht, C., Biesele, M. (eds.): Heritage and cultures in modern Namibia. In-depth views of the country. A TUCSIN-Festschrift: 64–77. Windhoek & Göttingen: Klaus Hess.

Wisch, U., Petersen, A., Gröngröft, A., Eschenbach, A. (2010): Dryland farming in the Kavango region: Effect of land use on soil properties. – Zentralblatt für Geologie und Paläontologie, Teil I, **2008**: 189–211.

General data

Number	Name	Alternative name(s)
S02	Mutompo	n.a.
Implementation	**Country**	**Province/ region**
2001	Namibia	Kavango
District/ constituency	**Locality**	**Farm name**
Rundu	near Cove	Mutompo
Latitude	**Longitude**	**Altitude**
18.301782 S	19.258331 E	1180 m a.s.l.
Rainfall season	**Biome**	**WWF Ecoregion**
Summer	Woodland Savanna	AT0726 Zambezian Baikiaea woodlands
Agro-Ecological Zone	**Relative intensity of land use**	**Tenure**
KAL3-2	High	Communal
Type and history of landuse	**Land owner**	
Cropping and cattle grazing	Government of Namibia	

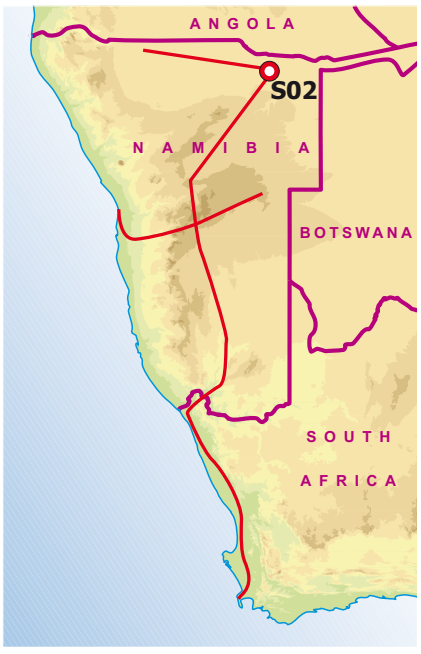
Mutompo (S02)

Kavango woodlands at Mutompo Observatory. Photo: A. Gröngröft.

The BIOTA Observatory Mutompo (S02) is situated adjacent to the Livestock Development Centre Alex Muranda, ca. 60 km south-west of Rundu in the Kavango Region of Namibia. It falls within the extensive sand plateau of the Northern Kalahari, and possesses linear east-west orientated structures which are remnants of a prehistoric dune field (Thomas 1984), which was deposited ca 18,000–13,000 years ago (Heine 1982). These dunes have since been eroded, sometimes to a level lower than the more loamy remnants in the adjacent inter-dune valleys. The deep sands of the Kalahari Plateau are stabilised by an open broad-leafed woodland. Depending on the degree of loam content in the soil, the inter-dune areas are dominated by vegetation ranging from open bushland to dense thicket. The vegetation on the Observatory is a typical example of the dry Woodland Savanna of the Northern Kalahari sensu Giess (1998). The average altitude is about 1180 m a.s.l. There is a typical summer rainfall climate, with an average annual rainfall of 536 mm.

The villages Mutompo and Epingiro are the nearest settlements, and the Observatory actually falls within the area utilised by the villagers of Epingiro. The land is used as communal grazing, whilst some of the land is cleared and converted to crop fields. During the course of the project, several hectares of the Observatory were utilised in such a manner.

This BIOTA Observatory was established to monitor potential variation of



climate-change impacts within the dry Woodland Savanna, especially regarding the predicted mobilisation of Kalahari dune systems due to global climate change (Thomas et al. 2005). This has been done in comparison with the adjacent Observatory Mile 46 (S01), and the more southern Observatories Sonop (S03), Sandveld (S41) and Alpha (S17. In addition, the study of the effects of regular fires and a communal landuse system was also possible.

Responsible author: B.J. Strohbach & D.H. Haarmeyer

Remote sensing and landscape

Geomorphology	Geological units	Lithological units
Degraded dunes and interdunes of Kalahari dune veld	Kalahari Sands	Sands and Calcrete
Mean EVI	**EVI absolute range**	**Mean leaf area index**
0.241 (0.159–0.376)	0.121 (2001)–0.413 (2006)	0.72

Grid map of Observatory

	0	1	2	3	4	5	6	7	8	9
0	49	78	92	30	79	59	1	84	71	62
1	99	39	82	72	32	5	86	6	83	53
2	64	47	21	67	12	66	81	97	100	94
3	85	73	11	89	90	80	43	55	57	75
4	17	7	44	56	9	29	61	13	34	48
5	63	50	4	20	25	10	58	54	28	8
6	37	27	31	14	19	35	41	46	38	18
7	60	98	16	33	76	52	3	23	40	65
8	96	36	77	26	88	68	93	42	74	15
9	70	69	87	2	24	91	51	22	45	95

1 Closed woodland savanna on degraded dune
2 Open woodland savanna on degraded dune
3 Woodland-thornbush transitional savanna on transition zone dune/interdune
4 Thornbush thicket on interdune
5 Acacia thornbush savanna on interdune

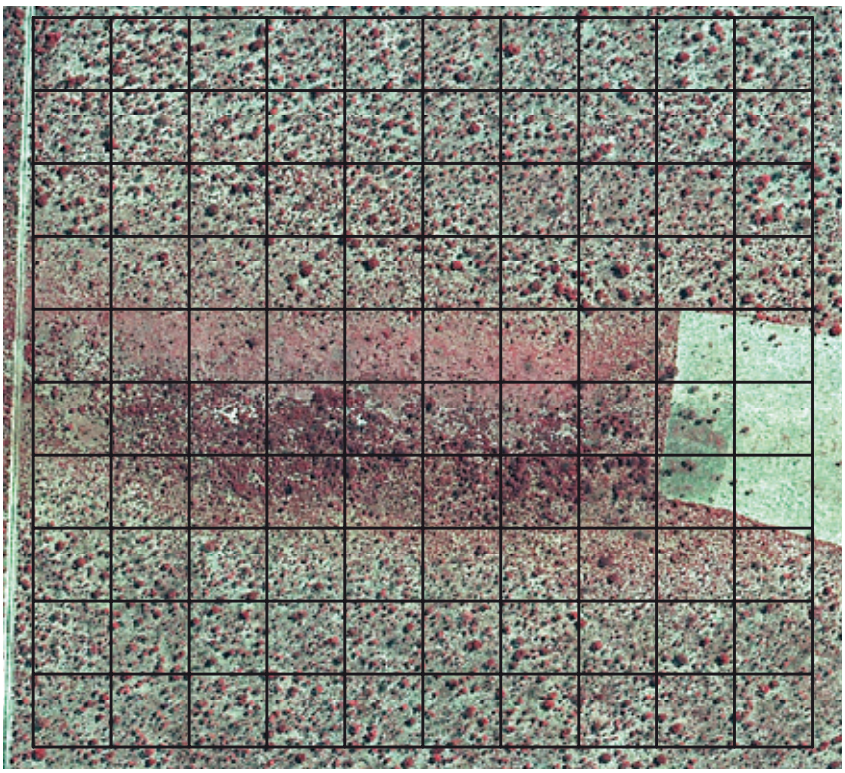
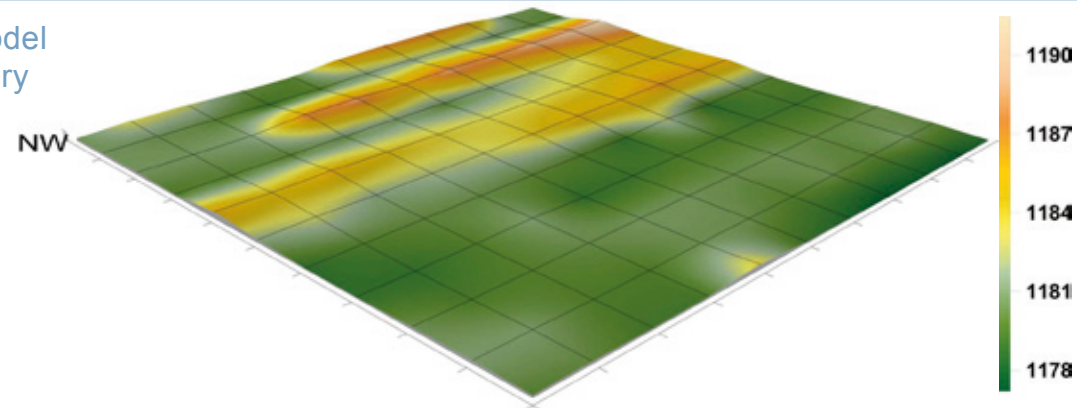


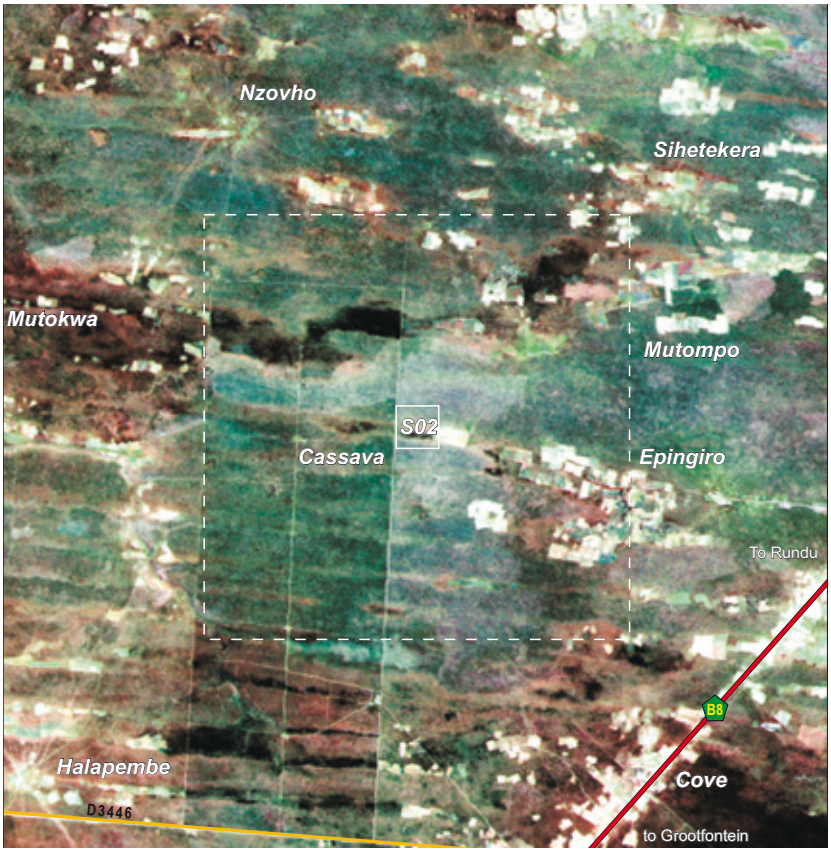
Image: Quickbird, 5 April 2007

Elevation model of Observatory



Landsat image

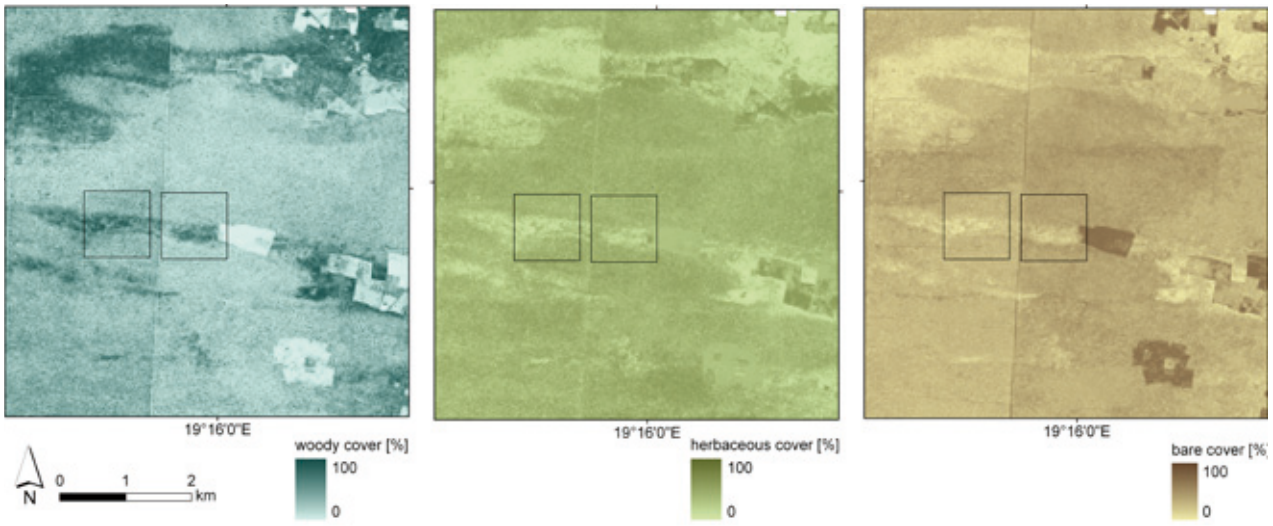
The dunes of the slightly undulating Kalahari landscape, which were formed approximately 30,000 years ago by easterly winds, are east-west orientated. Some parts of the dune-ridges were eroded, whereas the finer particles in the valleys were able to resist the forces of wind. Therefore, the relief is relative heterogeneous nowadays. The surface structure has a relative height difference of a maximum of 10 m, and the distance between neighbouring dune-ridges is generally between 800 m and 1000 m. The vegetation type is an open Woodland Savanna, with variable patterns of grasses and shrubs underlying the tree layer (normally greenish and light brown colours, but in this scene blue-grey and brownish colours resulting from the influence of bushfires in former years). The vegetation in the dune valleys is denser and often consists of dense Thornbush vegetation (displayed as dark red and brown tones).



Scene: 177/73, acquisition date: 06 May 2007

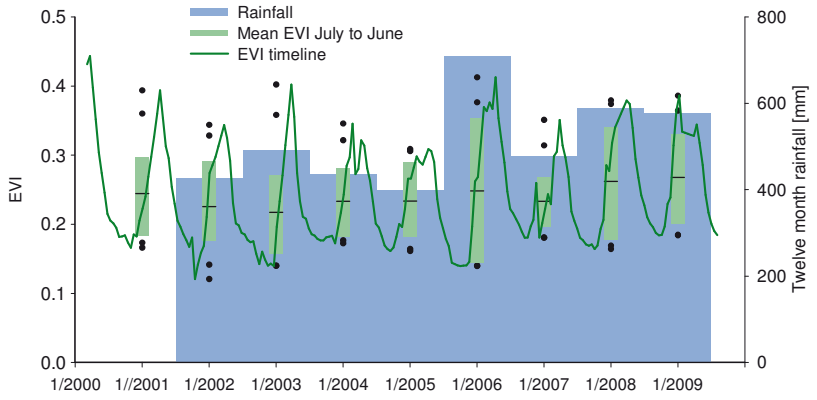
In the communal area of Mutompo, which is separated by a fence and a firebreak along the boundary of the state farm Mile 46 (Observatory S01), the bush vegetation is frequently cleared and converted to agricultural fields (white patches). A recently cleared area (light green) can be detected in the north-eastern part of the image.

Fractional cover image



MODIS time series

Temporal patterns of annual rainfall, vegetation cover, and phenology



Responsible authors: M. Keil & T. Labitzky

Climate

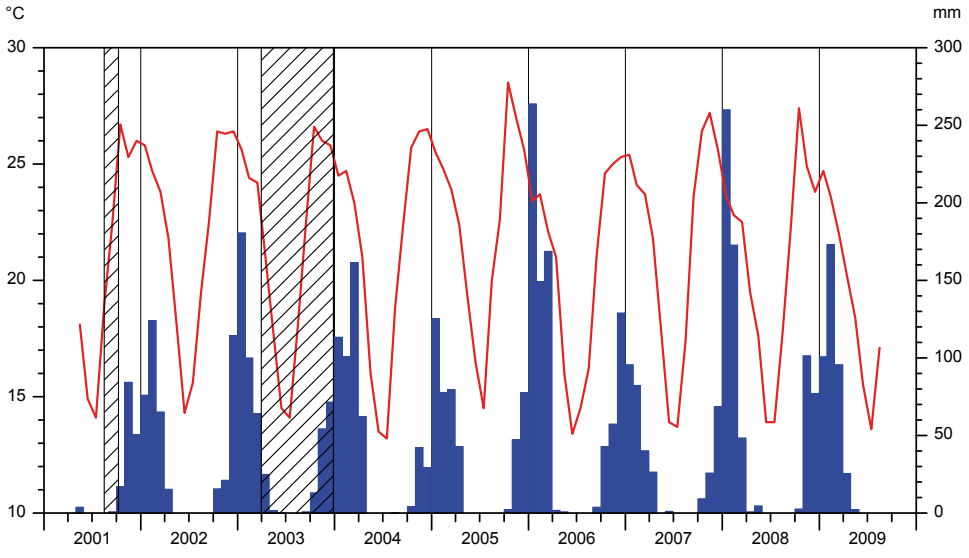
Data from BIOTA weather station

Location	Recorded period	Mean temperature
Mile 46 (S01)	2001–2009	22.6 (-1.8–43.9) °C
Mean solar radiation	**Mean wind speed**	**Mean annual precipitation**
491 (263–754) $MJ \cdot m^{-2} \cdot month^{-1}$	1.1 (4.9) $m \cdot s^{-1}$	527 (348–816) mm
Mean annual potential evapotranspiration	**Interannual precipitation variability**	**Mean relative humidity**
1340 mm	131%	55% (23–84%)
Aridity index (UNEP)		
0.39 (semi-arid)		

Modelled data

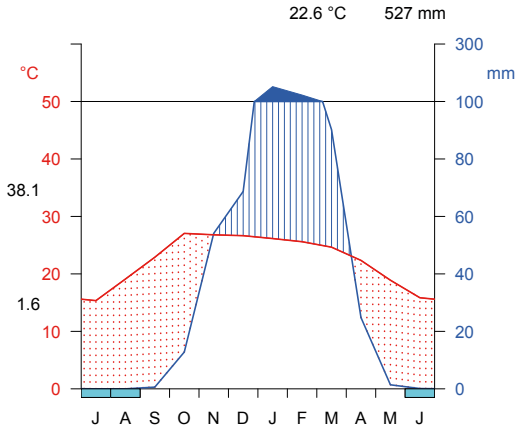
Mean temperature	Mean annual temperature range	Mean diurnal temperature range
22.2 (6.5–34.0) °C	9.7 °C	15.7 °C
Mean annual precipitation	**Precipitation seasonality**	**Percentage winter precipitation**
536 mm	106%	8% (strong summer)
Climate type	**Length of dry season**	**Aridity index (De Martonne)**
BSh	7 months	16.6 (semi-dry)

Time series: rainfall and temperature

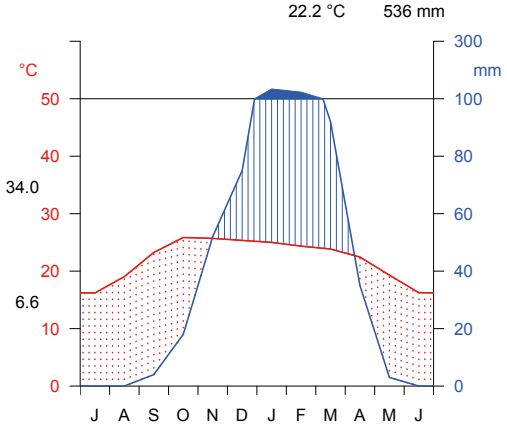


Climate diagrams

Recorded data (BIOTA)

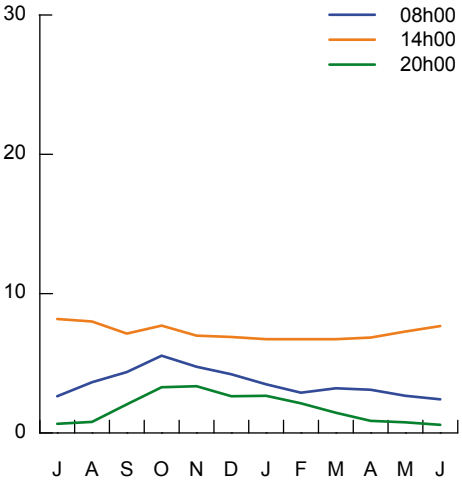


Modelled data (WorldClim)

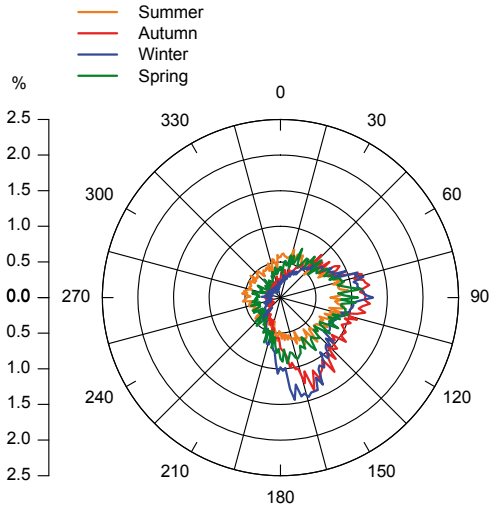


Wind diagrams

Speed



Directions



The climate at the Observatory is characterised by semi-arid conditions. Rainfall shows a strong seasonality with almost all rainfall falling during the summer season, peaking in January. Mean annual rainfall is about 527 mm, making this Observatory, together with Mile 46 (S01), the wettest Observatory within the Woodland Savanna. However, substantial interannual variability is evident. Observed near-surface air temperatures show a moderate seasonal cycle. The observed mean annual temperature is 22.6°C and is therefore close to the average for the Observatories in this biome. The observed mean minimum temperature is above the freezing point, but there is still a possibility of the occurrence of frost during the months of June to August. Compared to the interpolated long-term data taken from the WorldClim dataset, only minor differences in mean annual temperature are evident. However, the station records of temperature extremes deviate substantially from the WorldClim data, showing warmer maximum and colder minimum temperatures. For precipitation, mean annual rainfall is slightly lower at the BIOTA weather station in comparison to the WorldClim dataset.

The observed near-surface winds at the Observatory are mainly constituted of easterly and south-easterly flows, with a slightly enhanced southerly component during the autumn and winter periods. Mean wind speed is highest during the early afternoon, reaching about 8 to 10 km/h. Winds during that time of the day stay fairly constant throughout the year, whereas a weak annual cycle is evident for the mean wind speed recorded during the mornings and evenings. The same weather data as for Mile 46 (S01) is valid for this Observatory.

Responsible authors: K. Berger, A. Haensler & J. Luther-Mosebach

Soils

Year of sampling	Hectare plots sampled	SOTER unit
2001	19 (R1–15, R20, R22, R31, R90)	NA17
Soilscape	**Dominant soil group(s)**	**Reference group richness**
Arenosols (AR)	Arenosol	2
Soil unit richness	**Soil unit evenness**	**Soil ecotype richness**
3	0.249	4
Parametric space	**pH**	**Electrical conductivity**
2.43	5.6 (4.6–6.7)	14 (4–30) $\mu S \cdot cm^{-1}$
Organic carbon		
0.44% (0.31–0.69%)		

Most of the profiles on this Observatory are classified as Ferralic Arenosols, which are subdivided by a second qualifier into 'Eutric' and 'Dystric'. A detailed description of the differences between Arenosol (Dystric) and Arenosols (Eutric) in the region is given in the Soil Section of Observatory S01 (Mile 46).

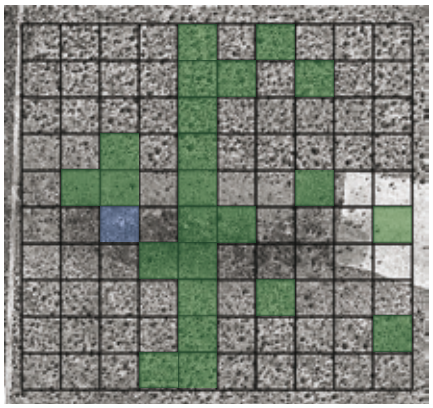
One single profile situated close to a small pan was classified as Stagnic Regosol. Prominent mottles of iron oxides indicate seasonal water logging for this profile. The stratification of the substrates with sharp borderlines in the profile is most likely created by fluvial influence.

The mean pH values and carbon content in the subsoil are higher on this Observatory than on Mile 46 (S01) due to a higher proportion of Arenosols (Eutric) in inter-dunal sites. These soils have a slightly higher content of organic carbon, clay, as well as higher pH values especially in the subsoil.

Due to the higher contents of clay and organic carbon, also contents of exchangeable potassium are slightly higher on this Observatory. The range of exchangeable cations is slightly higher, due to a higher proportion of inter-dune profiles on this Observatory. Nutrient levels, however, are generally very low.

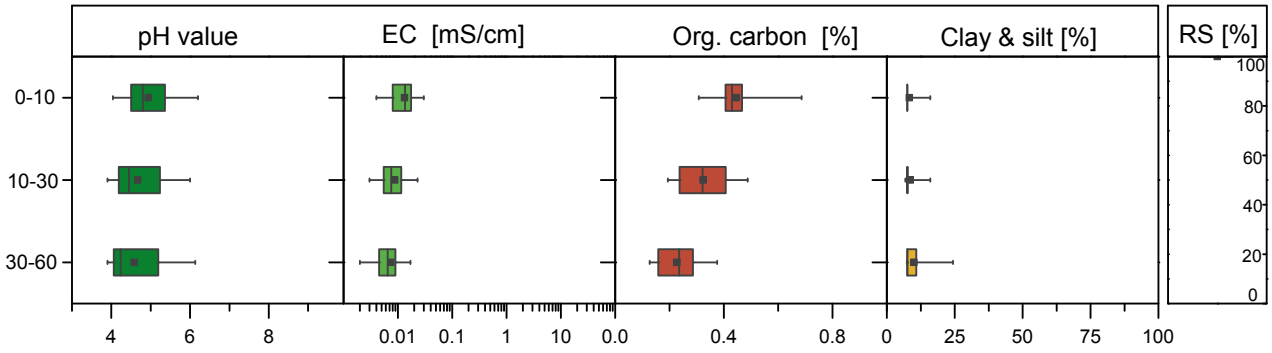
According to Article III.5.4, the comparison of top-soil characteristics between this Observatory and Mile 46 (S01) indicate a significantly stronger fire influence on Mutompo (S02).

Map of soil profiles

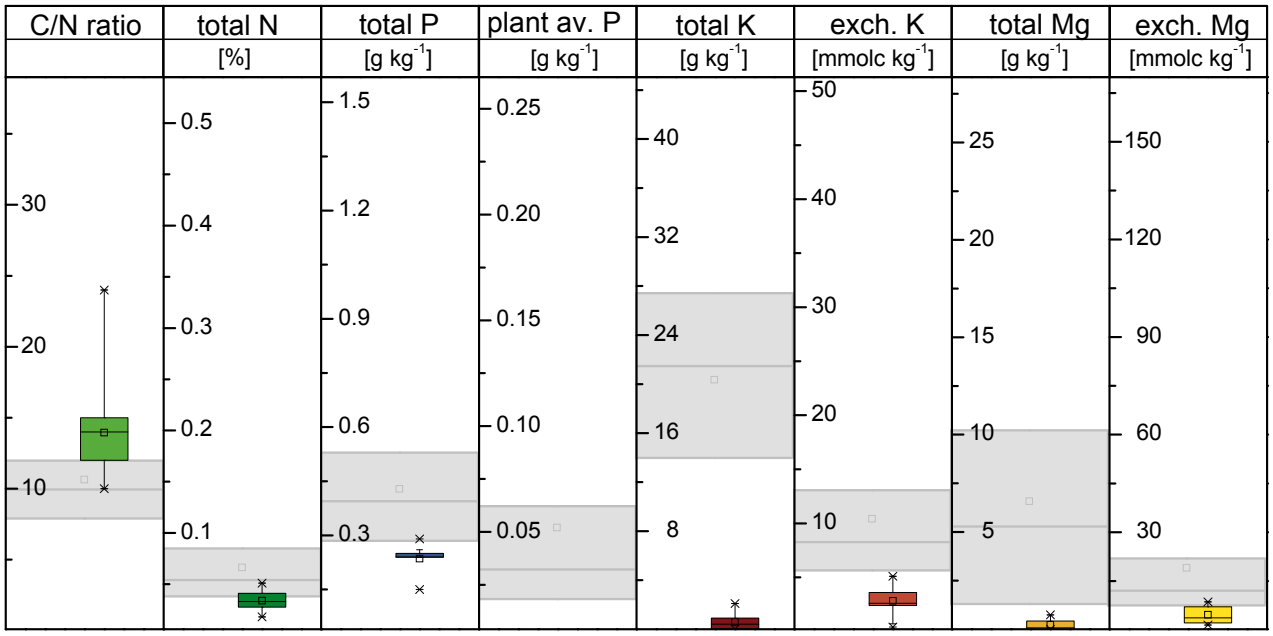


Ferralic Arenosol
Stagnic Regosol

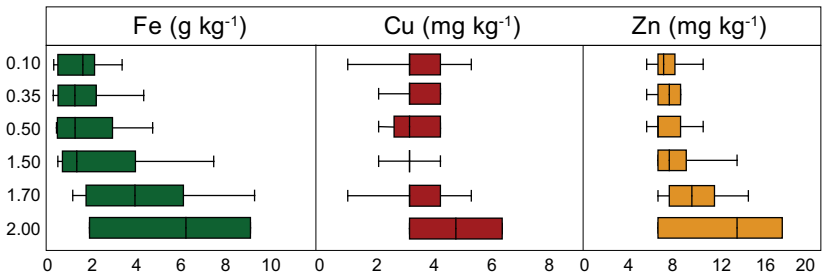
Soil characteristics



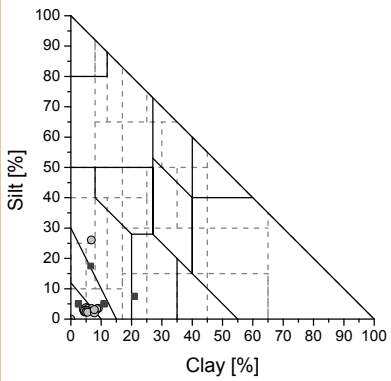
Soil nutrients



Soil micronutrients



Soil texture triangle

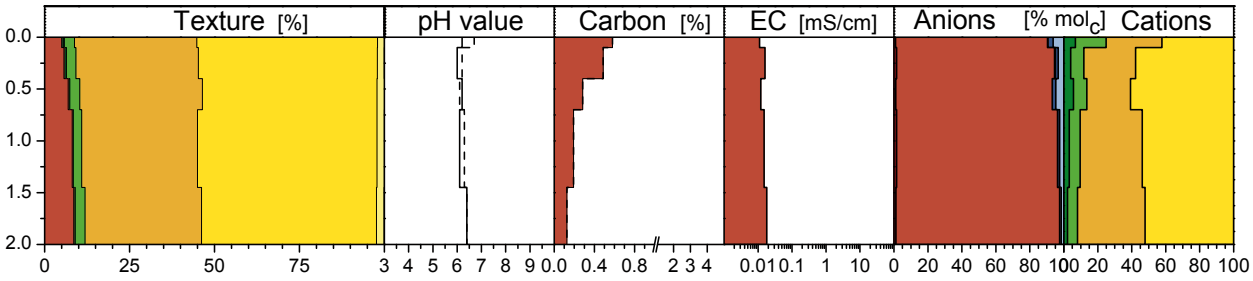


Reference profile (H64)

This **Ferralic Arenosol (Eutric, Greyic)** is an example of soils developed in the loamier central part of the Observatory. Most parameters show only marginal vertical changes within the profile. The texture is clayey sand, with a slight increase of clay content with depth. The sand fraction is dominated by medium and fine sand. The amount of fine sand is higher, with a mean quotient of medium sand to fine sand of 1.5 compared to the Ferralic Arenosols (Dystric), which have a mean quotient of 3.

The soil reaction is neutral to slightly acid over the entire profile. The organic carbon reaches 0.58% in the topsoil and shows only a slight decrease with depth. In combination with the dark brown greyish colour of the profile, this indicates a deep accumulation of organic matter by bioturbation or a colluvial genesis of the profile. In all horizons, the electrical conductivity is very low (around 20 µS cm^{-1}). Compared to profiles in pure dune sands, this profile exhibits higher total element contents, which results in only slightly increased values of the total base reserve (12–37 $cmol_c$ kg^{-1}). Due to the higher amounts of clay, humus and the increased pH values, the cation exchange capacity of Ferralic Arenosols (Eutric) is substantially higher with values of 30–45 $mmol_c$ kg^{-1} compared to the Arenosols (Dystric) (5–10 $mmol_c$ kg^{-1}). The concentration of water-soluble ions is low (2–7 $mmol_c$ kg^{-1}), with the highest values occurring in the subsoil.

This soil type is the preferred ground for rain-fed agriculture (see Subchapter IV.1.5).



Responsible authors: U. Wisch, A. Petersen, A. Gröngröft & D. Mager

Biological soil crusts

Sampling period(s)	Hectare plots sampled	Types of soil crusts
2003	2 (R1, R2)	1
Crust thickness	**Cover**	**Carbon [weight %]**
< 3 mm	less than 1%	0.492
Nitrogen [weight %]	**Chlorophyll *a* [mg/m²]**	**Chlorophyll *a+b* [mg/m²]**
0.008	45	79

Similarly to the twin Observatory, S01 (Mile 46), biological soil crusts are restricted to recently burned areas, but absent inside the mature forest. As on Mile 46, the carbon and nitrogen content of the soil are particularly low.

Biological soil crust characteristics

	H06	H93
Soil characteristics	Grey sand with significant burnt plant material and wood	Grey sand; few burnt wood particles
Crust characteristics	BSC not easily identifiable; few pieces	Only few fragile pieces, that are probably BSC
Chlorophyll a [mg/m²]	-	45.21
Chlorophyll a+b [mg/m²]	-	78.63
Carbon [weight %]	0.55	0.43
Nitrogen [weight %]	0.01	0.01

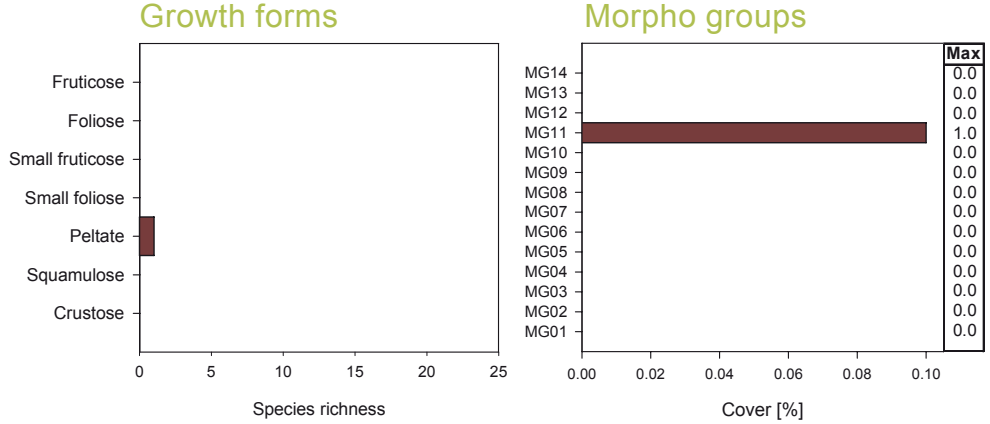
Responsible authors: B. Weber, K. Deutschewitz, S. Dojani & B. Büdel

Lichens

Sampling period(s)	Hectare plots sampled	Cover
2001, 2004	10 (R1−R10)	0.1% (0−1%)
Total species richness	**Species richness on soil [1 km²]**	**Species richness on rock [1 km²]**
4	1 (25%)	0
Species richness on plants [1 km²]	**Species richness on soil [1000 cm²]**	
3 (75%)	0.1 (0−1)	

This Observatory has very poor lichen diversity on all substrates, despite being climatically suitable for lichen growth in terms of the relatively high rainfall. Just one ubiquitous peltate cyanolichen species is found on soils. The low number of soil-inhabiting lichens is due to the presence of sandy, unstable and acidic soils with limited calcium carbonate contents. Frequent fires also inhibit lichen growth here.

The percentage cover of lichens is very low on all investigated hectare plots, and only one morphological group (MG11) was recorded from hectare plot 76. Soil-inhabiting lichens are completely lacking on the other hectare plots.



List of taxa

Terricolous (on soil):

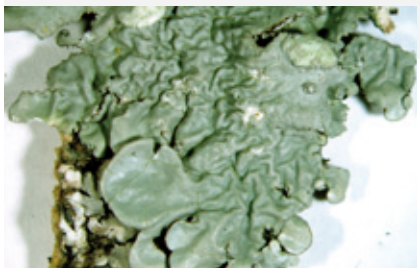
Peltula patellata

Saxicolous (on rock):

No records

Epiphytic (on plants):

Hyperphyscia adglutinata
Parmotrema austrosinense
Physcia undulata



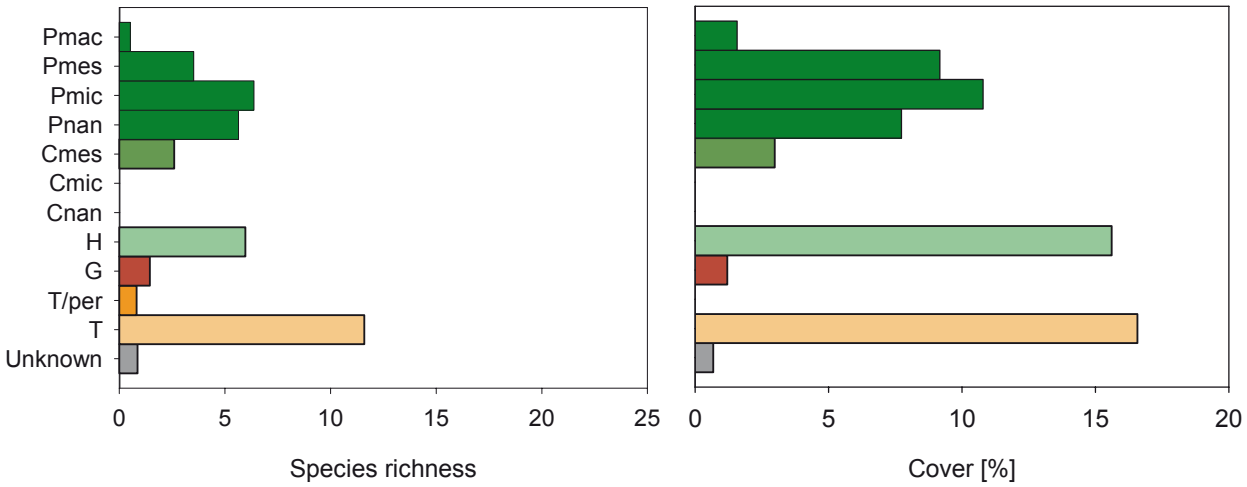
Parmotrema austrosinense.
Photo: L. Zedda & G. Rambold

Responsible authors:
L. Zedda & G. Rambold

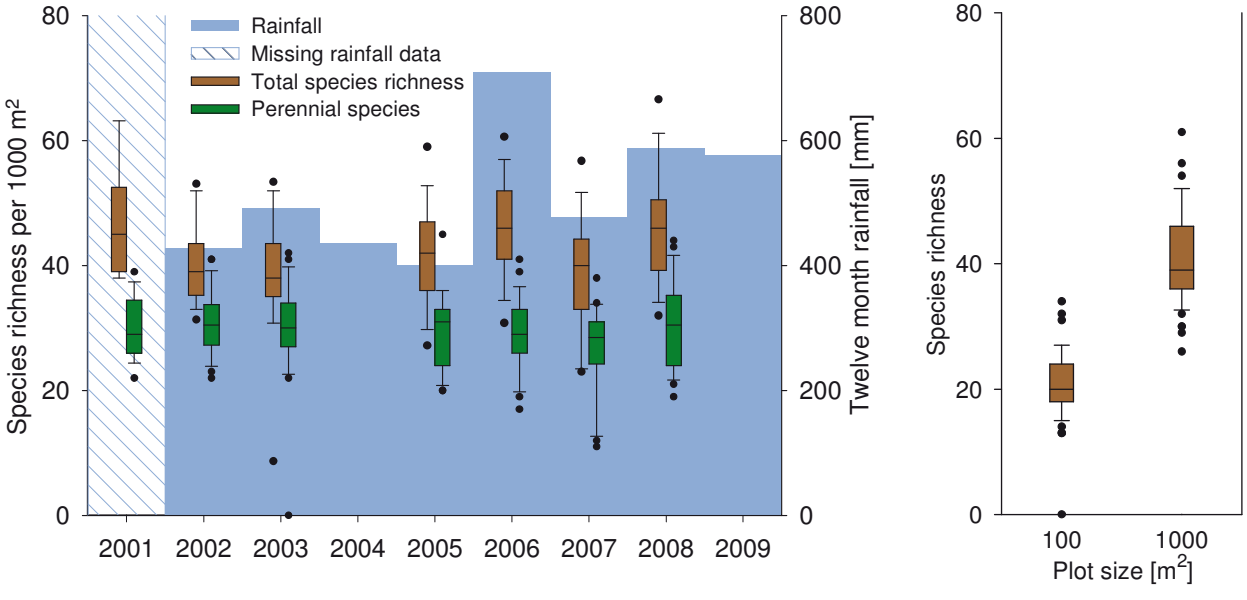
Vascular plants

Sampling period(s)	Hectare plots sampled	Biome
2001–2003, 2005–2009	20 (R1–R20)	Woodland Savanna
Vegetation unit (level 1)	**Vegetation unit (level 2)**	**Identification rate**
Tree Savanna and Woodland (Northern Kalahari)	n.a.	93% – 99% – 100%
Cumulative family richness	**Dominant families (cover)**	**Dominant families (richness)**
58	Poaceae, Fabaceae, Combretaceae	Fabaceae, Poaceae, Convolvulaceae
Cumulative species richness (1 km²)	**Species richness (1000 m²)**	**Species richness (100 m²)**
348 – 172	42.5 (0–68)	20.6 (0–34)
***z*-value**	**Species richness change per year (1000 m²)**	**Evenness (1000 m²)**
0.315 (0.134–0.463)	0.04	0.771 (0.466–0.908)
Evenness (100 m²)	**Simpson (1000 m²)**	**Simpson (100 m²)**
0.752 (0.552–0.950)	0.896 (0.532–0.967)	0.820 (0.634–0.941)

Life forms



Species richness



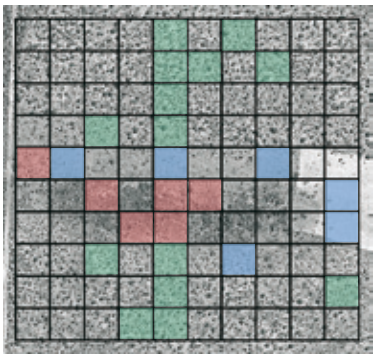
Unit 1, 2003. Photo: B. Strohbach.

The vegetation of the Mutompo Observatory is very similar to that of the neighbouring Mile 46 (S01) Observatory, and follows the same environmental patterns. The vegetation consists of closed woodlands, open bushlands, and thickets. These are closely linked to the prevailing soil patterns, with the deep, pure aeolian sands of the Kalahari supporting the typical Kavango woodlands, dominated by a range of broad-leafed trees and shrubs associated with more mesic environments. The more loamy sands are associated with the old inter-dunal valleys and omiramba [singular: omuramba] support a dense *Acacia* thicket. These are described by King (1963) as sand- or silt-filled riverbeds to the extent that local gradients have been lost. Various transitional forms and successional stages, which are also driven by fire dynamics, are visible. Plant diversity is very high at the Observatory, with 58 plant families being recorded. The Poaceae and Fabaceae dominate the Observatory in terms of both cover and species richness. Not surprisingly, beta diversity in this Woodland is very low, with very high species evenness at all spatial scales.

The Mutompo Observatory has far more open bush in the woodland understory in comparison to the neighbouring Mile 46 Observatory (S01). This is due to fire, which generally destroys low, small trees and shrubs provided there is sufficient grass fuel available. Large trees are generally not affected unless the fire spreads into the tree canopies (Geldenhuys 1977). More open shrub layers are especially evident in the transitional zones between the broad-leafed woodlands and the *Acacia*-thickets, where the grass sward is relative dense and provides a large fuel load for effective fires. The understorey of the Kavango woodlands is also affected by these regular fires.

The *Acacia luederitzii-Croton gratissimus* community (unit 1) is typically found on the loamy remnants of inter-dunal valleys (haplic Arenosols). This closed, continuous thicket is dominated by *Acacia luederitzii* trees, associated with various other thicket-forming phanerophytes, e.g. *Dichrostachys cinerea, Acacia mellifera subsp. detinens*, *Combretum hereroense*, *Mundulea sericea*, *Ochna cinnabarina*, *Croton gratissimus* and even *Acacia erioloba* trees. The average tree cover (P mic-P mac) is 13%, shrub cover (P mic) is 60%, and grasses have an average cover of 20%. The lianous *Hippocratea parvifolia,* as well as numerous shade-loving plants, e.g. *Pupalia lappacea and Sporobolus fimbriatus,* are also associated with these thickets (Strohbach & Petersen 2007). This community has a fairly high species diversity due to the protection that the dense woody layer provides against grazing and fires, as well as the specialised niche habitats present in dense vegetation associated with generally nutrient-rich soils. This almost impenetrable community is not an important grazing resource because of the dense cover of woody species.

Map of vegetation units



The *Acacia fleckii-Brachiaria nigropedata* community (unit 2) is a typical ecotonal association between the dense thickets of the *Acacia luederitzii-Croton gratissimus* community and the *Pterocarpus angolensis-Guibourtia coleosperma* community (unit 3) of the deep Kalahari Sands. Strohbach & Petersen (2007) subdivided this community into two closely related types: the *Bauhinia petersiana-Acacia fleckii* shrublands; and the *Eragrostis rigidior-Acacia fleckii* bushlands. The former is characterised by very dense stands of shrubby *Bauhinia petersiana,* with an average shrub cover of 57%. The tree cover is only 2% (P mes-P mac), whilst the grass cover reaches 21%. The *Eragrostis rigidior-Acacia fleckii* bushlands are dominated by scattered *Acacia erioloba* trees (on average 5% tree cover), with a far lower shrub cover (P mic) of only 40%. The grass cover may reach 28%, and is dominated by *Schmidtia pappophoroides, Digitaria seriata, Eragrostis rigidior, Stipagrostis uniplumis*, and *Brachiaria nigropedata.* These grasses form a valuable grazing resource, and also provide high fuel loads for potential veld fires. The fact that this community occurs on relatively fertile soils is also a threat to the community, as the local land users tend to clear these bushlands for new crop fields. Interestingly, the diversity in very young crop fields is not much different to the diversity of uncleared bushland: grass species are weeded out vigorously and replaced with a crop of *Pennisetum glaucum* (pearl millet or mahangu). Depending on the availability of labour and the effective-

Classification table 2008

Column		Cover	All	1	2	3
Number of relevés			**24**	**6**	**6**	**14**
Mean cover [%]			117.4	117.2	122.2	115.5
Mean species richness (1000 m²)			46.3	48.5	51.5	43.2
Mean soil pH			4.90	5.44	5.24	4.54
Mean electrical conductivity [µS·cm^{-1}]			13	16	13	12
Organic carbon [%]			0.44	0.47	0.42	0.45
Unit 1: Acacia luederitzii-Croton gratissimus community						
Pmic	Combretum hereroense	1.43	27	83	33	.
Pmic	Croton gratissimus	2.50	31	100	33	.
Pmes	Acacia luederitzii	4.00	23	100	.	.
Pnan	Asparagus cooperi	2.88	31	67	50	7
H	Eragrostis rigidior	3.70	38	100	50	7
T	Chamaecrista absus	1.05	38	100	50	7
T	Commelina benghalensis	0.63	31	100	33	.
Cmes	Helinus integrifolius	5.40	19	83	.	.
H	Sporobolus fimbriatus	1.14	27	50	67	.
Pmic	Grewia flava	6.33	23	100	.	.
T	Ipomoea coptica	0.53	15	50	17	.
Pnan	Indigofera trita	1.00	35	67	67	7
Pmic	Acacia fleckii	2.69	50	100	83	14
T	Ipomoea sinensis	0.67	23	100	.	.
n.a.	Melanthera scandens	1.00	8	33	.	.
Cmes	Ehretia rigida	0.50	8	33	.	.
T	Ipomoea hackeliana	0.50	8	33	.	.
Pmic	Acacia mellifera ssp. detinens	3.00	8	33	.	.
Unit 2: Acacia fleckii-Brachiaria nigropedata community						
Cmes	Hermannia tomentosa	2.79	27	33	83	.
G	Harpagophytum zeyheri	1.10	19	.	50	14
H	Brachiaria nigropedata	1.90	19	.	67	7
Pmes	Lonchocarpus nelsii	2.06	62	67	100	43
Pmic	Ozoroa schinzii	1.55	38	33	100	14
T	Cleome rubella	0.63	46	67	100	14
Pnan	Commiphora africana	2.10	38	67	100	.
T	Tephrosia purpurea	1.03	58	83	100	29
Pmes	Baphia massaiensis ssp. obovata	7.25	38	67	100	.
n.a.	Pennisetum glaucum	2.00	8	.	33	.
T	Polygala albida	0.50	8	.	33	.
Cmes	Hoffmannseggia burchellii	0.50	8	.	33	.
Cmes	Indigofera daleoides	0.50	8	.	33	.
n.a.	Sebaea grandis	0.10	8	.	33	.
Unit 3: Pterocarpus angolensis-Guibourtia coleosperma community						
Pnan	Lannea gossweileri ssp. gossweileri	2.10	58	.	17	100
n.a.	Hermannia eenii	5.32	54	.	.	100
Pmac	Guibourtia coleosperma	4.15	50	17	17	79
H	Eragrostis pallens	8.10	58	.	17	100
T	Aristida stipitata	10.79	54	.	33	86
Pmic	Ochna pulchra	4.04	54	17	.	93
H	Evolvulus alsinoides	0.40	46	.	17	79
Pmes	Pterocarpus angolensis	5.21	54	.	50	79
Pmes	Burkea africana	14.82	65	.	50	100
Pmic	Combretum psidioides	4.39	54	.	.	100
T	Perotis patens	0.50	31	.	.	57
G	Diospyros chamaethamnus	0.69	31	.	.	57
Pmes	Dialium engleranum	0.75	38	33	.	57
T	Acrotome angustifolia	0.64	54	.	33	86
Pmic	Diplorhynchus condylocarpon	1.06	62	33	50	79
H	Phyllanthus pentandrus	0.61	54	.	.	100
Pnan	Grewia avellana	1.90	19	.	.	36
H	Bidens biternata	0.70	19	.	.	36

continued on next page

Unit 2, situation 2003.
Photo: B. Strohbach.

Unit 2, cleared and planted, second season, 2006. Photo: B. Strohbach.

Unit 3, 2003. Photo: B. Strohbach.

ness of weeding, many herbaceous plants occurring in this community grow more vigorously. Geophytes such as *Harpagophytum zeyheri* (Sand Devil's Claw) are especially favoured. Many of the felled tree species continue to coppice (e.g. *Acacia fleckii,* Sandveld Acacia), whilst the large Camelthorn trees *(Acacia erioloba)* remain unscathed. However, it is assumed that after a number of cropping cycles the coppices will also be removed, thus reducing the species diversity. The generally lower cover on these fields also results in a lower Simpson's index (i.e. higher diversity) for the Observatory compared to Mile 46 (0.8957 compared to 0.9208).

The *Pterocarpus angolensis-Guibourtia coleosperma* community (unit 3) forms the well-known landscape-dominating Kavango woodlands. Together with *P. angolensis* and *G. coleosperma,* the tree species *Baikiaea plurijuga, Burkea africana* and *Schinziophyton rautanenii,* and the shrub/small tree species *Diplorynchos condylocarpon, Ochna pulchra, Strychnos pungens,* and *Strychnos cocculoides* commonly occur within this community. The geoxylic suffrutices ("underground trees", or plants which are branched underneath the soil surface sensu White 1976) *Diospyros chamaethmanus, Lannea gossweilerii,* and *Gardenia brachythamnus* as well as the dwarf shrub *Fadogia* cf. *thamnus* are also conspicuous in this community. These species are well-adapted to fire due to their geophytic nature. The annual grass species *Melinis repens* subsp. *grandiflora* (Red-top) and *Aristida stipitata* (Bristle Grass) dominate the grass sward, although the perennial grasses *Digitaria seriata, Schmidtia pappophoroides, Brachiaria nigropedta,* and *Panicum kalahariense* are conspicuous. The psamophoric (sand-loving) tree/shrub species *Terminalia sericea, Combretum collinum, C. psidioides,* and *C. engleri* form small trees rather than shrubs as a result of the high-intensity fires at Mutompo. Their density is also generally lower than at the neighbouring Mile 46 Observatory.

Classification table (continued)

Column			All	1	2	3
Number of relevés		**Cover**	**28**	**8**	**10**	**10**
Most frequent companions						
T	Vernonia poskeana ssp. botswanica	0.71	92	100	67	100
Pnan	Bauhinia petersiana	9.20	88	100	100	79
Pmes	Terminalia sericea	8.45	85	50	83	100
H	Schmidtia pappophoroides	8.23	85	83	67	93
T	Oxygonum alatum	0.52	85	33	100	100
H	Digitaria seriata	3.61	73	67	67	79
H	Limeum fenestratum	0.50	73	33	67	93
H	Urochloa brachyura	4.47	69	100	100	43
G	Acanthosicyos naudinianus	2.94	69	17	83	86
H	Stipagrostis uniplumis	4.94	65	33	67	79
Pmic	Combretum collinum	3.53	62	17	67	79
T	Pogonarthria fleckii	0.88	62	100	100	29
H	Commelina africana	0.53	62	67	33	71
T	Lophiocarpus tenuissimus	0.48	62	33	50	79
T	Melinis repens ssp. grandiflora	3.54	54	33	33	71
Pnan	Asparagus nelsii	1.46	54	100	100	14
n.a.	Hibiscus marlothianus	0.54	54	33	67	57
Pnan	Clerodendrum ternatum	1.12	50	83	67	29
T	Chamaecrista biensis	1.08	50	33	17	71
T	Gisekia africana	0.48	50	50	67	43
Pmic	Combretum zeyheri	2.75	46	.	50	64
Pmes	Rhus tenuinervis	1.63	46	83	83	14
Cmic	Limeum myosotis	0.50	46	17	67	50
H	Cyperus amabilis	0.49	46	33	83	36
H	Eragrostis lehmanniana	3.82	42	67	33	36
Pmic	Grewia flavescens	2.95	42	83	67	14
Cmes	Indigofera pechuelii	0.82	42	.	33	64
H	Indigofera flavicans	0.73	42	17	50	50
n.a.	Kyllinga alata	0.32	42	.	67	50
Pmes	Dichrostachys cinerea	5.90	38	83	67	7
T	Crotalaria sphaerocarpa	0.85	38	83	67	7
G	Raphionacme velutina	0.75	38	17	17	57
H	Aristida meridionalis	0.70	38	.	33	57
H	Bulbostylis hispidula	0.65	38	50	67	21
n.a.	Spermacoce senensis	0.50	38	67	17	36
Pnan	Commiphora angolensis	1.11	35	50	50	21
Pmes	Acacia erioloba	4.19	31	67	67	.
T	Melinis repens ssp. repens	3.81	31	17	17	43
T	Tricholaena monachne	2.44	31	.	17	50
T	Jacquemontia tamnifolia	0.63	31	50	67	7
Pnan	Ximenia americana	1.79	27	67	50	.
H	Rhynchosia venulosa	0.71	27	50	33	14
T	Sesamum triphyllum	0.44	27	50	50	7
Pmes	Peltophorum africanum	2.75	23	50	33	7
H	Tristachya superba	1.58	23	.	33	29
T	Stylosanthes fruticosa	0.62	23	17	.	36
n.a.	Kohautia aspera	0.43	23	50	50	.
G	Gloriosa superba	0.43	23	.	50	21
H	Tephrosia lupinifolia	0.37	23	.	17	36
H	Aristida pilgeri	1.20	19	17	50	7
Pmes	Ziziphus mucronata	1.10	19	50	33	.
Pnan	Hemizygia bracteosa	0.60	19	33	17	14
H	Indigofera filipes	0.42	19	17	.	29
Cmes	Helichrysum candolleanum	4.15	15	17	50	.
Pmic	Acacia ataxacantha	2.13	15	33	33	.
Pmic	Strychnos pungens	1.00	15	.	.	29
H	Panicum kalaharense	0.75	15	.	17	21
T	Pavonia clathrata	0.63	15	17	50	.

Responsible authors: B.J. Strohbach & J. Luther-Mosebach

Millipedes

Sampling period(s)	Species richness
2003/III	1

Spirostreptus heros was also collected at this Observatory which is the twin of Mile 46 Observatory. Probably this fairly large species has got a large activity radius and is not restricted to specific microhabitats.

List of species

Species	Family	Relative frequency	Feeding group
Spirostreptus heros	Spirostreptidae	Frequent	Litter, fresh plant material

Responsible author: K. Vohland

Termites

Taxon richness	Abundance index	Dominant (sub-) family
11	22	Rhinotermitidae

Eleven taxa occur at this Observatory, making it the most diverse of all investigated Observatories. *Amitermes* sp. and *Schedorhinotermes lamanianus* occur here, but were not detected at the twin Observatory S01 (Mile 46).

List of taxa

Taxon	(Sub-)family	Frequency Index	Feeding substrate
Psammotermes allocerus	Rhinotermitidae	0.55	w, d
Fulleritermes	Termitidae (Nasutitermitinae)	0.45	s, w, g, l, m
Allodontermes	Termitidae (Macrotermitinae)	0.18	f (g, l, w)
Amitermes	Termitidae (Termitinae)	0.18	s, w, g
Hodotermes mossambicus	Hodotermitidae	0.18	g
Trinervitermes	Termitidae (Nasutitermitinae)	0.18	s, w, g, l, m
Microcerotermes	Termitidae (Termitinae)	0.09	s, w, g
Odontotermes sp. 2	Termitidae (Macrotermitinae)	0.09	f (g, l, w)
Promirotermes	Termitidae (Termitinae)	0.09	s, w, g
Microtermes	Termitidae (Macrotermitinae)	r	f (g, l, w)
Schedorhinotermes lamanianus	Rhinotermitidae	r	w, d

Responsible authors: C. Grohmann & K.E. Linsenmair

True bugs

Sampling period(s)	Methods	Family richness
2001/IV; 2002/III, IV; 2003/III; 2007/II	Trapping (light, pitfall traps, Malaise); beating of plants; hand collecting; net sweeping	26
Species richness	**Individuals sampled**	**Fisher's alpha diversity**
145	831	50.80

The Heteroptera fauna of the Observatory Mutompo (S02) is diverse and represented by species from 26 families, which is more than in any other Observatory. Miridae, Reduviidae, and Pentatomidae contain 57% of all collected species. More than half of the species were recorded only as single specimens. *Tupalus fasciatus* (Alydidae), *Cymus* sp. (Cymidae), *Limnogonus hypoleucus* (Gerridae), two *Bolbocoris* spp. (Pentatomidae), *Caura rufiventris* (Pentatomidae), *Cosmolestes pictus* (Reduviidae), and a few other Reduviidae were only recorded at this Observatory. Water bugs and water striders (Nepomorpha and Gerromorpha) were dominant at light sources. These species are active flyers and came from temporary wetland habitats north of the Observatory.

Mutompo shares at least 18 species with S05 (Otjiamongombe) and S04 (Toggekry). The congruence with these Observatories is higher than with any of the other studied Observatories.

Species richness of families

Family	*S*
Miridae	46
Pentatomidae	20
Reduviidae	16
Coreidae	7
Alydidae	6
Rhyparochromidae	6
Gerridae et al.	5
Cydnidae	4
Lygaeidae	4
Notonectidae	4
Scutelleridae	4
Tingidae	3
Berytidae	2
Corixidae	2
Mesoveliidae	2
Micronectidae	2
Pachygronthidae	2
Pleidae	2
Rhopalidae	2
Anthocoridae	1
Blissidae	1
Cymidae	1
Geocoridae	1
Nabidae	1
Saldidae	1
Total	**145**

Species abundances

Light traps

Species	Family	*N*	%
Micronecta spec.	Micronectidae	171	32
Gerromorpha spec.	Gerromorpha	68	13
Aethus lautipennis	Cydnidae	35	7
Paromius apicatus	Rhyparochromidae	30	6
Piezodorus purus	Pentatomidae	27	5
Others (68)		196	37

Pitfall traps

Species	Family	*N*	%
Euthetus leucostictus	Alydidae	2	20
Blissidae spec.	Blissidae	1	10
Brotheolus pugnax	Coreidae	1	10
Cydnidae spec.	Cydnidae	1	10
Rhaphidosomatini spec.	Reduviidae	1	10
Isometopinae spec.	Miridae	1	10
Miridae spec.	Miridae	1	10
Orius spec.	Anthocoridae	1	10
Eupododus spec.	Pentatomidae	1	10
Total		**10**	**100**

Responsible author: J. Deckert

Vertebrates

Total species richness	Reptile species richness	Bird species richness
32	n.a.	32
Large mammal species richness	**Small mammal species richness**	
n.a.	n.a.	

Birds

Passeriformes	**Perching birds**
Cercotrichas paena	Kalahari Scrub-Robin
Nectarinia talatala	White-bellied Sunbird
Prinia subflava	Tawny-flanked Prinia
Pytilia melba	Green-winged Pytilia
Batis molitor	Chinspot Batis
Dicrurus adsimilis	Fork-tailed Drongo
Eurocephalus anguitimens	White-crowned Shrike
Parisoma subcaeruleum	Chestnut-vented Tit-Babbler
Parus carpi	Carp's Black Tit
Pycnonotus barbatus	Common Bulbul
Serinus mozambicus	Yellow-fronted Canary
Sylvietta rufescens	Long-billed Crombec
Tchagra australis	Brown-crowned Tchagra
Uraeginthus granatinus	Violet-eared Waxbill
Cisticola chiniana	Rattling Cisticola
Emberiza flaviventris	African golden-breasted Bunting
Laniarius atrococcineus	Crimson-breasted Gonolek
Mirafra africanoides	Fawn-coloured Lark
Anthoscopus minutus	Cape Penduline-Tit
Sporopipes squamifrons	Scaly-fronted Weaver
Accipitriformes	**Birds of prey**
Circaetus cinereus	Brown Snake Eagle
Melierax metabates	Dark Chanting Goshawk
Piciformes	**Woodpeckers and relatives**
Dendropicos fuscescens	Cardinal Woodpecker
Strigiformes	**Owls**
Otus leucotis	White-faced Scops-owl
Piciformes	**Woodpeckers and relatives**
Dendropicos namaquus	Bearded Woodpecker
Tricholaema leucomelas	Acacia Pied Barbet
Coraciiformes	**Kingfishers and relatives**
Tockus nasutus	African Grey Hornbill
Halcyon chelicuti	Striped Kingfisher
Coracias caudata	Lilac-breasted Roller
Rhinopomastus cyanomelas	Common Scimitarbill
Upupa epops africana	African Hoopoe
Columbiformes	**Doves and pigeons**
Streptopelia capicola	Ring-necked Dove

Lilac-breasted Roller (*Coracias caudata*).
Photo: J. Deckert

Responsible authors:
J. Deckert, A. Hoffmann & A. Mills

The people

Study period	Size of study area	Population in study area
2004–2008	ca. 90 km²	737 people
Number of households	**Mean household size**	**Population growth**
107	6.1 people	1.5% (2006)
Total fertility rate	**Cohort fertility**	
6.5 children per woman	1920–1967: 6.1; 1968–1990: 6.0 children per woman	
Life expectancy	**Sex ratio (m/f)**	
41.7 years (2001)	0.85	

Fig. 02.1: Study area. Blue squares: Observatories Mile 46 & Mutompo. Green dots: Households. Red lines A,B,C,D define the survey area.

Socio-economic context of the Observatory pair Mile 46/Mutompo

The villages surrounding the Mile 46 and Mutompo Observatories (namely Mutompo, Epingiro, Makena, and Cove) have between 100 and 300 inhabitants and use the savanna areas adjacent to the Observatories for extensive small scale and rain-fed agriculture, as well as for grazing and as a reservoir of natural resources. Villages are still without electricity and sanitation, and the inhabitants depend mainly on agriculture for their livelihoods. People live in clay huts and reach their fields on foot. Transport to other settlements is predominantly by walking and ox-drawn carts. The tar road connecting the rural villages with the capital of Rundu has been a lifeline for many years. Nowadays, with the increase of motorized transportation and the post-war revitalization of tourism, villages along the road to Rundu have opened small shops and developed their own economic infrastructure. The entire area belonging to the villages surrounding the Observatories is communal land.

Demography and census

Sustainable use of natural resources can be strongly influenced by changes in

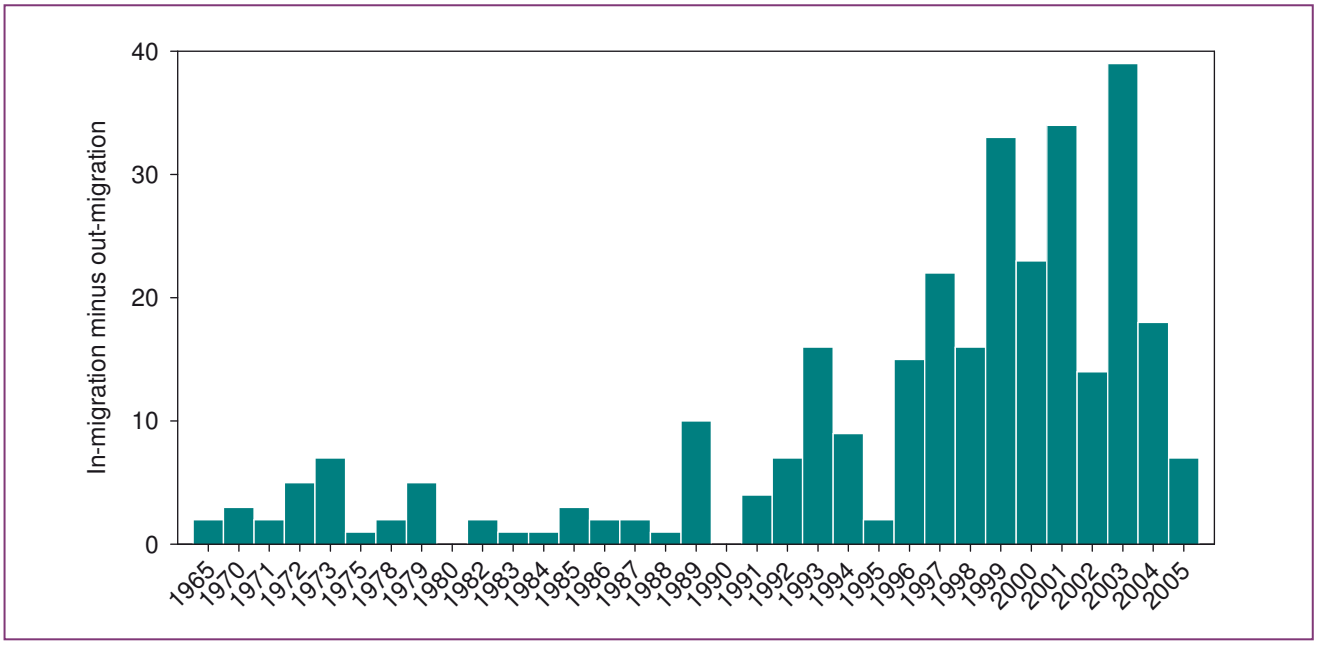


Fig. 02.2: Migration into the Mutompo/Epingiro research area (after Pröpper 2009).

population size, particularly population growth. For examining demographic effects of this type, knowledge about the determinants of the population size (i.e. fertility, mortality, and migration) is required to examine these types of demographic effects. Research focused on the question of whether the populations have experienced demographic changes, which have an influence on natural resource use. To analyse population dynamics around the Mile 46 and Mutompo Observatories (see blue squares in Fig. 02.1), a census sample of five villages surrounding the Observatories was taken. One hundred and seven households occur within the survey area, which was delimited by roads and sand paths (red lines) as boundaries. Natural resource use intensity and demographic data such as fertility, mortality, and migration were assessed for this 90-km² area using a standardized ethnographic census questionnaire.

The fertility rate in the survey area is 6.5 children per woman. The estimated annual population growth is 1.5% even though the immigration rate is declining, and increasing pressure on natural resources can thus be expected. A comparative cohort fertility analysis (1920–1967 versus 1986–1990) shows that fertility has not been declining in the area. Official figures show that mortality rates in the Kavango area are high and the life-expectancy has dropped significantly during the last decades (cf. Pröpper 2009). Mortality rates in the research area are below the average figures for the whole region. However, the empirical assessment of the specific causes of mortality remains a challenge as HIV-AIDS mortality is a taboo subject and people often do not remember important mortality-relevant data such as age, birthdays, number of children, and years/days since a death.

The analysis of net migration in the survey area showed clear parallels with landuse patterns. Immigration, which was driven by intensification of landuse along the Kavango River, started around 1970 and had a strong effect on local

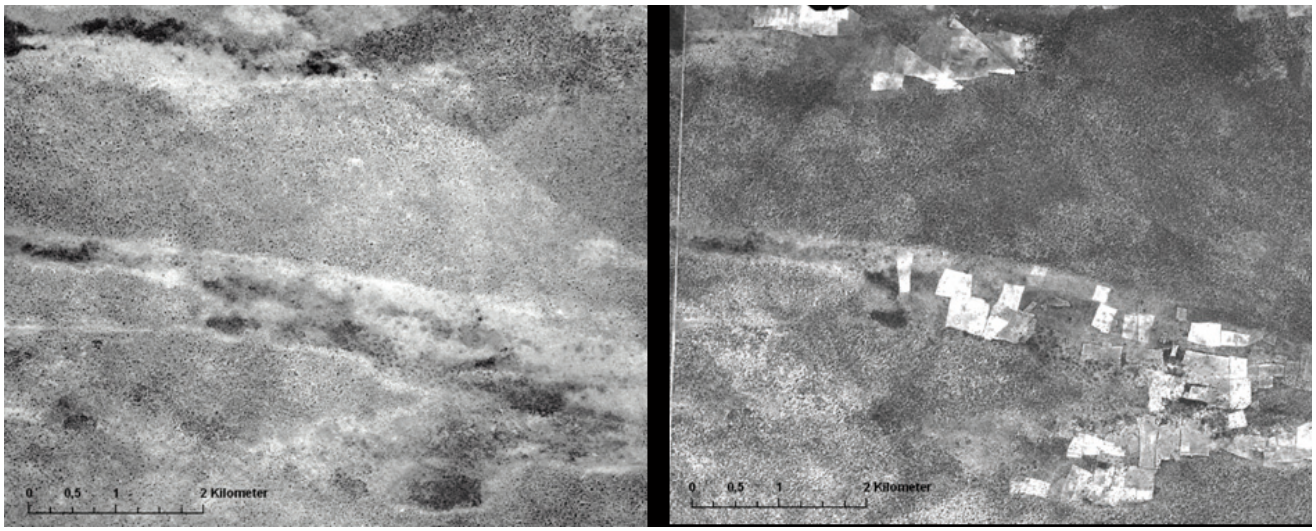


Fig. 02.3: Aerial photos of the research area in 1971 and 1996.

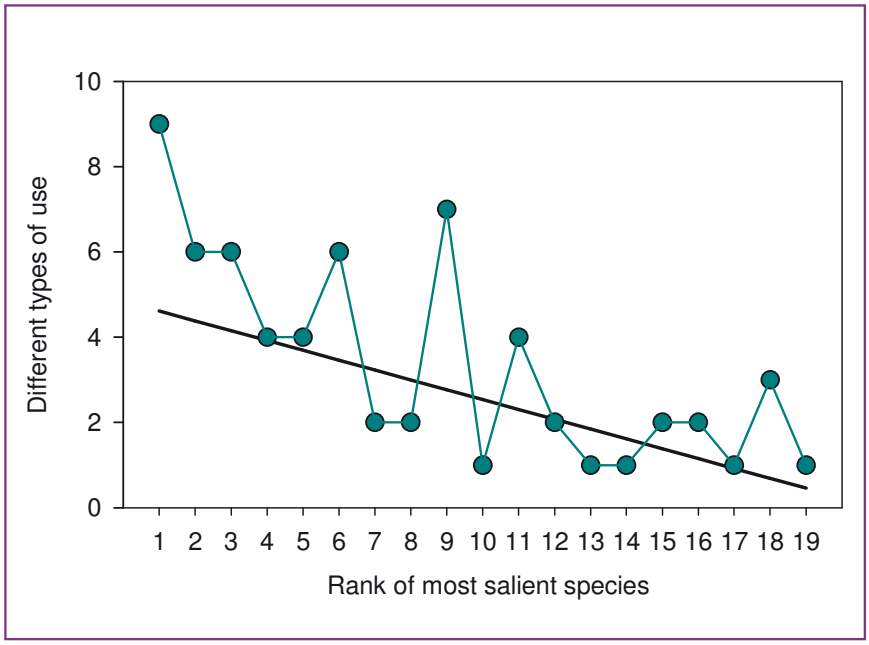


Fig. 02.4: Correlation between uses and rank of salience (measure of how well known an item is) for Kavango tree species (r = 0.757) (after Pröpper 2009).

resources. Net migration data shows that most migration took place after Namibian independence and peaked in 2003. After the Angolan war ended, immigration decreased rapidly.

The population in the research area has grown from 0 to 786 between 1970 and 2005 (data for the five villages surrounding the BIOTA Observatories Mile 46 and Mutompo). The impact of population growth is visible when comparing aerial photos from 1971, at the beginning of migration, and the situation in 1996 (compare Fig. 02.3). More recent pictures (see Chapter IV.1) support the finding that population growth has caused a substantial increase of cleared land.

The socio-cultural, economic, and institutional background

Against a background of poverty, family cooperation within rural-urban support networks seems to play an important role in the Kavango Region. Kinship, social networks, as well as cultural rules of social interaction, strongly influence the people's environmental decisions. People are first and foremost members of family households which are self-reliant economic units, although female-headed households are economically more vulnerable. These households can be described as nodes in larger trans-local (rural-urban, rural-riverside) kinship networks which cooperate by, for example, exchanging goods and taking care of children's school education. Households and household members within the villages have a long history of social interaction. Interaction between households involves mainly short-term balanced reciprocity and small scale giving. Deeper exchange relations are preferentially established with kin, followed by friends and function holders. These kinship-based networks are the nuclei of collective action and the main social capital of people. A closer look at social structures has shown that 'communities' and approaches of Community Based Natural Resource Management cannot succeed without detailed knowledge of the traditional rules and rights of social interaction that form people's scripts for action.

The traditional matrilineal kinship system is widely intact, although some transformation can be observed. The inhabitants of the rural villages still make use of clan and lineage identities and relevant rules of behaviour such as lineage economy. They also use classificatory kinship terminology which functions as a cultural script for the relevant rules for different groups of relatives (matrilineal, patrilineal, and affinal). Besides this, migration and settlement patterns seem to develop strongly along relationship lines.

Against a background of economic vulnerability and scarcity, households struggle with various domestic problems such as limited access to markets and financial capital, frequent alcoholism, unequal gendered labour division, domestic violence, and divorce. Additionally, teenage pregnancies and children from multiple fathers increase the vulnerability of young women. HIV and AIDS are also threats.

Landusers operate within a complex political-institutional framework. The land in Kavango is owned by the state and there tends to be a lack of clarity with regard to landuser rights and ownership. Due to this lack of clarity, resource users tend to adopt the traditional authority system and customary law for matters of natural-resource regulations. The traditional legal system is a three level authority headed by the Hompa, a traditional king and the leading legislative, judicative, and executive organ. Traditional authorities play a central role in resource protection and the dissemination of information and awareness.

Local cultural environmental knowledge

Cultural biodiversity knowledge is locally bounded, orally transmitted, dynamic and socially shared. It is one of the key components that guides landuser decisions and influences the local use of and the impacts on natural resources. An assessment of cultural domains and their contents was done in the Kavango Region using domain analysis and freelists.

A sample of 51 people produced an overall total of 178 named plant species. Species richness according to scientific observations is in fact far higher, with Strohbach & Strohbach (2004) observing 335 plant species around the Mutompo Observatory and estimating about 380 species for the area. Apparently certain additional plants are known (e.g. by specialists like healers) but were not captured by the freelist methodology. During ongoing research, another 25 species were named that were not included in the freelist data, raising the number of known

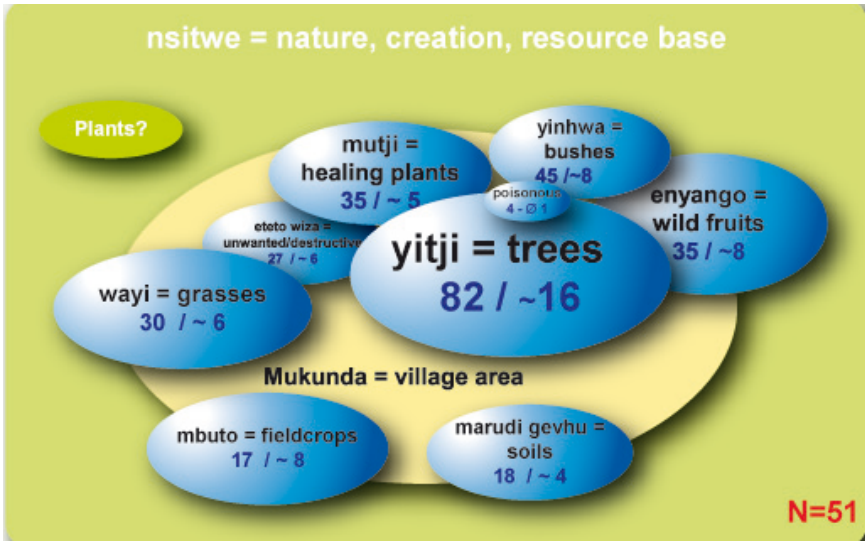


Fig. 02.5 Size and relationships of botanical domains (in blue; first number = all items/all informants, second number = average informant's share of knowledge) (Pröpper 2009).

plant species identified by the landusers to 203 so far.

No local term for 'plants' was found. Results (depicted in Fig. 02.5 above) show that local knowledge cognitive domains (e.g. "trees", "grasses", "wild fruits", etc.) do not differ substantially from western cognitive domains. Domain size (first number in figure = all items/all informants) and the average informant's share of knowledge (second number in figure) clearly differ. Trees and crops are well known but there is a danger of losing knowledge regarding medicinal plants. Freelist data from single domains were used to calculate the importance of items (i.e. measure of how well known an item is). Ethnographic data on tree uses and importance correlate clearly (r = 0.757, cf. Fig. 02.4). A known species is most often used, but not always. Our case studies reveal that there is a primary link between cultural biodiversity knowledge and utilitarian aspects.

Responsible authors: M. Pröpper & T. Falk

Landuse

Study period	Size of Observatory farm	Recommended stocking rate
2004–2008	ca. 90 km²	1.5 ha·SSU^{-1} (50 kg·ha^{-1})
Actual stocking rate	**Number of animals**	
5 ha·SSU^{-1} (15 kg·ha^{-1})	Total: 437 (57,828 kg); cattle: 197; goats: 226; sheep: 12; donkeys: 2 (2001)	

Crop production

Mixed production systems exist in the Kavango Woodland Savanna. Cultivation, cattle-breeding, and the extraction of natural resources are the most valued cultural practices with a long tradition. Farmers' livelihoods are mainly supported by practising small-scale, subsistence based, rainfed cultivation. In addition, natural resources are collected for food and physical capital (e.g. house construction, material culture). Among such extracted resources are thatching grasses, wild fruits, medicinal plants, and timber.

Due to climatic factors, the average annual growing period is only 90 to 120 days. As a result the fast-maturing crops, such as most varieties of millet, are cultivated. However, most farmers practise mixed cropping. Apart from millet (Rukwangali: Mahangu), farmers also grow sorghum, maize, beans, groundnuts, pumpkins, melons and vegetables, such as spinach, to a lesser extent (see Table 02.1: Frequency of crops). The production system is largely subsistence oriented, with high human but little physical capital input. Millet and maize are mainly used for food, while sorghum is often used to produce beer. In drought years, or when the rainy season starts late or is very short, the income yielded from harvests is not sufficient to carry over to the next harvest. Livestock and alternative sources of income are important during such periods of stress.

However, external sources of financial capital in the form of pensions, remittances, and wage-labour are generally fairly limited. Labour and cash markets and a system of efficient product distribution are largely informal or absent, although highly desired by the local population. Due to the unreliable rainfall and low soil fertility, people rely on very limited capital input and intensive, gender-biased labour input. Precise calculations of agricultural productivity are an empirical challenge but the estimated average yield of 95 kg mixed crops per ha indicates that productivity is extremely low. Comparative analyses indicate that low productivity is a problem in the whole of northern Namibia (Matanyaire 1997: 587; Mendelsohn & el Obeid 2003: 92ff; Tapscott 1994: 4). Declining yields are countered by the expansion of fields, which leads to deforestation and biodiversity loss.

Table 02.1: Frequency of crops planted by independent field owners in the census sample; *N* = 145 (Pröpper 2009).

			Users	%
Local name (Rukwangali)	**Common name (English)**	**Scientific name**		
Mahangu	Pearl Millet	Pennisetum glaucum	143	99
Epungu	Maize	Zea mays	138	95
Makunde	Cowpea	Vigna unguiculata	113	78
Nongomene	Bambara nut	Vigna subterranea	80	55
Ilyia	Sorghum	Sorghum bicolor	56	39
Nondongo	Peanuts	Arachis hypogaea	39	27
Katjama	Melon	Citrullus lanatus	36	25
Etanga	Pumpkin	Cucumis africanus	32	22
Nomusipo	Sugarcane	Saccharum officinarum	20	14
Tombo	Sorghum	Sorghum bicolor	14	10
Mutete	Wild spinach	Hibiscus sabdariffa	6	4
Rupotera	Pumpkin	Cucumis metuliferous	6	4
Maliangwa	Pumpkin	Cucurbita pepo	2	1
Total field owners			**145**	**100%**

Table 02.2: Comparison of sources regarding crop productivity (Pröpper 2009).

	Researcher and study period	
	Pröpper (2003–2005)	Mendelsohn & el Obeid (2003)
Plot size		
Average field size (ha)	9.82	4.50
Labour inputs		
Average HH labourers	3.48	
Average labour input per HH all crop production (man days)	256.56	
Average labour input per HH all crop production (HH work days)	73.72	130.00
Man days per ha all crop production	26.13	
Yield		
Net yields yearly all millet varieties (kg), mixed cropping	630.83	450.00
Net yields yearly maize (kg), mixed cropping	102.29	
Total yearly net yield two main crops (kg)	733.12	
Estimated total net yield all crops	933.00	
Labour productivity		
Labour productivity millet mixed cropping (kg/manday)	2.46	
Labour productivity millet mixed cropping (kg/HH workday)	8.56	3.46
Labour productivity all crops mixed cropping (kg/manday)	3.64	
Labour productivity all crops mixed cropping (kg/HH workday)	12.66	
Capital productivity		
Land-productivity millet mixed cropping (kg/ha)	64.24	100.00
Land-productivity all crops mixed cropping (kg/ha)	95.01	

Pastoralism and livestock production

There is a clear social stratification in terms of livestock possession that influences domestic consumption patterns (Table 02.3). Livestock keeping is the second-most dominant strategy to support household livelihoods. Kavango Sanga-type cattle and local goat-breeds are the main types of livestock kept. Cattle are mainly used for ploughing, capital accumulation, and insurance purposes, and are not primarily used for meat production. Only about 50% of households own cattle (see Table 02.3). Pastoralism strongly depends on access to water during most times of the year. Temporary natural ponds and waterbodies only offer sufficient water for livestock over a few months of the year during the rainy season. Grazing resources are sufficient in quantity, but the forage quality of the natural vegetation declines after the rainy season which can cause a shortage in protein supply (Schneiderat 2008; unpublished). During these times, leaves from bushes and trees are an important supplement, not only for browsers such as goats, but also for typical grazers like cattle.

Table 02.3: Households livestock ownership during the census; *N* = 120 (Pröpper 2009).

	Total	No. of households	%
Cattle	580	62	52%
Chicken	906	108	90%
Donkeys	5	2	2%
Goats	546	49	41%
Horses	1	1	1%
Pigs	20	5	4%

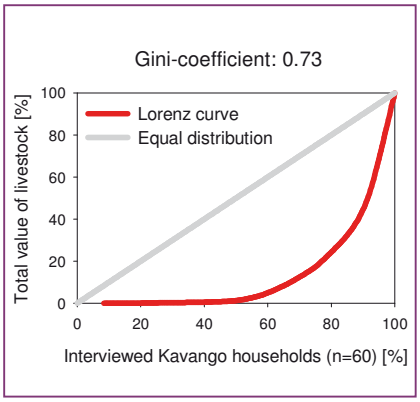


Fig. 02.6: Distribution of the total value of livestock amongst households (after Falk et al. 2009).

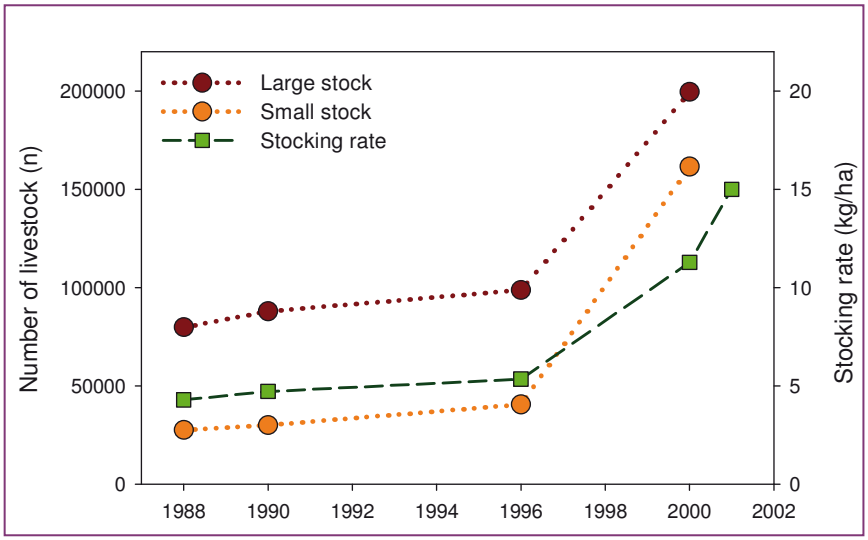


Fig. 02.7: Livestock number and stocking densities trends in the Kavango Region (1988–2000). Sources: DVS – Directorate of Veterinary Services, Adams et al. (1990), Yaron et al. (1992), Hengua Bovell (1997), DVS 2000, personal communication.

Manual timber logging in the Kavango Region. Photo: M. Pröpper.

Responsible authors: M. Pröpper & T. Falk

The institutional framework guiding natural resource management of Mutompo communal farmers (S02.01)

[T. Falk]

Sustainable biodiversity management requires effective institutional incentives. Document analyses, expert interviews, and empirical surveys were applied to describe the multiple rules and norms guiding the management of communal farmers around the Observatory S02 (Mutompo).

Key results show that multifaceted supportive but also conflicting interactions between the statutory and customary legal systems exist. Access to communal resources is efficiently regulated. However, institutions coordinating the management within a settlements' territory are weak. The currently implemented Rural Water Supply Reform increases incentives for sustainable water management. The harvest of timber resources is inefficiently regulated, monitored, and enforced both by statutory and traditional authorities. A reform of land rights is too inflexible to accommodate for customary practices and is therefore largely rejected by the farmer community. The resulting decrease in tenure security is problematic considering the increasing commercial pressure on the Kavango land market.

Diverse rules and norms of resource use exist in the research area. In order to increase their efficiency in the interest of biodiversity maintenance and economic development a stronger integration of sectoral policies and a more polycentric governance approach is recommended.

► *See also* **Chapter IV.1**

Falk, T. (2008): Communal farmers' natural resource use and biodiversity preservation. A new institutional economic analysis from case studies in Namibia and South Africa. – Göttingen: Cuvillier.

Falk, T., Bock, B., Kirk, M. (2009): Polycentrism and poverty: experiences of rural water supply reform in Namibia. – Water Alternatives **2**: 115–137.

Modelling of decision making and bio-economic dynamics in communal lands (S02.02)

[J. Hecht]

Farming activities are one of several driving forces that lead to continuous deterioration processes of tree and bush savannas in the Kavango Region. However, these farming activities are closely connected with securing subsistence needs of peasant farmers. Though the number of undernourished people declined in Namibia, a considerable portion of the population is still affected by malnutrition today. In this context the present study aims to assess long-term effects of farm household strategies on deterioration processes and food security by identifying (i) objectives of peasant farmers, (ii) their most prevailing on-farm and off-farm activities (iii) optimal farming strategies, and (iv) policy-induced changes.

These objectives are addressed by developing a multi-annual programming optimisation model of a typical village (Observatory S02/Mutompo) that includes relevant bio-physical features. Different data collection exercises served as data sources for different model parameters. Generally, results of the modelling approach indicate that (i) optimal farming strategies include a high diversity of activities, (ii) farm households are highly attracted by activities with a low labour demand. Obviously, family labour is one of the most prominent limiting factors. Since this factor might be threatened by several socioeconomic developments in the future, it seems to be of high relevance to promote labour-saving devices.

► *See also* **Chapter IV.1.**

Hecht, J. (subm.): Decision making of rural farm households in Namibia: lessons learned from multi-annual programming optimisation models. – PhD thesis. Gießen: Institute for Agricultural Policy and Market Research, Justus-Liebig University.

Vegetation of the Alex Muranda LDC and adjacent areas as example of the central Kavango woodlands

► *See* **S01.01**

Soil fertility and land use in the Kavango Region

► *See* **S01.02**

Further studies

Wisch, U., Petersen, A., Gröngröft, A., Eschenbach, A. (2010): Dryland farming in the Kavango region: Effect of land use on soil properties. – Zentralblatt für Geologie und Paläontologie, Teil I **2008**: 189–211.

General data

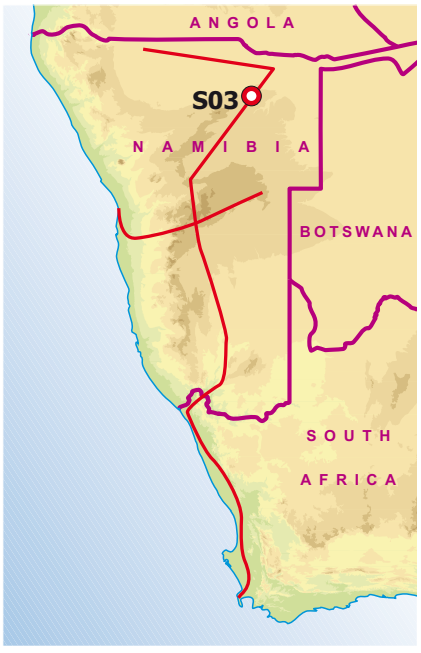
Number	Name	Alternative name(s)
S03	Sonop	n.a.
Implementation	**Country**	**Province/ region**
2001	Namibia	Otjozondjupa
District/ constituency	**Locality**	**Farm name**
Grootfontein	near Maroelaboom	Sonop 903
Latitude	**Longitude**	**Altitude**
19.073818 S	18.903897 E	1236 m a.s.l.
Rainfall season	**Biome**	**WWF Ecoregion**
Summer	Woodland Savanna	AT0709 Kalahari Acacia-Baikiaea woodlands
Agro-Ecological Zone	**Relative intensity of land use**	**Tenure**
KAL8	Medium	State
Type and history of landuse	**Land owner**	
Experimental farming with cattle, game	MAWF	

Sonop (S03)

Dense bushland vegetation on the dune at Sonop Observatory. Photo: G. Miehlich.

The BIOTA Observatory Sonop (S03) is situated on the Agricultural Research station Sonop, ca. 120 km north-east of Grootfontein in the Otjozondjupa Region of Namibia. It falls within the extensive dune fields of the Northern Kalahari (Thomas 1984), which was deposited ca 18,000–13,000 years ago (Heine 1982). These dunes have since been fixed with a relatively dense bushland, ca 4–12 m high, dominated by broad-leaved plant species. The dunes stand roughly 20–30 m tall above the inter-dunal valleys. These valleys have a slightly heavier soil, with higher loam and clay content, and occasionally are relatively shallow with calcretes in the subsoil. Here the vegetation is generally a more open bushland, dominated by a variety of Acacia species. The vegetation on the station is a typical example of the dry Woodland Savanna of the Northern Kalahari sensu Giess (1998). The average altitude is about 1236 m a.s.l. There is a typical summer rainfall climate, with an average annual rainfall of 497 mm.

The Sonop Research Station is owned by the Ministry of Agriculture, Water and Forestry and is used for livestock breeding programmes. A herd of Nguni and Sanga cattle produce breeding stock for commercial and small-scale farmers. In the past, trials were also conducted with game management on commercial farms. As a relic of these trials, a large number of eland and giraffe still forage on this farm, along with kudu and warthog, which are widespread.



This BIOTA Observatory was established to monitor potential variations of climate change impacts within the dry Woodland Savanna, especially regarding the predicted mobilisation of Kalahari dune systems due to global climate change (Thomas et al. 2005). In addition to this, experimentally cleared sites adjacent to the Observatory are used to monitor recovery of the vegetation, as well as soil water infiltration and extraction rates. For this purpose, one dune and one inter-dune valley site have been cleared of approximately 50% of all trees and shrubs, whilst a second set of sites has been cleared of all trees and shrubs, as well as all grasses surrounding the soil moisture station.

Responsible authors: B.J. Strohbach & D.H. Haarmeyer

Remote sensing and landscape

Geomorphology	Geological units	Lithological units
Dunes and interdunes of Kalahari dune veld	Kalahari Sands	Sands and Calcrete
Mean EVI	**EVI absolute range**	**Mean leaf area index**
0.226 (0.149–0.352)	0.134 (2001)–0.420 (2006)	0.71

Grid map of Observatory

	0	1	2	3	4	5	6	7	8	9
0	9	61	84	77	47	100	64	86	44	88
1	98	14	31	96	92	1	69	94	21	35
2	56	6	52	99	40	20	97	81	27	95
3	60	8	71	34	80	93	75	28	90	73
4	79	55	2	39	24	91	89	66	87	19
5	85	16	3	62	42	50	13	54	45	83
6	67	59	26	49	29	36	68	74	23	10
7	76	4	5	18	38	72	78	12	53	46
8	70	51	43	33	11	58	37	63	30	17
9	65	57	32	41	48	7	15	22	25	82

1 Dense Acacia-dominated thornbush savanna on loamy, red soils
2 Open Acacia-dominated thornbush savanna on loamy, red soils
3 Open Acacia-dominated thornbush savanna on loamy, yellow to pale soils
4 Open grass-dominated thornbush savanna on sandy soils
5 Open disturbed thornbush savanna with pioneer vegetation on sandy soils

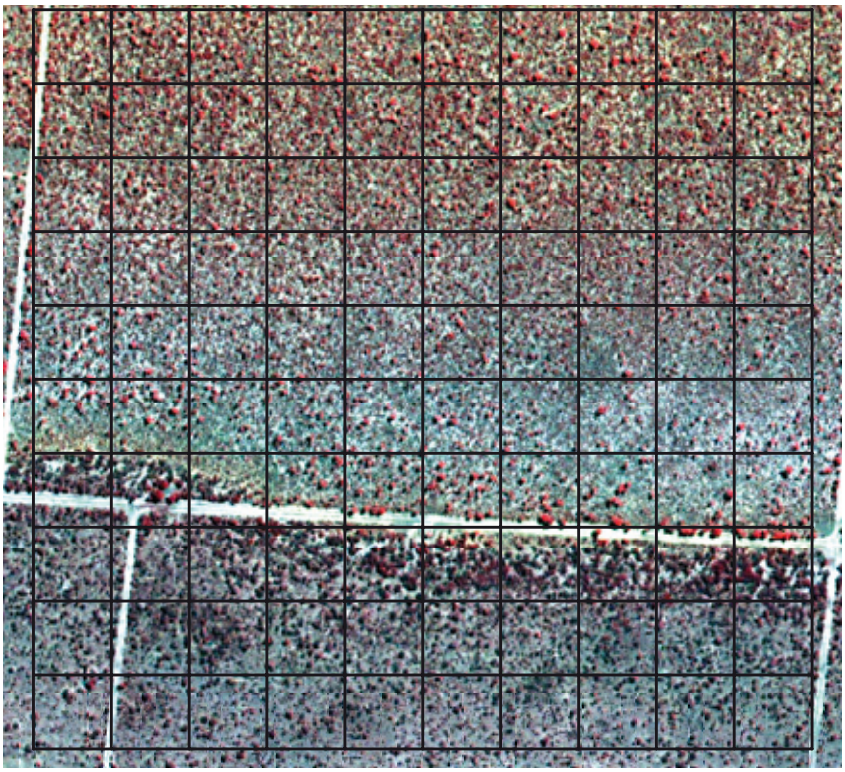
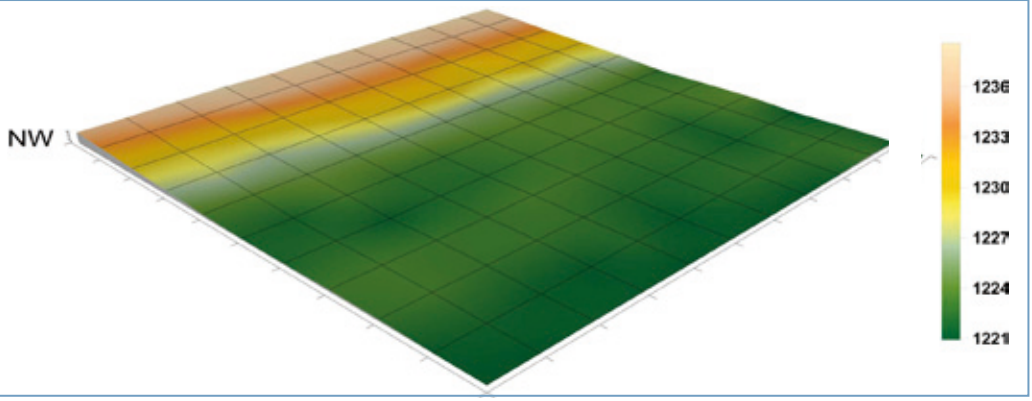


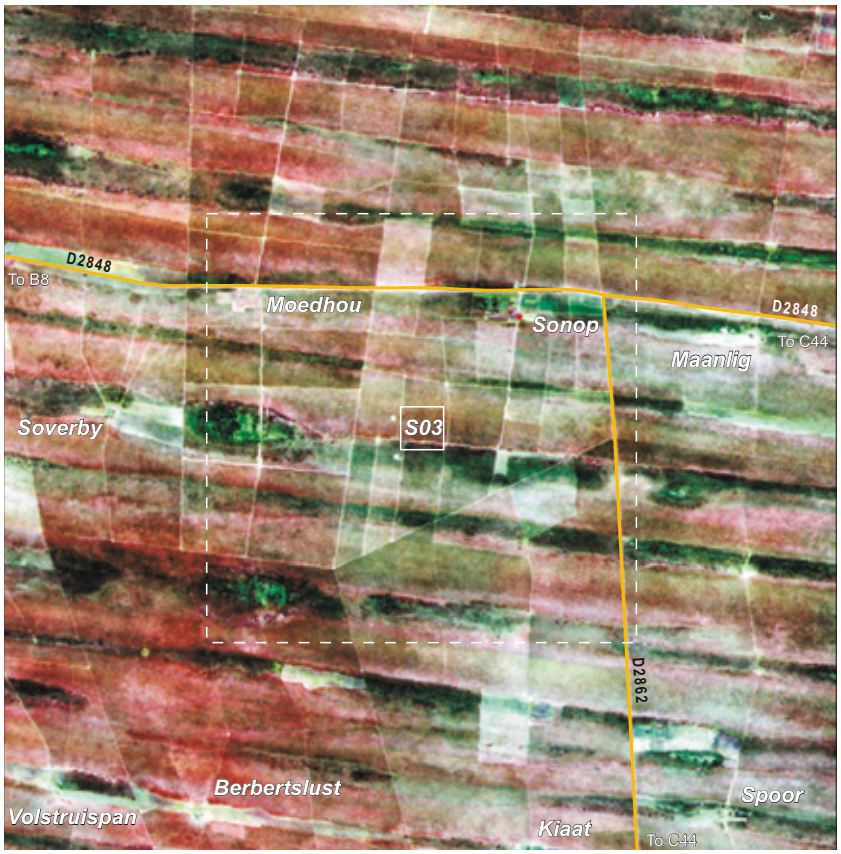
Image: IKONOS, 6 June 2008

Elevation model of Observatory



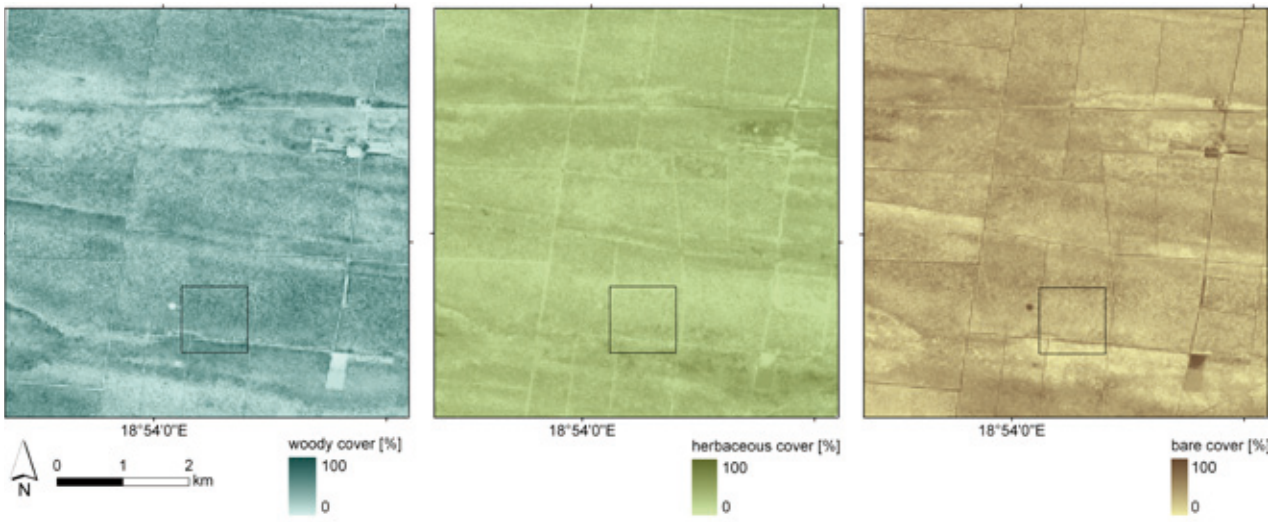
Landsat image

Two vegetated calcrete pans appear as dark green ovals to the west and south-west of the Observatory. The dunes are east-west orientated, approximately 20 meters high and are covered by open Woodland Savanna vegetation (dark red, thickets very dark red). The vegetation in the inter-dune valleys is more open and shows as brighter grey-red to greenish tones. Woodland areas that have been cleared for agricultural fields and also areas of recent heavy grazing impact appear as white rectangles. Bright red rectangles indicate crop fields.



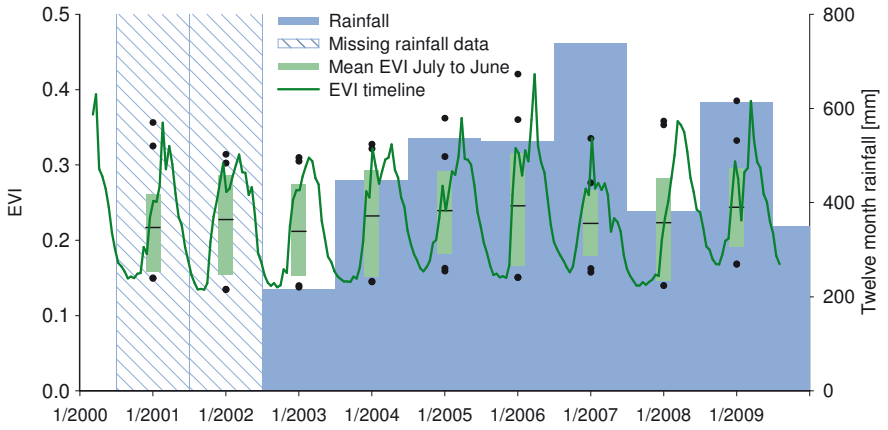
Scene: 177-73, acquisition date: 06 May 2007

Fractional cover image



MODIS time series

Temporal patterns of annual rainfall, vegetation cover, and phenology



Responsible authors: M. Keil & T. Labitzky

Climate

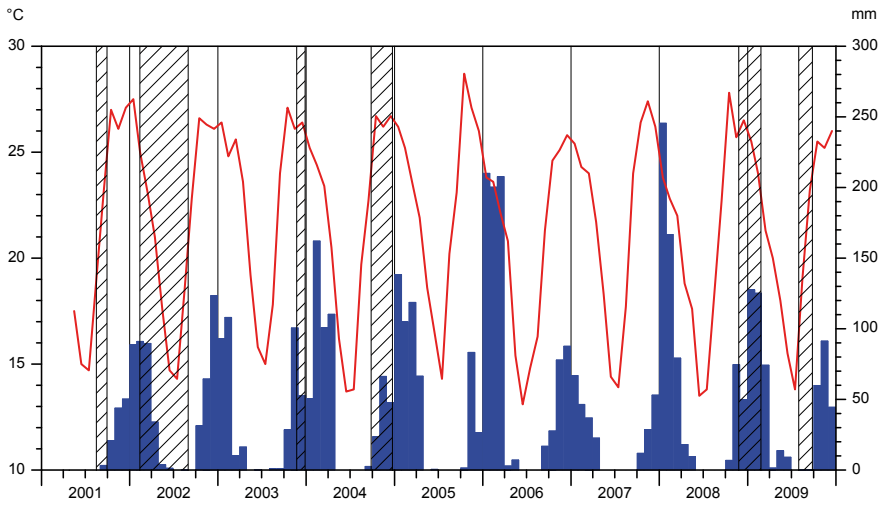
Data from BIOTA weather station

Location	Recorded period	Mean temperature
Sonop (S03)	2001–2009	23.1 (-1.5–43.0) °C
Mean solar radiation	**Mean wind speed**	**Mean annual precipitation**
372 (216–711) $MJ \cdot m^{-2} \cdot month^{-1}$	1.1 (5.2) $m \cdot s^{-1}$	498 (257–837) mm
Mean annual potential evapotranspiration	**Interannual precipitation variability**	**Mean relative humidity**
936 mm	136%	51% (21–82%)
Aridity index (UNEP)		
0.53 (dry subhumid)		

Modelled data

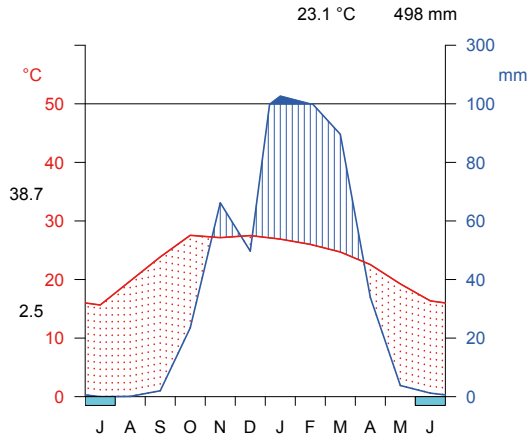
Mean temperature	Mean annual temperature range	Mean diurnal temperature range
21.8 (6.8–33.3) °C	9.9 °C	14.9 °C
Mean annual precipitation	**Precipitation seasonality**	**Percentage winter precipitation**
497 mm	105%	9% (strong summer)
Climate type	**Length of dry season**	**Aridity index (De Martonne)**
BSh	8 months	15.6 (semi-dry)

Time series: rainfall and temperature

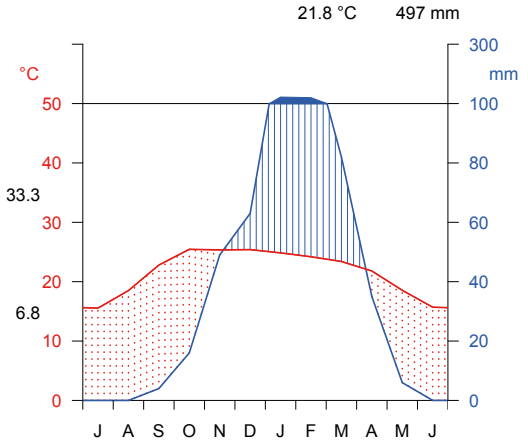


Climate diagrams

Recorded data (BIOTA)

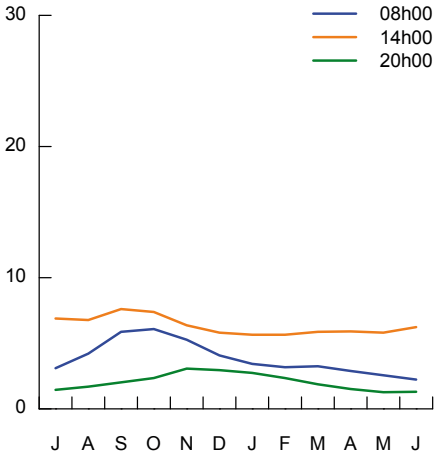


Modelled data (WorldClim)

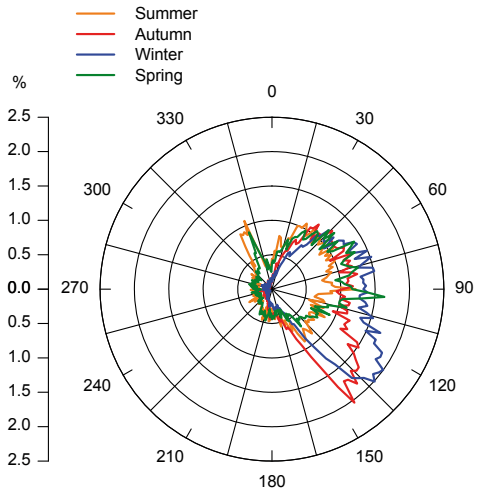


Wind diagrams

Speed



Directions



The climate at the Observatory is characterised by semi-arid conditions. Rainfall shows a strong seasonality with almost all rain falling during the summer season, peaking in January. The mean annual rainfall over the observation period was 498 mm, which is fairly wet in comparison to the average rainfall recorded at the Observatories over the entire transect, but corresponds with the mean rainfall of the Woodland Savanna Observatories. However, substantial interannual variability is evident. The observed near-surface air temperatures show a moderate seasonal cycle. The observed mean annual temperature is 23.1°C and this is therefore the second-warmest Observatory along the transect, and the warmest within the Woodland Savanna. However, this is only due to the absence of BIOTA weather data for the Ogongo (S42) and Omano go Ndjamba (S43) Observatories, since the interpolated long-term WorldClim data reveal even higher mean annual temperatures in the west. The observed mean minimum temperature is above the freezing point, but there is still a possibility of the occurrence of frost during the months June and July. Compared to the interpolated long-term data taken from the WorldClim dataset, only minor differences in mean annual temperature are evident. However, the station records of extreme temperatures deviate substantially from the WorldClim data, showing warmer maximum and colder minimum temperatures. For precipitation, the station data show a secondary rainfall maximum in early summer that is not evident in the WorldClim data.

The observed near-surface winds at the Observatory are mainly constituted of easterly flows during the spring and summer seasons, with a shift towards an enhanced southerly component during the autumn and winter periods. Mean wind speed is highest during the early afternoon, reaching about 8 to 10 km/h. Winds during that time of the day stay fairly constant throughout the year, whereas a weak annual cycle is evident for mean wind speeds recorded during the morning.

Responsible authors: K. Berger, A. Haensler & J. Luther-Mosebach

Soils

Year of sampling	Hectare plots sampled	SOTER unit
2001	30 (R1–25, R51, R55, R57, R59, R61)	NA25
Soilscape	**Dominant soil group(s)**	**Reference group richness**
Arenosols (AR)	Arenosol	3
Soil unit richness	**Soil unit evenness**	**Soil ecotype richness**
10	0.650	3
Parametric space	**pH**	**Electrical conductivity**
2.03	5.3 (4.1–8.3)	12 (6–208) $\mu S \cdot cm^{-1}$
Organic carbon		
0.30% (0.17–1.85%)		

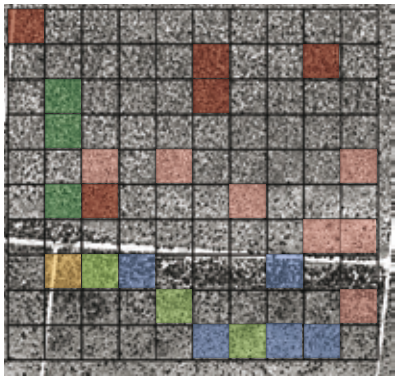
In addition to the standardised ranking procedure, this Observatory was surveyed by a north-south transect to cover all habitats in the dune system. In accordance with the vegetation analysis, the transect was elongated beyond the Observatory boarders for 200 m to the north and 400 m to the south to cover possible changes within the inter-dune and towards the dune top.

All profiles within the three dune habitats (see section on remote sensing and landscape ranking figure) are classified as Arenosols. They consist of well drained deep sands with little differentiation over a profile depth of 2 m. A distinction could be found in Rubic Arenosols (Dystric) in the northern part of the transect across this Observatory, which cover the upper dune part with more reddish substrates and Haplic Arenosols (Dystric) on the dune slope and the dune base with more pale sands.

In the inter-dune habitats to the south, soils show distinct colours and structures. Here, the common units are Haplic Cambisols and Haplic Calcisols. Both units display very similar soil properties; their distinction depends on the depth of the underlying calcrete or petrocalcic horizons, which regularly occur in the inter-dune area. Compared to the dune habitats, darker and greyer substrate colours occur where soils have a loamier texture and a harder structure.

A rare soil unit on the Observatory is the presence of Stagnic Regosols (Dystric), which occur in the micropans along the inter-dunal streets between the Calcisol-Cambisol association and the Arenosols of the dune habitats. These Stagnic Regosols (Dystric) consist of deep loamy sand to loam and are very distinct from the surrounding substrates with no signs of fluvial deposition. Prominent mottles of iron oxides indicate seasonal water logging. Also the lab analyses revealed a significant part of oxalate-extractable iron, which is an indicator of ongoing hydromorphologic dynamics of the stagnic classification.

Map of soil profiles



Haplic Arenosol
Rubis Arenosol
Ferralic Arenosol
Hypoluvic Arenosol
Haplic Cambisol
Haplic Calcisol

The variability of soil properties is mainly defined by two soil types, Arenosols and Cambisols. For all parameters shown, the Arenosols represent the lower values, while higher for Cambisols. The low variability of the pH values indicates the 'aggregated' character of this parameter. Vertical differences in the profiles are marginal, except for organic carbon. The only parameters with an uneven distribution are clay and silt content, due to the single pan-profile with high clay contents. The rooting space is nearly 100%, only in two Calcisol profiles a small restriction occurs.

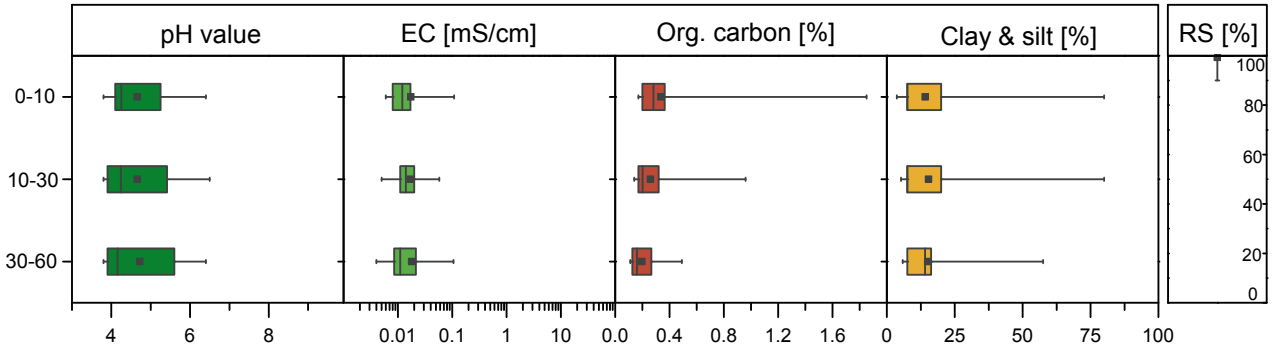
The sandy and clayey-sandy character is dominant in the soils of this Observatory, only few samples of the Stagnic Regosol have higher content of fine particles (finger tests). With respect to the sand fraction, the analysed samples can be subdivided into three clusters. The first cluster shows medium sand proportions (> 55%) and consists of samples of different depth from the Ferralic Rubic Arenosols (in the pure sand). The second cluster originates from samples of the loamier inter-dune soils with smaller medium sand (< 46%) and therefore higher fine sand content. The two samples between the clusters belong to the deepest subsoil horizons of the dune profiles. The differences are not significant but can be interpreted as a further hint for the different origin and/or genesis of the substrates.

Nutrient contents in the topsoil are generally low, similar to those of the other Observatories of the region (S01/Mile 46, S02/Mutompo). The concentration of the micronutrients iron, copper, and zinc is higher here, but still lower than in any

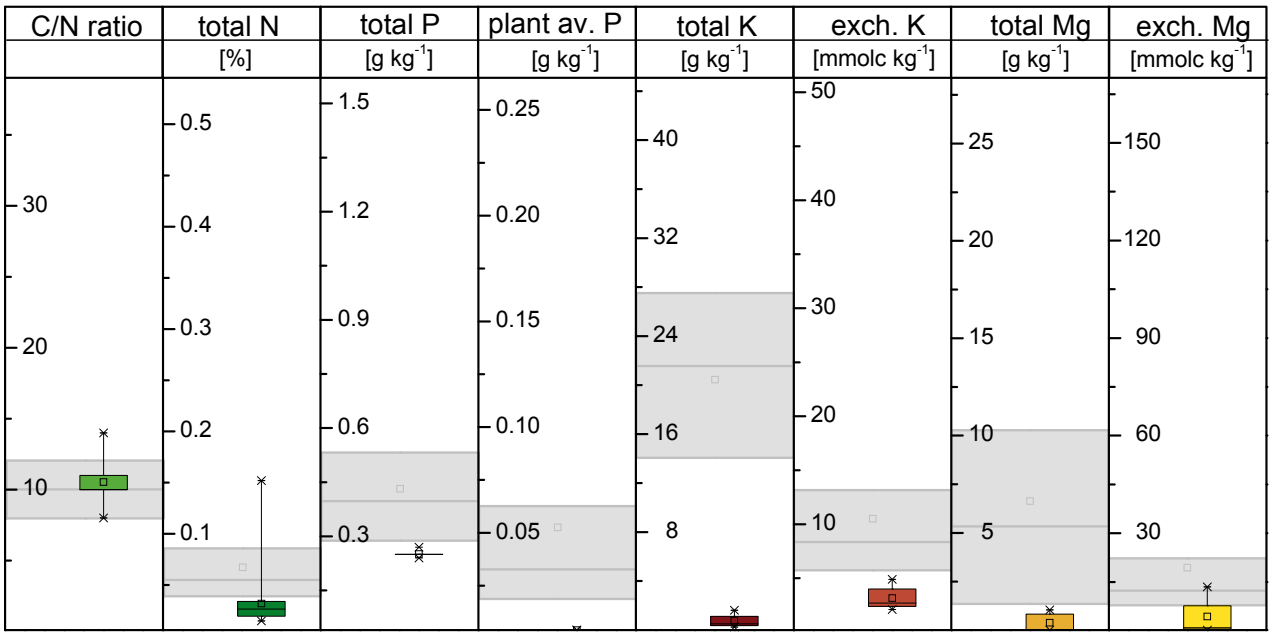
other Observatory of the BIOTA transect.

The transition from the central Namibian Thornbush Savanna to the northern Namibian Woodland Savanna in the region is reflected in the vegetation patterns of this Observatory (see Section Vascular Plants) which clearly reflect the soil properties in this Observatory. The drier Thornbush Savanna elements are restricted to the loamier and shallower inter-dune soils whereas the Woodland Savanna is found on the deep and pure sandy dunes. The main factor for this differentiation seems to be the water supply, which is mainly driven by soil texture, but additionally by the nutrient reserve and availability, which are generally low though slightly elevated in the inter-dune area.

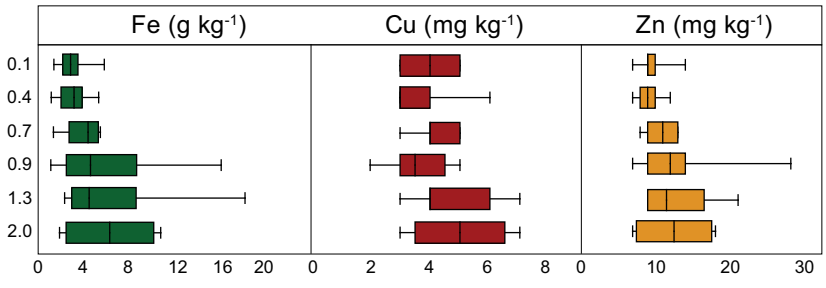
Soil characteristics



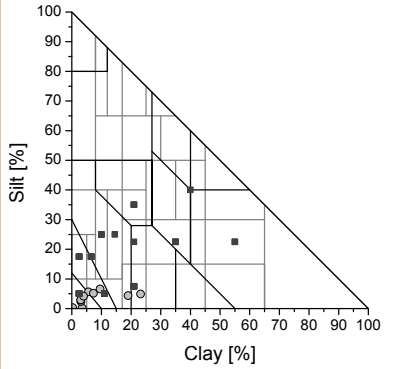
Soil nutrients



Soil micronutrients



Soil texture triangle

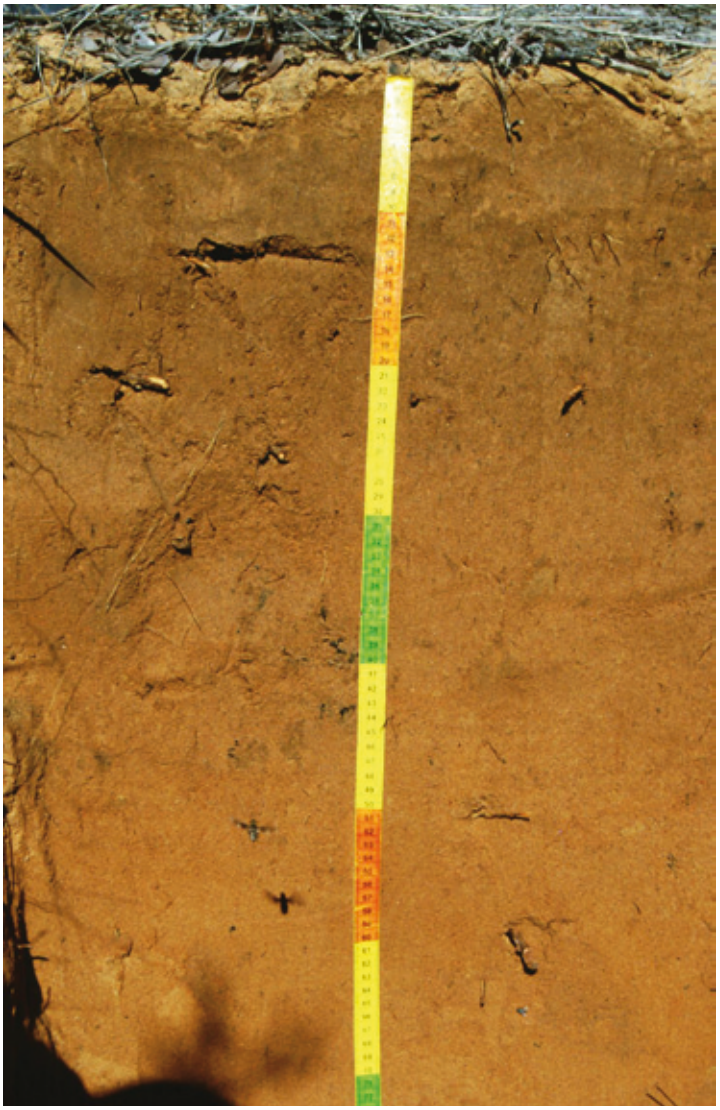


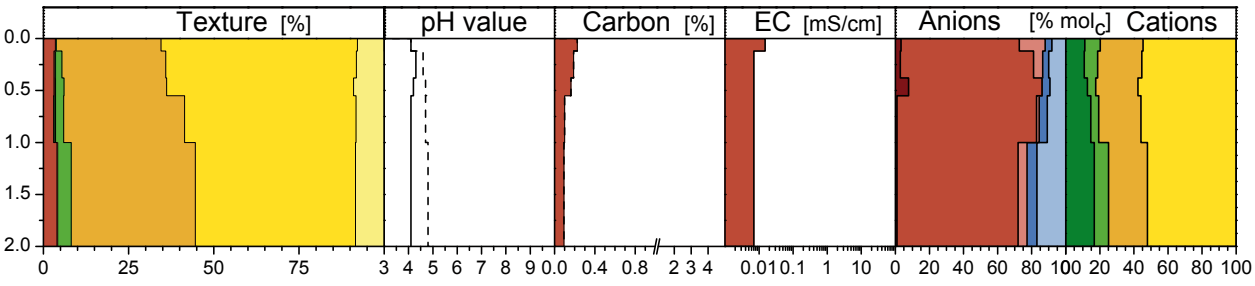
Reference profile

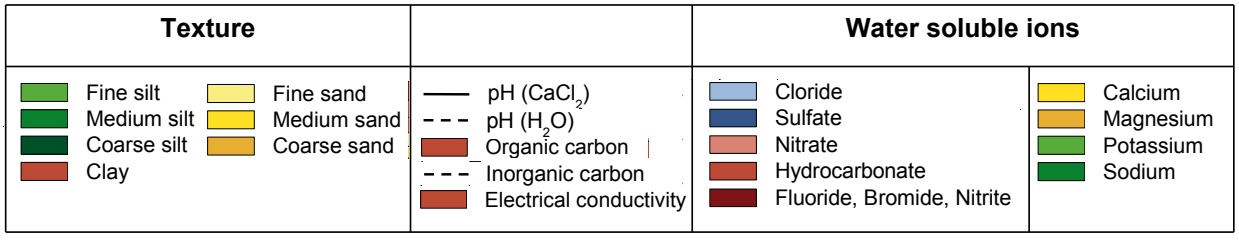
(at the northern end of the transect outside the Observatory)

This **Ferralic Rubic Arenosol (Dystric)** is a typical example of soils developed in the upper dune parts with deep, reddish pure sands. Except for the colour, it also represents the properties of the paler Arenosols in the dune slopes. The texture is dominated by medium sand with a slight increase of the fine sand proportion with depth; excavation difficulty is low. The organic carbon reaches only 0.23% in the topsoil and shows a considerable decrease with depth while the C/N ratios are constant at approximately 11. Both the soil pH and the electrical conductivity are very low (7–15 µS cm^{-1}) across the entire profile and so is the content of water soluble ions (1–2 $mmol_c$ kg^{-1}). The cation exchange capacity is between 6 and 9 $mmol_c$ kg^{-1}.

According to the quartz-dominated nature of the substrate, the total content of nutrients (Mg, Ca, K) is very low across all horizons, only the concentration of iron is high with 4 g kg^{-1}, and more than 80% of it is of pedogenic origin (iron oxides), which causes the reddish colour.







Responsible authors: U. Wisch, A. Petersen, A. Gröngröft & D. Mager

Biological soil crusts

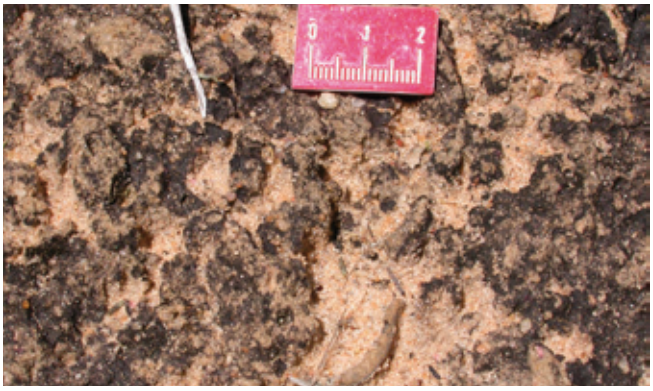
Sampling period(s)	Hectare plots sampled	Types of soil crusts
2001	4 (R1−R3, R5)	2, 5b
Crust thickness	**Cover**	**Carbon [weight %]**
3–4 mm	up to 20%	1.510
Nitrogen [weight %]	**Chlorophyll *a* [mg/m²]**	**Chlorophyll *a+b* [mg/m²]**
0.035	65	113

Well-developed cyanobacteria-dominated biological soil crusts, particularly frequent under shrubs and tree canopies, are the main crust type within this Observatory. Moss-dominated soil crusts also occur under tree and shrub canopies (see Photo). Well-developed crust patches, as in hectare plot 15, contain significantly high amounts of chlorophyll, whereas the overall chlorophyll content is moderate. Biological soil crusts have a high diversity of cyanobacteria, whereas the number of green algae is within average. Especially the filamentous cyanobacteria like *Microcoleus vaginatus* are capable of forming large sheaths composed by extracellular polysaccharides. Due to entrapment of soil mineral particles, their occurrence promotes enhanced soil stability. Additionally, such soils show increased soil water content compared to soils with fewer cyanobacteria.

Cyanobacteria
Calothrix cf. *braunii*
Leptolyngbya compacta
Leptolyngbya sp.1
Leptolyngbya sp.2
Limnothrix cf. *vacuolifera*
Microcoleus vaginatus
Nostoc cf. *punctiforme*
Nostoc sp.
Phormidium aerugineo-caeruleum
Phormidium cf. *caerulescens*
Phormidium cf. *nigrum*
Pseudanabaena cf. *starmachii*
Schizothrix sp.
Scytonema hofmanni
Scytonema millei
Scytonema ocellatum
Trichocoleus cf. *delicatulus*

Green algae
Chlorosarcinopsis minor
Eustigmatos magnus
Pseudochlorococcum typicum
Scenedesmus sp.4
Scenedesmus cf. *rotundus*

Well developed cyanobacterial crusts under shrub canopies.
Photo: K. Deutschewitz.



Close-up of a well-developed cyanobacterial crust.
Photo: K. Deutschewitz.

Responsible authors: B. Weber, K. Deutschewitz, S. Dojani, T. Friedl, T. Darienko, K. Mohr & B. Büdel

Biological soil crust characteristics

	H15	H42	H52	H72
Soil characteristics	Reddish to yellow sand with wood pieces	Light grey to yellow sand	Coarse grey to yellow sand with wood pieces	Black to grey sand with coarse and fine fractions
Crust characteristics	Dark to blackish BSC covering large areas; no lichens	Light BSC; thin and fragile pieces	Few pieces of light BSC	Dark and light BSC covering large areas
Chlorophyll *a* [mg/m²]	191.05	10.79	32.17	27.71
Chlorophyll *a+b* [mg/m²]	337.09	12.95	62.48	40.48
Carbon [weight %]	0.79	-	1.26	2.47
Nitrogen [weight %]	0.02	-	0.02	0.06

Lichens

Sampling period(s)	Hectare plots sampled	Cover
2001	n.a.	n.a.
Total species richness	**Species richness on soil [1 km²]**	**Species richness on rock [1 km²]**
26	4 (15%)	n.a.
Species richness on plants [1 km²]	**Species richness on soil [1000 cm²]**	
22 (85%)	n.a.	

This Observatory is very rich in epiphytic lichens, but poor in terricolous and saxicolous species. Several species collected in Sonop were recorded for the first time in Namibia and for the African continent (e.g. *Chaenothecopsis nana* and *Hypocenomyce anthracophila* are new to Africa) (Zedda et al. 2009). The relatively high diversity of lichens on trees can be attributed to a favourable macroclimate, the presence of older trees in the more closed bushland habitat, and to the apparently lower impact of fire compared to the Observatories of northern Namibia, S01 (Mile 46) and S02 (Mutompo). The relatively low richness of terricolous taxa is due to the presence of sandy, unstable and acidic soils. Only a few species occur on patches of compact, calciferous soils. The recorded soil-inhabiting lichens have a squamulose, peltate or small foliose growth habit, and dominant cyanobacterial photobionts. The species *Placidium lacinulatum* is considered to be a suitable indicator of sandy soils, also in other semi-arid regions of the world.

List of taxa

Terricolous (on soil):

Collema coccophorum
Heppia sp.
Peltula patellata
Placidium lacinulatum

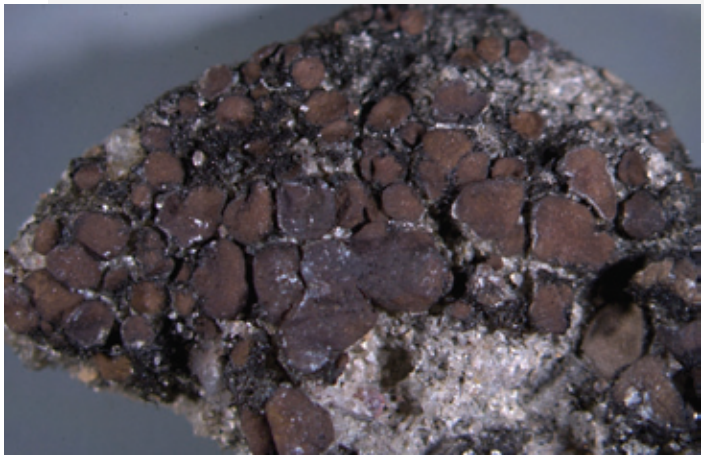
Saxicolous (on rock):

No records

Epiphytic (on plants):

Amandinea extenuata
Arthonia sp.
Bulbothrix hypocraea
Caloplaca alnetorum
Caloplaca citrina
Caloplaca sp.
Candelaria concolor
Canoparmelia epileuca
Chaenothecopsis nana
Collema occultatum
Hyperphyscia adglutinata
Hyperphyscia granulata
Hyperphyscia syncolla
Hypocenomyce anthracophila
Parmotrema austrosinense
Parmotrema eciliatum
Pertusaria coccodes
Phaeographis sp.
Phaeophyscia confusa
Phaeophyscia orbicularis
Pyxine nubila
Pyxine petricola

Pyxine petricola. Photo: L. Zedda & G. Rambold.



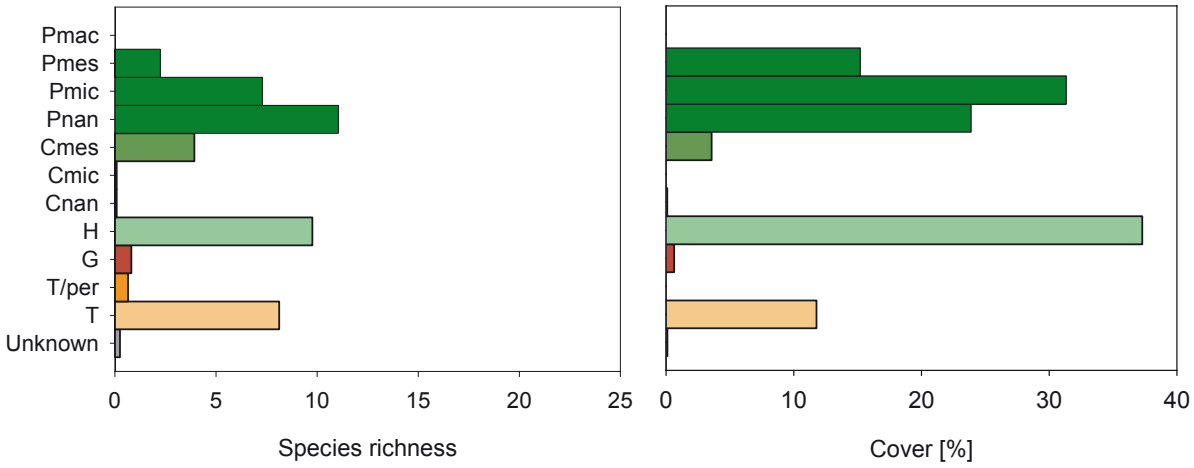
Placidium lacinulatum. Photo: L. Zedda & G. Rambold.

Responsible authors: L. Zedda & G. Rambold

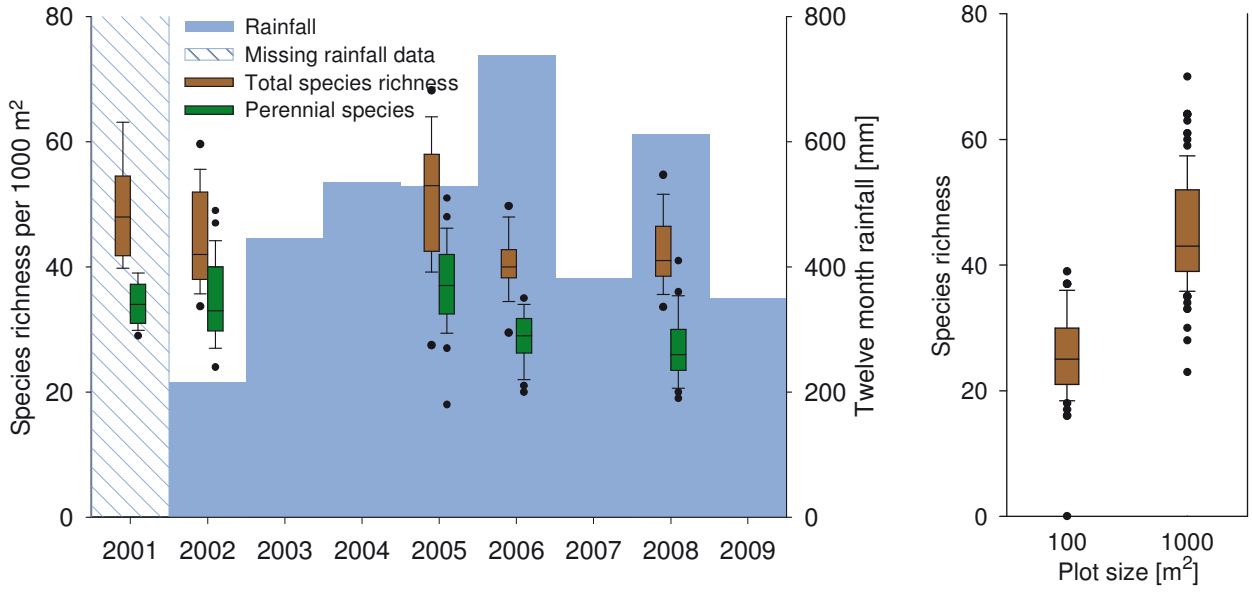
Vascular plants

Sampling period(s)	Hectare plots sampled	Biome
2001–2003, 2005, 2006, 2008, 2009	20 (R1–R20)	Woodland Savanna
Vegetation unit (level 1)	**Vegetation unit (level 2)**	**Identification rate**
Tree Savanna and Woodland (Northern Kalahari)	n.a.	92% – 99% – 100%
Cumulative family richness	**Dominant families (cover)**	**Dominant families (richness)**
65	Poaceae, Fabaceae, Combretaceae	Poaceae, Fabaceae, Convolvulaceae
Cumulative species richness (1 km²)	**Species richness (1000 m²)**	**Species richness (100 m²)**
385 – 161	45.1 (23–70)	25.6 (0–39)
***z*-value**	**Species richness change per year (1000 m²)**	**Evenness (1000 m²)**
0.246 (0.000–0.443)	n.a.	0.774 (0.533–0.914)
Evenness (100 m²)	**Simpson (1000 m²)**	**Simpson (100 m²)**
0.777 (0.520–0.912)	0.900 (0.613–0.953)	0.859 (0.643–0.941)

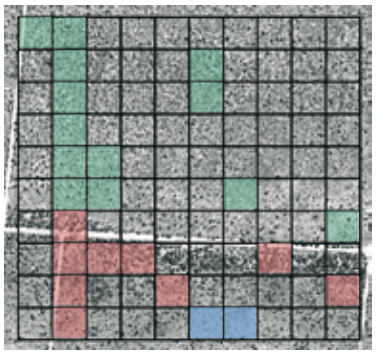
Life forms



Species richness



Map of vegetation units



The Observatory lies within the ancient dune field of the northern Kalahari, as described by Thomas (1984). These longitudinal east-west dunes, with their interdunal valleys, dominate the landscape as well as the vegetation. Similar to the two northern Observatories Mile 46 (S01) and Mutompo (S02), the deep sands of the dunes are dominated by broad-leaved trees and shrubs, whilst the heavier soils in the inter-dune valley support an open to closed Thornbush Savanna. The composition and density of this Thornbush Savanna depends on the depth and the loam content of the soils. With 65 vascular plant families, this Observatory is the most diverse in terms of family richness along the transects in southern Africa. Very similar to the Observatories Mile 46 and Mutompo, the dominant families are Poaceae and Fabaceae, with Combretaceae following in third place cover-wise, and Convolvulaceae diversity-wise.

The vegetation of the dunes has composition-wise much in common with the Kavango Woodlands, except that it is not dominated by large tree species. The occasional (relatively small) trees of *Pterocarpus angolensis* remind of the fact that this ecosystem is transitional to the Kavango Woodlands. The shrub and lower tree matrix is dominated by *Terminalia sericea* (Silver Terminalia) and various *Combretum* species, which occur at a very high density. Anecdotal evidence has it that these areas were far more open in the past, with a dense grass layer. This can be the effect of two factors—the change in grazing regime, from

Classification table (2008) *

Column		Cover	All	1.1	1.2	2
Number of relevés			**25**	**9**	**2**	**14**
Mean cover [%]			84.2	77.0	79.4	89.6
Mean species richness (1000 m²)			42.4	42.6	40.0	42.6
Inclination [°]			1.4	0.67	0	2.47
Mean soil pH			4.70	5.45	5.30	4.08
Mean electrical conductivity [µS·cm^{-1}]			19	22	15	18
Organic carbon [%]			0.36	0.56	0.31	0.21
Nitrogen [%]			0.03	0.05	0.03	0.02
Unit 1: Acacia mellifera-Eragrostis rigidior community						
G	Talinum arnotii	0.55	40	89	100	.
Pmic	Acacia mellifera ssp. detinens	19.6	44	100	100	.
H	Eragrostis rigidior	11.2	40	89	100	.
H	Sporobolus fimbriatus	2.45	40	100	50	.
Pmes	Acacia luederitzii	4.35	40	89	100	.
Pmes	Rhus tenuinervis	0.55	44	89	100	7
Pnan	Asparagus cooperi	0.68	44	100	100	.
Pmes	Dichrostachys cinerea	1.61	36	67	100	7
T	Stylosanthes fruticosa	0.63	32	78	50	.
Pnan	Commiphora africana	0.83	24	56	50	.
T	Ipomoea sinensis	1.75	32	89	.	.
Cmes	Melhania acuminata	1.00	40	67	100	14
Pnan	Solanum delagoense	0.63	32	89	.	.
Cmes	Lantana angolensis	0.71	28	56	100	.
Cmes	Ehretia rigida	0.67	24	56	50	.
H	Ocimum americanum	0.50	28	67	50	.
Pnan	Commiphora pyracanthoides	0.83	12	33	.	.
Unit 1.1: Acacia luederitzii-Brachiaria deflexa community						
n.a.	Euphorbia inaequilatera var. inaequilatera	0.27	28	78	.	.
H	Brachiaria deflexa	3.50	40	100	50	.
T	Tragus berteronianus	0.55	40	100	50	.
Pnan	Indigofera trita	0.75	32	89	.	.
G	Cyperus fulgens	0.50	20	56	.	.
T	Commelina benghalensis	0.75	32	78	50	.
Cmes	Helinus integrifolius	1.13	16	44	.	.
Cmes	Portulaca kermesina	0.50	16	44	.	.
G	Cenchrus ciliaris	0.63	16	44	.	.
H	Indigofera charlieriana	0.51	32	67	.	14
G	Raphionacme velutina	0.50	20	56	.	.
H	Eragrostis lehmanniana	1.58	24	56	.	7
n.a.	Kohautia aspera	0.50	20	56	.	.
T	Ipomoea coptica	0.37	24	56	50	.
T	Limeum sulcatum	0.50	24	56	50	.
Unit 1.2: Acacia erioloba-Ozoroa paniculosa community						
Cmes	Hermannia tomentosa	0.10	4	.	50	.
Pmes	Acacia erioloba	1.50	12	.	100	7
Pmic	Ozoroa paniculosa	3.00	16	22	100	.
Pmic	Combretum hereroense	0.75	8	11	50	.
H	Schmidtia pappophoroides	1.00	28	33	100	14
T	Cleome rubella	0.10	8	11	.	7
H	Brachiaria nigropedata	0.50	4	.	.	7
Pmic	Grewia flava	5.44	36	67	100	7
H	Cyperus chersinus	0.23	12	11	100	.
Pmes	Peltophorum africanum	1.00	12	11	100	.
H	Digitaria seriata	0.70	20	.	50	29
H	Rhynchosia venulosa	0.50	48	44	100	43

**classification is based on data also including relevés outside the Observatory*

continued on next page

Thicket formed by *Acacia luederitzii-Brachiaria deflexa* community (unit 1.1), 2003. Photo: B. Strohbach.

Densely covered pond within unit 1.1, 2003. Photo: B. Strohbach.

game (mixed grazers/browsers) to cattle (dominantly grazers), as well as the exclusion of fires since the 1950s/1960s, when the area was settled and developed for farmland.

The *Acacia mellifera-Eragrostis rigidior* bushlands and thickets (unit 1) are typically found on the loamy soils of inter-dunal valleys. *Acacia luederitzii*, *Dichrostachys cinerea*, the shrubs *Rhus tenuinervis* (Kalahari Currant), *Commiphora africana* (Hairy Corkwood), *Lantana angolensis* and *Ehretria alba* (White Puzzle Bush) as well as the grasses *Eragrostis rigidior* and *Sporobolus fimbriatus* (Dropseed) are typical representatives of this vegetation unit. Two distinct communities can be discerned within these bushlands and thickets:

The *Acacia luederitzii-Brachiaria deflexa* community (subunit 1.1) occurs along the edges of the inter-dunal street. This community forms an extremely dense thicket. The shade-loving annual grass *Brachiaria deflexa* is typical for this community, growing under a closed canopy of *Acacia mellifera* subsp. *detinens* and *A. luederitzii*. The occasional presence of *Cenchrus cilliaris* (Buffalo Grass) is indicative of a relative shallow calcrete layer in the subsoil. Generally, however, the grass cover within these thickets is low, limited to few individual perennial grass plants, as well as low growing, low producing annual grasses like *Brachiaria deflexa*, *Digitaria velutina*, and *Tragus berteronianus* (Small Carrot-seed Grass).

An interesting feature of these dense thickets is the occasional occurrence of ephemeral ponds. Depending on the depth of these ponds, and the rainfall during the season, these ponds are dominated by either *Eragrostis rotifer* (Vlei Love-grass) and/or various other wetland species, including *Diandrochloa pusilla*, *Echinochloa cruss-galli*, *Marsilea aegyptica*, *Nicolasia stenoptera* and *Schoenoplectus praelongatus*. Hectare plot 61 is an example of such a pond community.

The *Acacia erioloba-Ozoroa paniculosa* community (subunit 1.2) is a moderately-closed bushland dominated by occasional

Classification table (continued)

Column		Cover	All	1.1	1.2	2
Number of relevés			**25**	**9**	**2**	**14**
Unit 2: Terminalia sericea-Combretum collinum community						
n.a.	Hibiscus marlothianus	0.50	52	.	.	93
Pmes	Baphia massaiensis ssp. obovata	9.64	56	.	.	100
T	Jacquemontia tamnifolia	5.10	60	11	.	100
Pmes	Burkea africana	6.58	48	.	.	86
Pmic	Combretum collinum	7.96	56	.	.	100
L	Baissea wulfhorstii	1.42	52	.	.	93
H	Panicum kalaharense	1.91	44	.	.	79
T	Sesamum triphyllum	0.43	44	.	.	79
T	Ipomoea chloroneura	0.93	56	11	.	93
H	Eragrostis pallens	3.08	52	.	.	93
Pmic	Acacia ataxacantha	2.18	44	.	.	79
Pnan	Psydrax livida	4.00	40	.	.	71
Pmic	Combretum engleri	1.64	44	.	.	79
Cmes	Merremia verecunda	0.46	44	.	.	79
T	Ipomoea hackeliana	1.11	36	.	.	64
Pmic	Combretum psidioides	2.86	44	.	.	79
T	Aristida stipitata	2.82	44	.	.	79
Pmes	Terminalia sericea	9.00	56	.	.	100
Pnan	Bauhinia petersiana	4.36	56	.	.	100
Cmes	Indigofera pechuelii	0.37	36	.	.	64
Cmic	Limeum myosotis	0.47	56	11	.	93
T	Acrotome angustifolia	0.44	28	.	.	50
T	Oxygonum alatum	1.09	64	.	100	100
H	Phyllanthus pentandrus	0.48	80	56	50	100
Pmic	Ochna pulchra	0.86	28	.	.	50
n.a.	Hermannia eenii	0.86	28	.	.	50
Pnan	Commiphora angolensis	3.92	72	44	.	100
H	Indigofera filipes	0.26	20	.	.	36
H	Triraphis schinzii	0.93	28	.	.	50
Most frequent companions						
Pmic	Grewia flavescens	3.43	92	100	50	93
T	Gisekia africana	0.50	84	67	50	100
H	Urochloa brachyura	1.20	80	100	100	64
T	Tephrosia purpurea	0.48	68	44	100	79
H	Stipagrostis uniplumis	1.50	64	44	50	79
Pmic	Acacia fleckii	1.94	60	33	100	71
Pmic	Croton gratissimus	1.10	60	33	100	71
H	Bulbostylis hispidula	0.63	60	78	100	43
Cmes	Mundulea sericea	3.57	56	33	50	71
Pnan	Asparagus nelsii	0.89	56	56	100	50
Pnan	Clerodendrum ternatum	0.52	52	78	50	36
Pmes	Lonchocarpus nelsii	2.55	44	11	.	71
H	Commelina africana	0.35	44	22	50	57
Pmic	Ozoroa schinzii	1.06	36	11	.	57
Cmes	Euphorbia austro-occidentalis	0.46	36	22	.	50
Cmes	Seddera suffruticosa	0.56	32	67	100	.
G	Gloriosa superba	0.50	32	44	.	29
n.a.	Asparagus virgatus	0.45	32	33	.	36
H	Evolvulus alsinoides	0.40	32	56	50	14
Pnan	Asparagus suaveolens	1.00	28	.	50	43
Cmes	Pavetta zeyheri	0.79	28	56	100	.
T	Melinis repens ssp. repens	0.64	28	11	.	43
T	Vernonia poskeana ssp. botswanica	0.44	28	11	.	43
n.a.	Kyllinga alata	0.33	28	.	.	50
T	Pavonia clathrata	0.50	24	44	50	7
Cmes	Pavonia burchellii	0.50	24	56	50	.

**classification is based on data also including relevés outside the Observatory*

Moderately closed bushland of the *Acacia erioloba-Ozoroa paniculosa* community (unit 1.2), 2003. Photo: B. Strohbach.

The dune foot is characterised by a dense bushland dominated by *Burkea africana* trees (unit 2), 2003. Photo: B. Strohbach.

Acacia erioloba trees, as well as shrubs of *Acacia fleckii*, *A. mellifera* subsp. *detinens*, *A. luederitzii*, *Dichrostachys cinerea* and *Peltophorum africanum* (African Wattle). As the tree- and shrub cover is relatively low (less than 50%), the grass sward is well developed, with the bulk biomass produced by *Eragrostis rigidior* and *Stipagrostis uniplumis* var. *uniplumis*, whilst *Anthephora pubescens*, *Brachiaria brizantha* (Broodsaadgras), *B. nigropedata*, *Digitaria seriata* and *Schmidtia pappophoroides* provide a highly palatable combination of perennial grass species. The herbaceous layer is dominated by a number of geophytes, of which *Eulophia hereroensis* (a ground orchid) is one of the rarities.

The dunes are covered by the *Terminalia sericea-Combretum collinum* community (unit 2). It forms a dense shrub- and bushland, dominated by, in addition to the two name-giving species, *Acacia ataxacantha* (Roosdoring), *Baphia massaiensis* subsp. *obovata* (Sand Camwood), *Bauhinia petersiana* subsp. *macrantha*, *Combretum engleri*, *C. psidioides*, *Grewia flavescens*, *Lonchocarpus nelsii* (Kalahari Apple Leaf) and *Ochna pulchra*. The grass sward is largely reduced, with *Digitaria seriata*, *Schmidtia pappophoroides* and *Stipagrostis uniplumis* var. *uniplumis* as perennial species, and *Aristida stipitata*, *Megaloprotachne albescens*, *Melinis repens* subsp. *grandiflora* and *Urochloa brachyura* as annual species. The herb layer is also highly diverse and dominated by annual species. One of the notable exceptions is the lianous *Baissea wulfhorstii*, which is quite common in this community. Three variants of this community can be recognised: The midslopes contain the typical closed shrub- and bushlands described above. The crests of the high dunes (the far north-western hectares of the Observatory) feature interspersed *Pterocarpus angolensis* trees—at a very low density, and also generally smaller than in the Kavango woodlands. The very foot of the dune is characterised as a bushland dominated by tall *Burkea africana* trees amongst the shrubby matrix of *Terminalia sericea* and *Combretum* spp.

Unit 1.1, *Heterantha callifolia*, 2003. Photo: B. Strohbach.

Typical dense bushland of the dune slope (unit 2), 2003. Photo: B. Strohbach.

Baphia massaiensis. Photo: B. Strohbach.

Ceropegia nilotica. Photo: B. Strohbach.

Responsible authors: B.J. Strohbach & J. Luther-Mosebach

Vertebrates

Total species richness	Reptile species richness	Bird species richness
24	n.a.	24
Large mammal species richness	Small mammal species richness	
n.a.	n.a.	

Birds

Strigiformes	**Owls**
Glaucidium perlatum	Pearl-spotted Owlet
Passeriformes	**Perching birds**
Prionops plumatus	White Helmet-shrike
Bradornis mariquensis	Marico Flycatcher
Cercotrichas leucophrys	White-browed Scrub-Robin
Cercotrichas paena	Kalahari Scrub-Robin
Mirafra sabota	Sabota Lark
Bubalornis niger	Red-billed Buffalo-Weaver
Eurocephalus anguitimens	White-crowned Shrike
Parus cinerascens	Ashy Tit
Plocepasser mahali	White-browed Sparrow-weaver
Pycnonotus barbatus	Common Bulbul
Cisticola chiniana	Rattling Cisticola
Laniarius atrococcineus	Crimson-breasted Gonolek
Dicrurus adsimilis	Fork-tailed Drongo
Parisoma subcaeruleum	Chestnut-vented Tit-Babbler
Prinia flavicans	Black-chested Prinia
Coraciiformes	**Kingfishers and relatives**
Merops hirundineus	Swallow-tailed Bee-eater
Tockus leucomelas	Southern yellow-billed Hornbill
Piciformes	**Woodpeckers and relatives**
Tricholaema leucomelas	Acacia Pied Barbet
Columbiformes	**Doves and pigeons**
Streptopelia capicola	Ring-necked Dove
Charadriiformes	**Gulls, terns, plovers, and other shorebirds**
Vanellus coronatus	Crowned Plower
Accipitriformes	**Birds of prey**
Terathopius ecaudatus	Bateleur
Cuculiformes	**Cuckoos and anis**
Corythaixoides concolor	Grey go-away-Bird
Galliformes	**Fowl-like birds**
Numida meleagris	Helmeted Guineafowl

Responsible authors: J. Deckert, A. Hoffmann & A. Mills

Sociable Weaver (*Philetairus socius*). Photo: J. Deckert.

Sociable Weaver (*Philetairus socius*). Photo: J. Deckert.

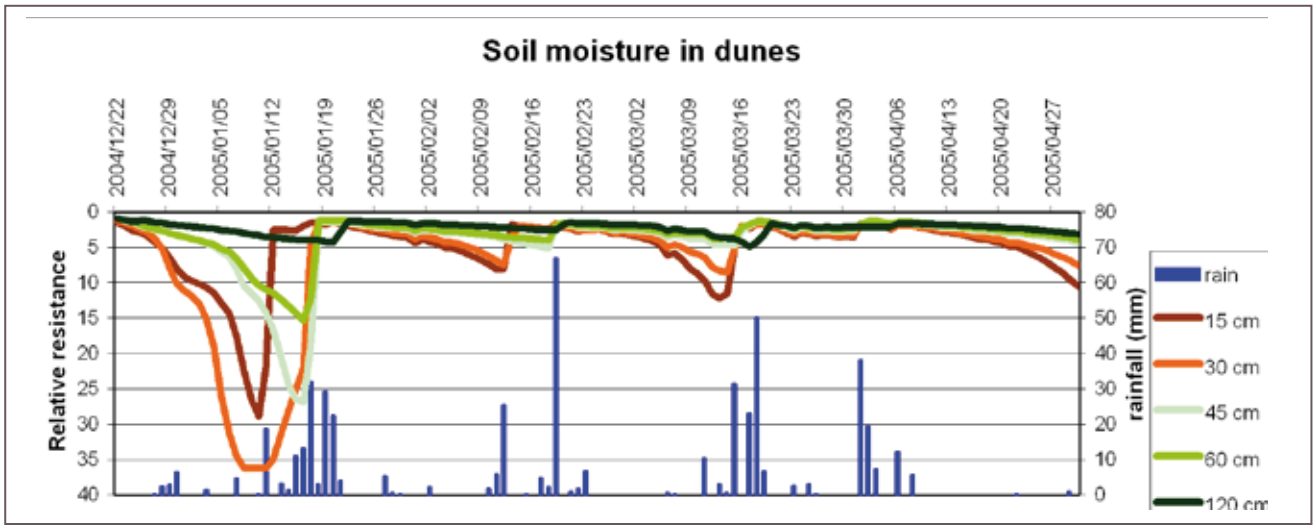


Fig. SSS03.01: Soil moisture in dunes at Sonop.

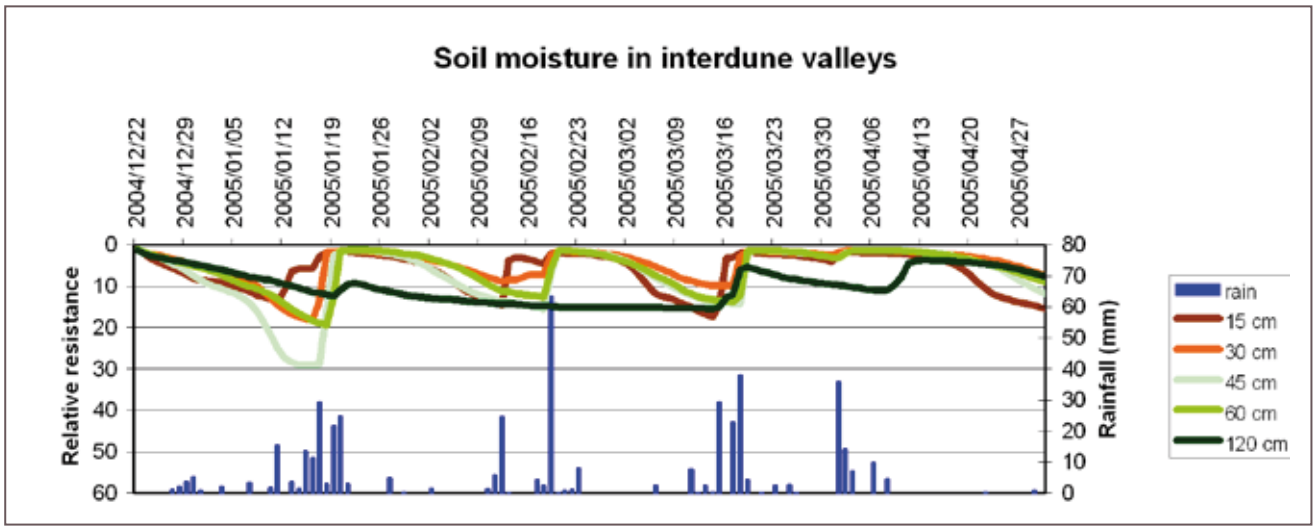


Fig. SSS03.02. Soil moisture in interdune valleys

Soil moisture patterns between different soil types and topographic positions at Sonop Research Station (S03.01)

[B.J. Strohbach]

It is generally assumed that sandy soils are more xeric than loamy soils. However, at Sonop, the dunes (> 95% sand) are covered with a dense bushland dominated by broad-leaved phanerophytic species generally associated with more mesic/humid environments. The vegetation of the inter-dune valleys is dominated by a semi-open, microphyllous Acacia savanna, which in turn are normally associated with that are more arid. In order to clarify this phenomenon, soil moisture probes were buried at various depths below the soil surface. These were linked to a data logger, measuring the relative resistance on an hourly basis.

Initial results indicated an extremely dry upper soil layer on the dune site at the onset of the rainy season, whereas the deeper soil layers show more moist conditions. The first rainfall events have no significant effects on soil moisture, whilst the slightly longer, more intense series of rainfall events wetted the soil layers to beyond 120 cm depth. The topsoil layers dried out relatively fast again after rainfall events, whereas the lower soil profiles stayed relatively constantly moist during the rainfall periods (Fig. SSS03.01-1).

The more loamy soils of the interdune valleys show also significant wetting of all layers except the deepest only during the more intense series of rainfall events after the initial falls. At 120 cm depth, only a slight increase in moisture content is detectable. This lower layer was also by far not as wet at the onset of the rainy season as the dune sands at similar depth. The lowest soil layer only became moist very late in the season. All layers showed pronounced drying cycles after the rainfall event series, indicating active extraction of water by the vegetation and evaporation. Although both sites

(dune and inter-dune) received similar amounts of rainfall, the drying cycle of the interdune was much faster than on the dune (Fig. SSS03.01-2).

Further trials have been undertaken with selective bush clearing as well as clearing of vegetation, to explore the changes in soil moisture content under different vegetation cover regimes.

Influence of soil features on soil lichen diversity in the summer-rainfall biomes (S03.02)

[L. Zedda, A. Gröngröft, A. Petersen, U. Wisch & G. Rambold]

The association of soil-inhabiting lichens with soil features was studied in detail in the summer-rainfall biomes, with the aim of comparing lichen-incrusted and bare soils of different sites, and of linking lichen patterns to soil parameters.

Field work was carried out in the period 2007–2009 on four selected Observatories of the Woodland Savanna, the Thornbush Savanna, and the Nama Karoo. Within the farms Sonop (S03; Woodland Savanna), Erichsfelde (S05; Thornbush Savanna), Narais (S39), Duruchaus (S40; both Nama Karoo), and their surroundings, 126 plots were investigated following the methods as described in Chapter II.1.3. Plots were selected within habitats of different types. The following soil parameters were measured: acidity, electric conductivity (EC), calcium carbonate, total carbon, and nitrogen contents.

Preliminary results show that 20 lichen species, grouped into four morphological groups (MGs), occur in the savanna biomes and that their frequency and cover are strongly positively correlated with soil alkalinity. Also the presence of calcium carbonate and increased soil nutrient status (indicated by EC) are linked with the higher diversity of all lichen MGs. By contrast, cover by pebbles, gravel, and stones negatively influence the total lichen cover. The results show that under climatic conditions that are favourable for lichen growth, soil parameters greatly influence lichen presence and dominance.

General data

Number	Name	Alternative name(s)
S42	Ogongo	n.a.
Implementation	**Country**	**Province/ region**
2006	Namibia	Omusati
District/ constituency	**Locality**	**Farm name**
Uutapi	Ogongo	Ogongo
Latitude	**Longitude**	**Altitude**
17.697198 S	15.305209 E	1103 m a.s.l.
Rainfall season	**Biome**	**WWF Ecoregion**
Summer	Woodland Savanna	AT0702 Angolan Mopane woodlands
Agro-Ecological Zone	**Relative intensity of land use**	**Tenure**
KAL9-4	Low	State
Type and history of landuse	**Land owner**	
Demonstration farming with cattle	University of Namibia Research Station	

Ogongo (S42)

A deep pond covered with water lilies at the Ogongo Observatory. Photo: B. Strohbach.

The BIOTA Observatory Ogongo (S42) is situated on the farm premises of Ogongo Agricultural College, a training farm co-owned by the Ministry of Agriculture and Forestry and the University of Namibia through a smart partnership. The Observatory is situated in the central-northern part of Namibia, in the Uutapi District of the Omusati Region, about 50 km northwest of Oshakati. Topographically, the area is an extensive plain, about 1100 m a.s.l., that is partly flooded by watercourses (locally known as 'oshanas') and covered by sand on slightly elevated terraces. The area is geologically described as a relatively flat plain, lying on an old continental base of granites, gneisses, and volcanic rocks. The Mopane savanna vegetation occurring here is characterized by semi-deciduous tree species as well as grasses and wetland species typical of the region. The area is located in a prime summer rainfall zone, receiving a mean annual rainfall of 400–500 mm (Mendelsohn et al. 2000). Rainfall is highly variable in time, space, and quantity, but occasional floodwaters from the Angolan highlands recharge surface and underground water resources in the region.

At present, small-scale agricultural research is conducted at the college, particularly animal and crop production for the purpose of agricultural training. There are several camps on the farm, which are used for the rotational grazing of livestock such as cattle, goats, and sheep. Additionally, there is a game camp where game species such as zebra, giraffe, and

springbok have been re-introduced for educational and research purposes.

The BIOTA observatory was established to monitor the impacts of different land use types and intensities on biodiversity, rangeland quality, and ecosystem functioning of this savanna system, by comparative investigations on the twin Observatory Omano go Ndjamba (S43), located 4 km west of Ogongo. The main goal is to identify threats to biodiversity through multi-disciplinary and interactive research, and ultimately to encourage sustainable utilization of natural resources in the area.

Responsible authors: F.N. Kangombe & D.H. Haarmeyer

Remote sensing and landscape

Geomorphology	Geological units	Lithological units
Alluvial plains, depressions	Kalahari and Namib Sands of Kalahari Group	Sands and Calcrete
Mean EVI	**EVI absolute range**	**Mean leaf area index**
0.204 (0.162–0.281)	0.154 (2005)–0.330 (2006)	0.68

Grid map of Observatory

	0	1	2	3	4	5	6	7	8	9
0	20	88	6	10	58	71	79	81	42	100
1	46	47	26	5	61	53	50	95	90	35
2	77	78	1	97	93	4	54	92	89	9
3	99	13	98	69	65	67	96	62	16	83
4	85	70	66	31	86	73	94	33	82	84
5	57	74	40	2	91	28	41	87	23	80
6	38	49	51	76	19	18	75	68	17	32
7	27	15	55	63	59	24	11	56	3	60
8	44	29	36	25	43	7	39	34	30	64
9	22	14	37	45	52	72	8	12	48	21

1 Mopane dominated savanna on alluvial deposits
2 Depressions / pans
3 Grass-dominated vegetation
4 Oshana

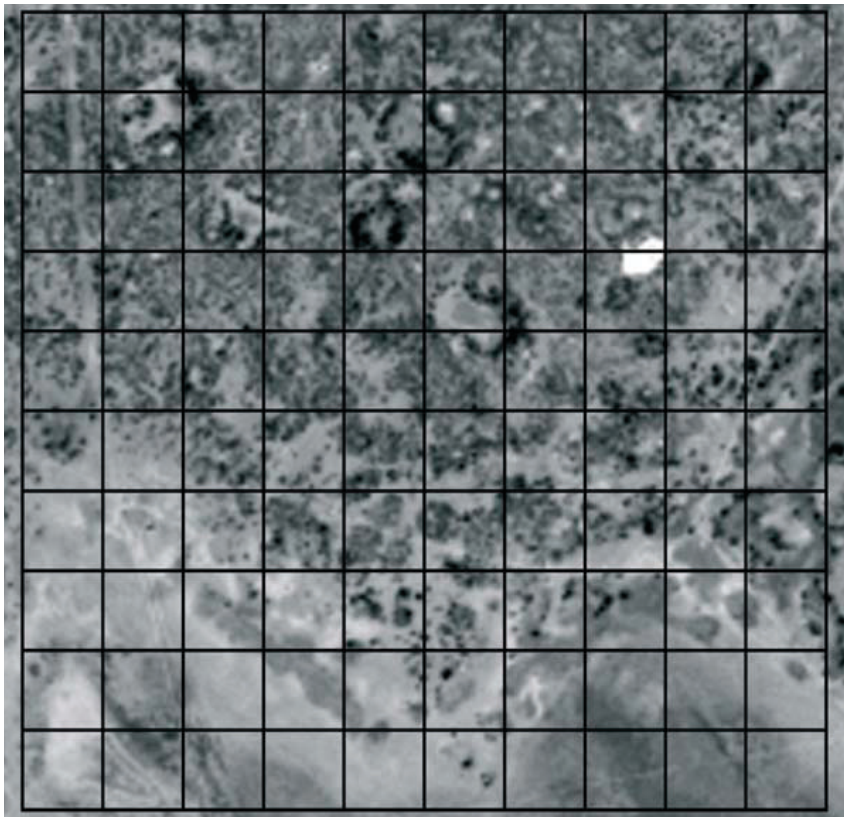
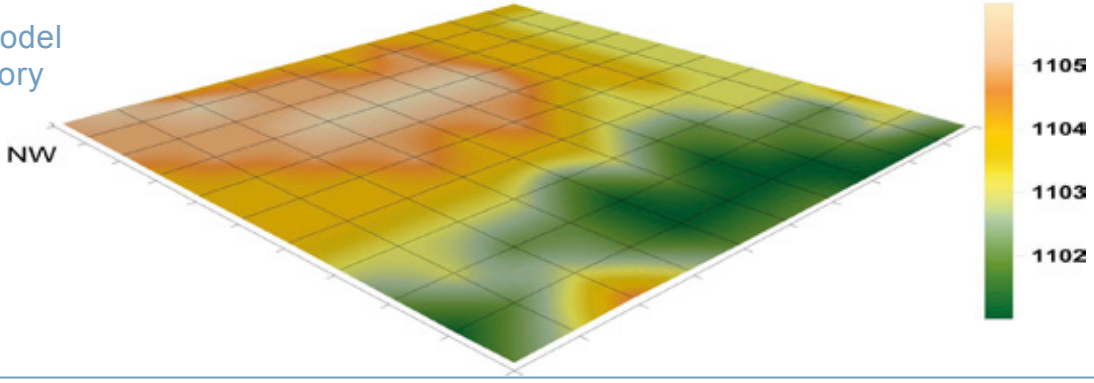


Image: aerial photograph

Elevation model of Observatory



Landsat image

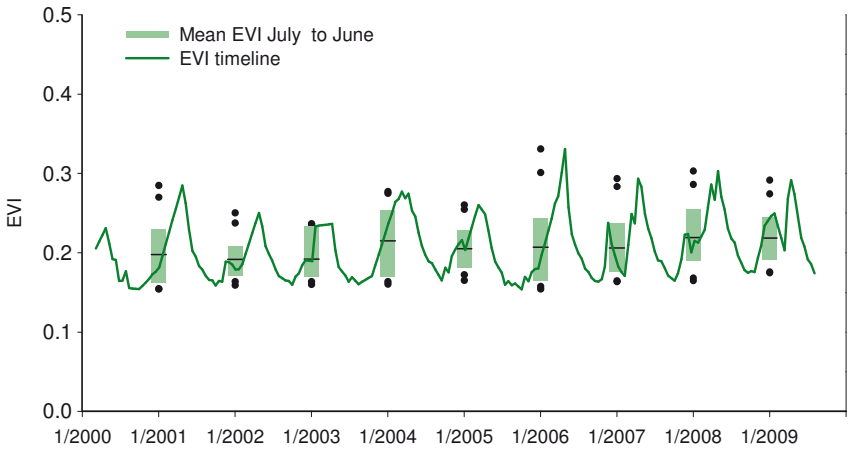
The Observatory Ogongo is located in the central-northern part of Namibia, about 50 km north-west of Oshakati. The Observatory is situated on the farmlands of the Ogongo Agricultural College (central and upper part of the image). At present, agricultural research is conducted at this institution, particularly animal and crop production for training purposes, with several camps where livestock such as cattle, goats, and sheep are kept and grazed on a rotational basis. Topographically, the area is an extensive plain at about 1100 m a.s.l., that is partly flooded by watercourses (locally known as 'oshanas', see the grey-green and whitish "channels" mainly in the lower part of the image) and covered by sand on slightly elevated terraces. On 22 April 2003 near the end of the rainy season, most parts of the oshanas are covered by dense grass and herb cover (bright green tones), and some parts are filled with water (blue-grey tones). Another flooded area is situated in the north-western part of the image (dark brown to black tones), where parts of a forest (red-brown tones) in a depression appear to be inundated.

Scene: 180/72, acquisition date: 22 April 2003

The natural vegetation type of the region is the Mopane savanna, which is characterized by semi-deciduous tree species (brownish tones) as well as grasses and wetland species (in green tones). The original Mopane woodland (closed dark brown region) is only conserved within the Ogongo Agricultural College. The North Central region of Namibia experiences high land use pressure, and the areas outside the Agricultural College (see the neighbouring regions in the south) are covered by dispersed settlements and by crop fields (small bright green patches) between patches of Mopane savanna and the oshanas.

MODIS time series

Temporal patterns of vegetation cover, and phenology



Responsible authors: M. Keil & T. Labitzky

Climate

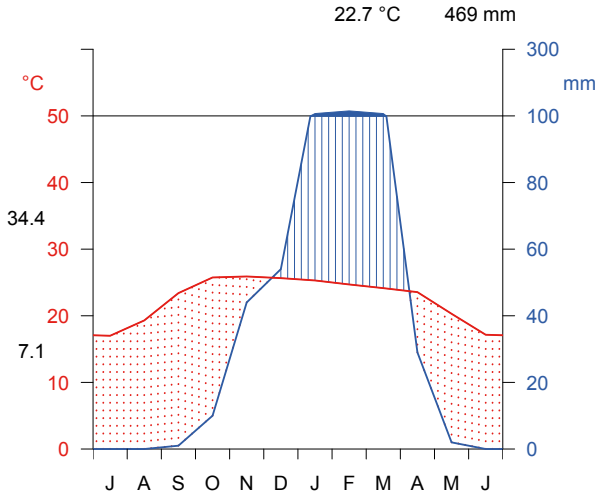
Modelled data

Mean temperature	Mean annual temperature range	Mean diurnal temperature range
22.7 (7.1–34.4) °C	8.9 °C	16.1 °C
Mean annual precipitation	**Precipitation seasonality**	**Percentage winter precipitation**
469 mm	111%	7% (strong summer)
Climate type	**Length of dry season**	**Aridity index (De Martonne)**
BSh	8 months	14.3 (semi-dry)

Only interpolated data from the WorldClim dataset is available for this Observatory. The climate at the Observatory is characterised by semi-arid conditions. Rainfall shows a strong seasonality with the major portion of rain falling during the summer season, peaking in February. The mean annual rainfall is 469 mm, which is fairly wet in comparison to the average rainfall recorded over the entire transect, but intermediate within the Woodland Savanna. Near-surface air temperatures show a moderate seasonal cycle. The mean annual temperature is 22.7°C, which is intermediate for this biome.

Climate diagrams

Modelled data (WorldClim)



Responsible authors: K. Berger, A. Haensler & J. Luther-Mosebach

Soils

Year of sampling	Hectare plots sampled	SOTER unit
2008	24 (R1–24)	NA34
Soilscape	**Dominant soil group(s)**	**Reference group richness**
Fluvisol	Solonetz	3
Soil unit richness	**Soil unit evenness**	**Soil ecotype richness**
15	0.790	n.a.
Parametric space	**pH**	**Electrical conductivity**
n.a.	6.0 (4.4–7.6)	92 (28–2200) µS·cm^{-1}
Organic carbon		
0.29% (0.17–0.78%)		

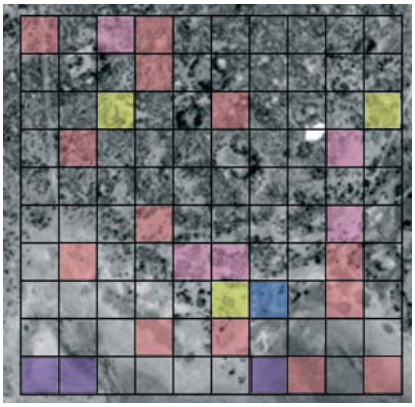
The soils of this Observatory are characterised by high amounts of soluble salts typical for the Oshana region in general. The predominant part of the soils (68%) on the Observatory is characterised by the occurrence of a dark-coloured and fine-grained horizon with a pH value above 8.5 and the development of strong, round-topped columnar aggregates. These horizons, typically found in the subsoil (mean upper boundary at 27 cm below soil surface), are classified as

'Natric' and qualify for the soil reference group Solonetz. The strong alkalinity results from the high proportion of soluble and exchangeable sodium, also responsible for clay illuviation.

Parts of the profiles additionally develop bright, bleached horizons directly above and sometimes tonguing into the natric horizons. These properties qualify for Albic or even Glossalbic Solonetz. All of these profiles are salt-enriched at least in the subsoil. In many cases the zone of strong enrichment starts above 50 cm (Episalic), and the content is above 30 S m-1 (Hypersalic), measured as electrical conductivity in a saturation extract. All other soils of the Observatory can be regarded as deviation from this type. Soil profiles with lower alkalinity (pH < 5) or missing columnar structure but similar salt enrichment as the Solonetz are classified as Solonchak (20% of profiles). If also the salt is missing, the soils belong to the reference group Luvisols (12%), characterised by their clay enrichment.

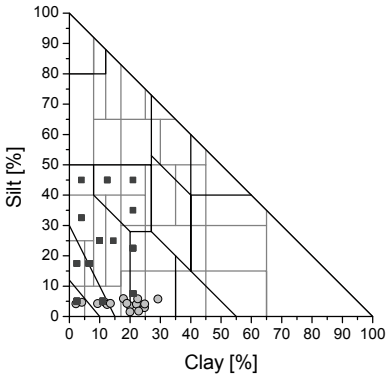
The soil properties vary extremely with depth. Both pH and electrical conductivity increase significantly with depth. Whereas the sandy topsoil is moderately to strong acid, the subsoil is alkaline. A shift of 5 units of pH values within 35 cm is not unusual. The soil texture analysis showed constant shares of silt particles with varying proportions of clay. Some of the soils show signs of water stagnation within the soil as clay enrichment of the subsoil horizons leads to low hydraulic conductivity. The subsoil horizons are not only enriched with soluble salts but also often with calcium carbonate, which may be nodular.

Map of soil profiles

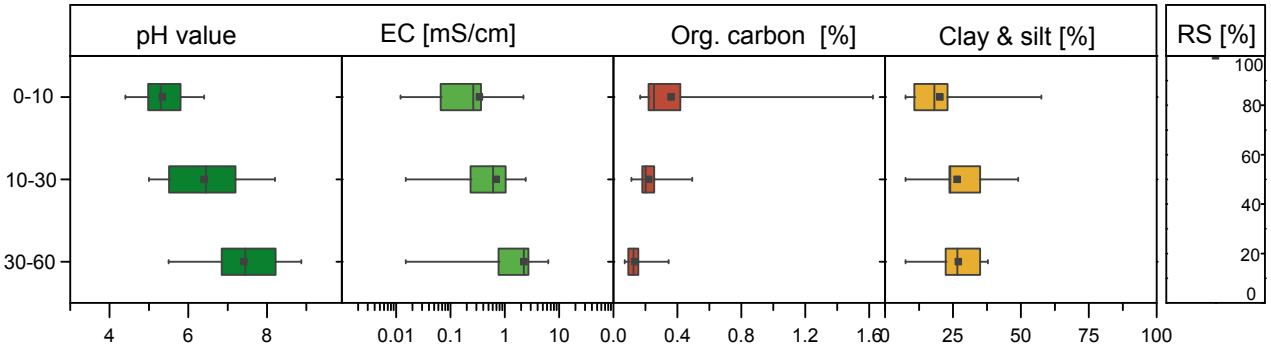


Haplic/Albic Luvisol
Epi(-hyper)salic Solonetz
Epi(-hyper)salic Solonchak
Endo(-hyper)salic Solonetz
Calcic Solonetz

Soil texture triangle

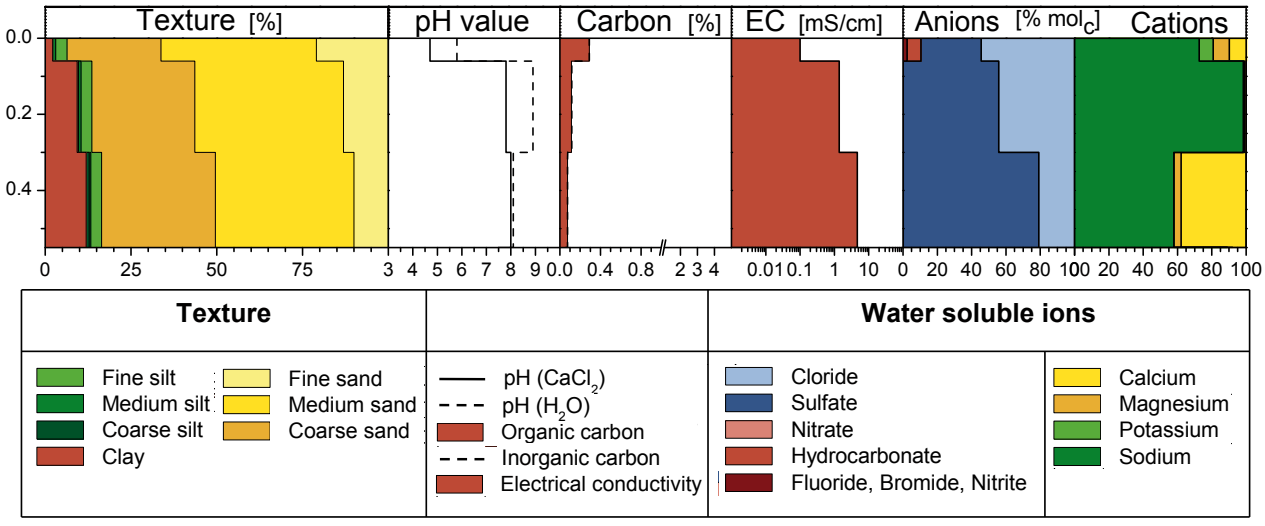


Soil characteristics



Reference profile (H53)

The **Epihypersalic Solonetz (Albic, Abruptic)** is the typical salt-dominated soil of the region. The electrical conductivity is high; especially water soluble sulphate (4.7 g l^{-1}), chloride (1.8 g l^{-1}) and sodium (1.5 g l^{-1}) were exceptionally high. The profile is characterised by the strong columnar structure starting below 6 cm, also reflected in the chemical properties of the soil, where, for example, the pH abruptly rises by 3 units. The columns are covered with a thin layer of brighter colour. The soil texture is dominated by sand, with slightly higher clay content in the columns without rock fragments. Excavation difficulty is low in the topsoil but gets high below 6 cm, where single columns can be broken out of the profile. Rooting is concentrated on the topsoil with 30 roots dm^{-2}.

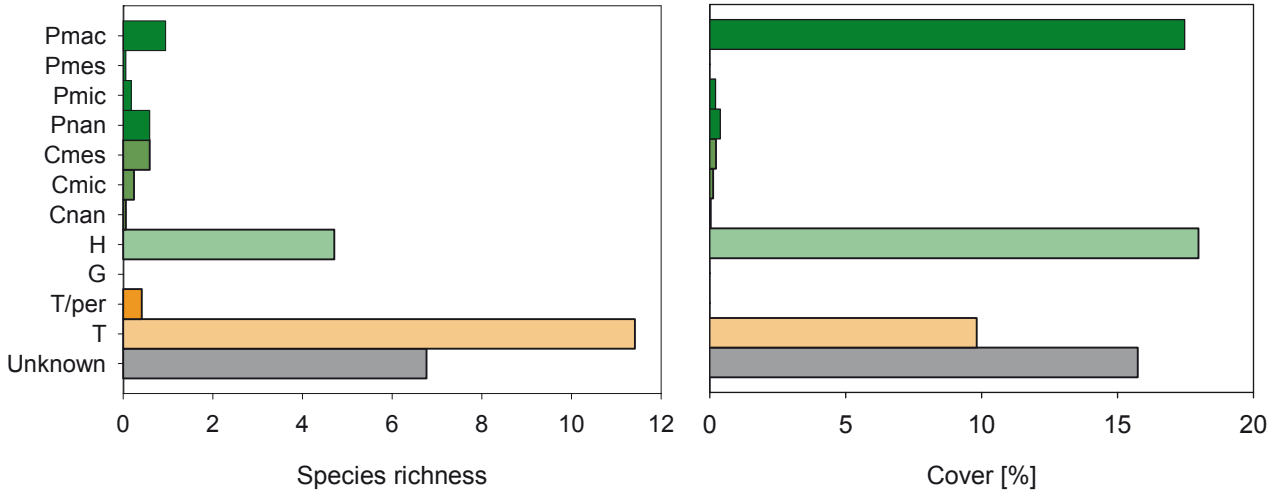


Responsible authors: T. Labitzky, U. Wisch, A. Petersen, A. Gröngröft & D. Mager

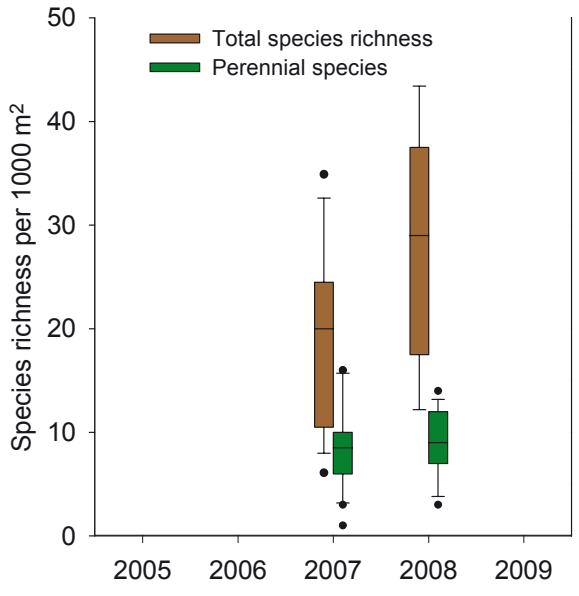
Vascular plants

Sampling period(s)	Hectare plots sampled	Biome
2007–2009	20 (R1–R20)	Woodland Savanna
Vegetation unit (level 1)	**Vegetation unit (level 2)**	**Identification rate**
Mopane Savanna	n.a.	95% – 95% – n.a.
Cumulative family richness	**Dominant families (cover)**	**Dominant families (richness)**
41	Poaceae, Fabaceae, Cyperaceae	Poaceae, Cyperaceae, Fabaceae
Cumulative species richness (1 km²)	**Species richness (1000 m²)**	**Species richness (100 m²)**
137 – 102	23.4 (6–45)	n.a.
***z*-value**	**Species richness change per year (1000 m²)**	**Evenness (1000 m²)**
n.a.	-1.41	0.710 (0.359–0.860)
Evenness (100 m²)	**Simpson (1000 m²)**	**Simpson (100 m²)**
n.a.	0.784 (0.313–0.909)	n.a.

Life forms



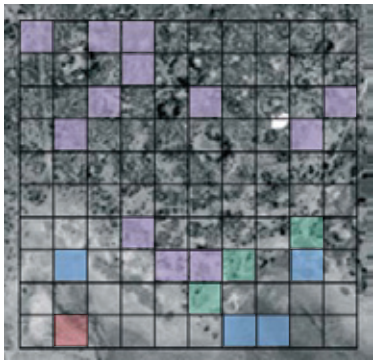
Species richness



The Ogongo Observatory, on the Ogongo Agricultural College, is situated in the central western Cuvelai delta, which is a typical part of the Mopane savanna sensu Giess (1998). The landscape is characterised by shallow water courses (Oshanas) of the Cuvelai dissecting a relatively flat plain consisting of sandy-loam soils. The plains are covered with a moderately closed savanna dominated by *Colophospermum mopane* (Mopane), whilst the Oshana vegetation is a typical ephemeral wetland vegetation-type, which depends on the water in the Oshana. The depth of water in the Oshana is dependent on the strength of the "Efundja"—the annual floods from the Angolan Highlands.

Species diversity is not very high at the Observatory, which is typical of Mopane savannas (du Plessis 2001). The Ogongo Agricultural College is used for light rotational grazing, and the vegetation at the Observatory is therefore as near to a climax state as possible. This is in stark contrast to the surrounding communal farming areas, which are used for cropping

Map of vegetation units



and grazing, as well as for the harvesting of timber and non-timber forest products.

The *Nymphaea nouchali-Nymphoides indica* association (unit 1) sensu Kangombe (2007) occurs at deep ponds. Observatory Ha 91 is located on such a pond, which occurs at the headwater of a minor branch of an Oshana. It is between 80 and 150 cm deep, depending on the position in the pond and degree of flooding. *Nymphoides indica* does not occur here due to the depth of the pond. Instead, the deep-water hydrophytic species *Neptunia oleracea, Oryzidium barnardii, Panicum trichonode*, and *Aeschynomene indica* are present. As with other wetlands in the ecosystem, *Leptochloa fusca* (Swamp Grass) is a dominant species in this community (albeit more along the fringes) as is the Common Water Lily *Nymphaea nouchali* in the centre of the pond. The sedges associated with these ponds are variable, with *Schoenoplectus senegalensis* occurring here.

The *Leptocloa fusca-Aponogeton junceus* association is represented by the deep-water Oshana community (unit 2.1). In most places, water depth ranges between 20 and 50 cm. A dense cover of the water grass *Leptochloa fusca* in association with other water grasses such as *Eragrostis rotifer* (Vlei Love-grass) and *E. cilianensis* is typical of this community. *Willkommia sarmentosa* (Brackarmgrass) is a wide-spread grass in this area, and also populates the Oshanas. This grass becomes more important in the dry season as a ground cover than

Classification table (2007)

Column		Cover	All	1	2.1	2.2	4
Number of relevés			**20**	**1**	**4**	**3**	**12**
Mean cover [%]			27.9	21.5	28.1	34.1	26.8
Mean species richness (1000 m²)			19.1	6.0	10.0	14.0	24.5
Mean soil pH			5.46	5.80	3.86	6.07	5.27
Mean electrical conductivity [µS·cm^{-1}]			405	266	220	675	378
Organic carbon [%]			0.32	0.49	0.55	0.31	0.24
Nitrogen [%]			0.03	0.06	0.06	0.03	0.02
Unit 1: Nymphaea nouchali-Nymphoides indica association sensu Kangombe							
T	Schoenoplectus senegalensis	3.00	5	100	.	.	.
Hyd	Nymphaea nouchali	10.0	5	100	.	.	.
n.a.	Neptunia oleracea	0.50	5	100	.	.	.
n.a.	Aeschynomene indica	0.50	5	100	.	.	.
H	Oryzidium barnardii	7.00	5	100	.	.	.
n.a.	Panicum trichonode	0.37	15	100	25	.	8
H	Eragrostis rotifer	5.55	55	.	100	100	33.3
T	Eragrostis cilianensis	3.20	25	.	75	66.7	.
Hyd	Aponogeton junceus	3.42	30	.	100	66.7	.
Unit 2.1: Leptocloa fusca-Aponogeton junceus association							
Hyd	Marsilea sp. 9919	1.75	40	.	100	33	25
n.a.	Cyperus procerus	0.83	15	.	75	.	.
n.a.	Leptochloa fusca	2.67	15	.	50	33	.
G	Ledebouria cooperi	5.50	10	.	50	.	.
G	Crinum rautanenianum	1.25	10	.	50	.	.
Unit 2.2: Hyphaene petersiana-Acacia arenaria association sensu Kangombe							
Pmic	Acacia hebeclada ssp. tristes	1.13	20	.	25	100	.
Unit 3: Colophospermum mopane-Eragrostis trichophora association sensu Kangombe							
T	Anthephora schinzii	1.04	65	.	.	33	100
H	Eragrostis trichophora	1.58	65	.	25	33	92
T	Portulaca hereroensis	0.51	50	.	.	.	83
T	Commelina benghalensis	0.55	55	.	.	33	83
T	Brachiaria xantholeuca	0.40	60	.	25	33	83
T	Gisekia africana	0.37	45	.	.	.	75
H	Chloris virgata	0.47	50	.	.	33	75
H	Cyperus fulgens	0.60	50	.	.	33	75
T	Sesuvium sesuvioides	0.50	35	.	.	.	58
Hper	Kyllinga alata	0.51	35	.	.	.	58
H	Eragrostis lehmanniana	1.46	45	.	25	33	58
T	Euphorbia inaequilatera	0.23	30	.	.	.	50
T	Ipomoea coptica	0.35	40	.	.	67	50
Most frequent companions							
Pmac	Colophospermum mopane	7.61	90	.	75	100	100
n.a.	Willkommia sarmentosa	3.50	75	.	75	67	83
n.a.	Acacia nilotica	2.31	75	.	50	100	83
H	Sporobolus ioclados	0.79	70	.	50	100	75
n.a.	Commelina subulata	0.46	35	.	25	33	42
T/Hper	Vahlia capensis	0.50	25	.	.	33	33
T	Urochloa brachyura	0.34	25	.	.	.	42
Hper	Pterodiscus aurantiacus	0.18	25	.	.	.	42
n.a.	Acacia arenaria	4.88	20	.	.	33	25
Pnan	Commiphora glandulosa	0.75	20	.	.	.	33
Cmes	Ipomoea bolusiana	0.53	20	.	.	.	33
Hper	Ocimum americanum	0.50	20	.	.	.	33
Pnan	Asparagus cooperi	0.43	20	.	.	33	25
n.a.	Fockea multiflora	0.30	20	.	.	.	33

continued on next page

Classification table (continued)

Column		Cover	All	1	2.1	2.2	4
Number of relevés			**20**	**1**	**4**	**3**	**12**
T	Cleome rubella	0.20	20	.	.	.	33
T	Indigofera charlieriana	0.20	20	.	.	33	25
T	Aristida adscensionis	0.10	20	.	.	33	25
T	Mollugo cerviana	0.50	15	.	.	.	25
T	Bulbostylis hispidula	0.50	15	.	.	.	25
T	Tragus racemosus	0.50	15	.	.	.	25
Pnan	Asparagus nelsii	0.50	15	.	.	.	25
Pnan	Cyphostemma congestum	0.50	15	.	.	.	25
G	Raphionacme velutina	0.37	15	.	.	.	25
Pnan	Solanum rigescentoides	0.37	15	.	.	.	25
T	Dactyloctenium aegyptium	0.37	15	.	.	33	17
n.a.	Tavaresia barklyi	0.27	15	.	.	.	25
n.a.	Microloma sp. 9919	0.23	15	.	.	.	25
T	Hibiscus sidiformis	0.23	15	.	.	.	25
T	Kohautia azurea	0.10	15	.	.	33	17

Nymphaea nouchali, 2007. Photo: F.N. Kangombe.

Nymphoides indica, 2006. Photo: B. Strohbach.

during the wet season. Other hydrophytes generally found in this community are the geophytic species *Crinum rautanenianum* and *Aponogeton junceus*, water ferns of the genus *Marsilea,* as well as the sedge *Cyperus procerus*. These Oshanas are generally grazed year-round, even during the wet season.

Unit 2.2 represents the *Hyphaene petersiana-Acacia arenaria* association sensu Kangombe (2007). This community forms a transition between the deep Oshanas and the dry mopane savannas. Depending on the intensity of the Efundja, this community can become flooded occasionally, resulting in a relatively low tree and shrub cover, but high grass cover. At the Observatory, the tree layer is characterised by *Acacia hebeclada* subsp. *tristes* (Weeping Candle-pod Acacia), whilst occasional Mopane trees (*Colophospermum mopane*) also occur. Not recorded in the sampled plots (but present on the Observatory) are *Acacia arenaria* (Sand Acacia) and *Hyphaene petersiana* (Makalani Palm). The grass sward is dominated by *Willkommia sarmentosa* and *Eragrostis rotifer*. The low-growing *Eragrostis cilianensis* also occurs here. This combination, which also occurs in the Oshanas, is indicative of the wetland nature of this community.

Unit 3 represents the *Colophospermum mopane-Eragrostis trichophora* association *sensu* Kangombe (2007). Four different subassociations are recognised, of which this community forms part of the *Colophospermum mopane-Willkommia sarmentosa* subassociation. The presence of the grasses *Eragrostis rotifer* and *Willkommia sarmentosa* are indicative of the temporarily waterlogged soils of this community. Other typical grasses associated with the moist soils occurring here are *Chloris virgata* (Feather-top Chloris) and *Brachiaria xantholeuca.* The grass sward is fairly sparse, even though the College grounds are only lightly utilised for grazing. This is typical of many mopane-dominated savannas.

Unit 2.1, 2006. Photo: B. Strohbach.

Unit 2.2, 2009. Photo: F.N. Kangombe.

Unit 3, 2006. Photo: B. Strohbach.

Responsible authors: B.J. Strohbach, F.N. Kangombe & J. Luther-Mosebach

Vegetation of the Ogongo Agricultural College and surrounding communal farming areas (S42.01)

[F.N. Kangombe & B.J. Strohbach]

The aim of this study was to describe and map the vegetation of Ogongo Agricultural College and the surroundings in the central-northern part of Namibia with the aid of satellite imagery. Ogongo Agricultural College is a predominant cattle farm, whilst agro-silvo pastoralism is the dominant land use in the surrounding areas. The study area belongs to the Mopane savanna, most of which in central-northern Namibia is intersected by a network of shallow water courses, locally known as "oshanas".

A total of 411 species were recorded across 227 relevés. The classification yielded three vegetation classes, seven associations, and seven sub-associations, which were described on the basis of species composition and distribution. The vegetation classes are *Terminalia sericea-Combretum* spp. shrublands, *Colophospermum mopane-Acacia nilotica* shrublands and *Diplachne fusca-Nymphaea nouchali* wetlands. The seven associations described in this study are *Burkea africana-Croton gratissimus* shrublands, *Terminalia sericea-Combretum collinum* shrublands, *Hyphaene petersiana-Acacia arenaria* shrublands, *Colophospermum mopane-Eragrostis trichophora* shrublands, *Diplachne fusca-Marsilea* spp. oshanas, *Nymphaea nouchali-Nymphoides* ponds, and *Pennisetum glaucum-Amaranthus thunbergii* crop fields. Landsat 7 ETM scene 180-72 (22 April 2003) was used for mapping these vegetation units. The Mopane shrublands represent the largest associations inside Ogongo Agricultural College, but are replaced by crop fields in the surrounding communal farming areas indicating extensive vegetation transformation into cropland.

Kangombe, F.N. (2007): Vegetation description and mapping of Ogongo Agricultural College and the surrounds with the aid of satellite imagery. – BSc thesis in Botany. Pretoria: University of Pretoria.

General data

Number	Name	Alternative name(s)
S43	Omano go Ndjamba	n.a.
Implementation	**Country**	**Province/ region**
2006	Namibia	Omusati
District/ constituency	**Locality**	**Farm name**
Uutapi	Ogongo	Omano go Ndjamba
Latitude	**Longitude**	**Altitude**
17.708034 S	15.264798 E	1100 m a.s.l.
Rainfall season	**Biome**	**WWF Ecoregion**
Summer	Woodland Savanna	AT0702 Angolan Mopane woodlands
Agro-Ecological Zone	**Relative intensity of land use**	**Tenure**
KAL9-4	High	Communal
Type and history of landuse	**Land owner**	
Cropping and cattle and smallstock	Government of Namibia	

Omano go Ndjamba (S43)

A mahangu field on the Omano go Ndjamba Observatory. Photo: B. Strohbach.

The BIOTA Observatory Omano go Ndjamba is situated on the communal farming areas of Omano go Ndjamba village, next to the Ogongo Agricultural College.

The Observatory is situated in the central-northern part of Namibia, in the Uutapi District of the Omusati Region, about 50 km north-west of Oshakati. Topographically, the area is an extensive plain, about 1100 m a.s.l., that is partly flooded by watercourses (locally known as 'oshanas') and covered by sand on slightly elevated terraces. The area is geologically described as a relatively flat plain, lying on an old continental base of granites, gneisses, and volcanic rocks. The Mopane savanna vegetation occurring here is characterised by semi-deciduous tree species as well as grasses and wetland species typical of the region. The area is located in a prime summer rainfall zone, receiving a mean annual rainfall of 400–500 mm (Mendelsohn et al. 2000). Rainfall is highly variable in time, space, and quantity, but annual floodwaters from the Angolan highlands recharge surface and underground water resources in the region.

The main land-use system in this village, as in most communal areas of central-northern Namibia is agro-silvo-pastoralism, based primarily on Pearl Millet *Pennisetum glaucum* (locally known as Mahangu) as the crop component, livestock keeping through communal grazing, and the multipurpose use of indigenous plants (e.g. wood harvesting).

Although this conventional way of life has protected the environment for many decades, the system is currently believed to be under stress mainly due to human population increases. As a result, key natural resources are being depleted at an alarming rate, and there is a need to re-evaluate and improve knowledge of natural resource management in the area.

The Omano go Ndjamba Observatory was established to compare the impacts of traditional communal farming in the village with the modern 'semi-commercial' farming practices at the Ogongo Agricultural College on biodiversity, rangeland quality, ecosystem functioning and resilience. The two Observatories therefore fit in well within BIOTA's comparative research framework and will ultimately yield results for improved natural resource management, particularly in the communal farming areas of central north Namibia.

Responsible authors: F.N. Kangombe & D.H. Haarmeyer

Remote sensing and landscape

Geomorphology	Geological units	Lithological units
Alluvial plains, depressions	Kalahari and Namib Sands of Kalahari Group	Sands and Calcrete
Mean EVI	**EVI absolute range**	**Mean leaf area index**
0.211 (0.163–0.279)	0.137 (2003)–0.297 (2008)	0.60

Grid map of Observatory

	0	1	2	3	4	5	6	7	8	9
0	49	83	3	21	16	34	96	86	8	79
1	24	73	46	29	59	2	47	77	39	22
2	58	15	41	78	60	4	50	81	97	48
3	62	54	14	90	28	84	53	91	36	52
4	72	27	31	38	32	74	45	89	56	88
5	6	70	9	5	57	18	42	13	26	94
6	65	23	40	1	67	43	55	82	85	93
7	66	7	87	20	92	25	10	61	75	35
8	33	37	76	100	44	12	95	98	19	68
9	80	69	11	99	51	63	17	71	64	30

1	Mopane-dominated savanna on alluvial deposits
2	Depressions / pans
3	Grass-dominated vegetation
4	Oshana
5	Crop fields on alluvial deposit

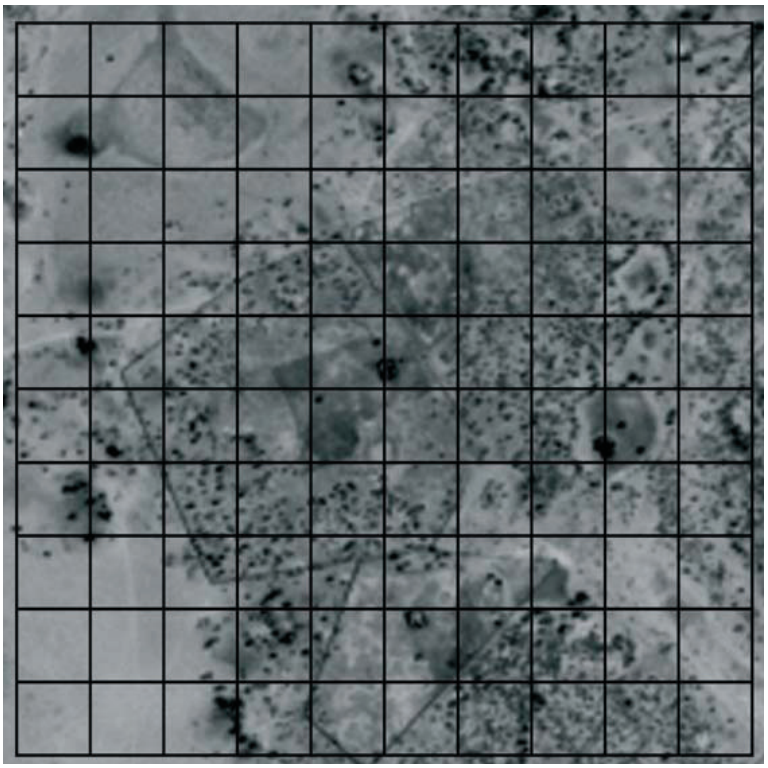
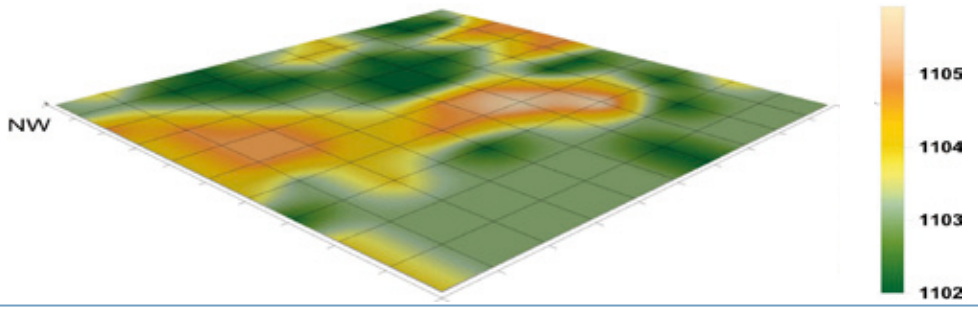


Image: aerial photograph

Elevation model of Observatory



Landsat image

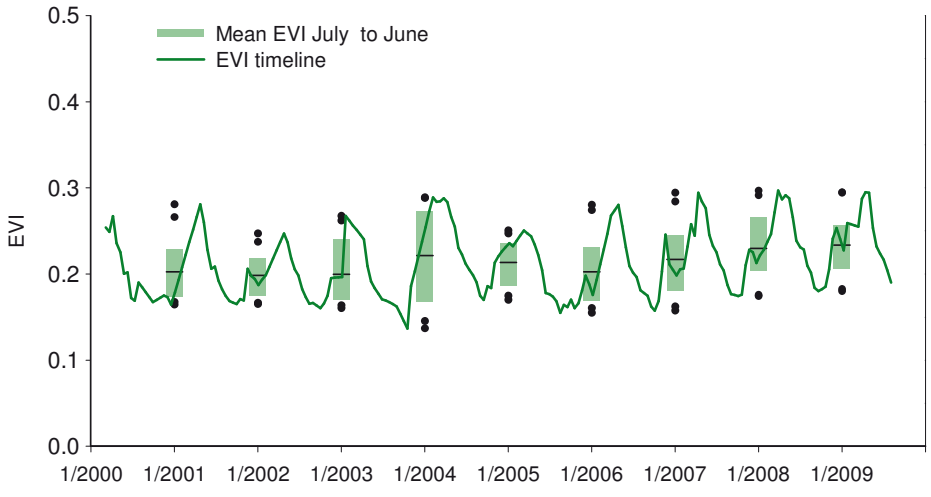
The Observatory Omano go Ndjamba is located in the central-northern part of Namibia, about 50 km north-west of Oshakati, and is situated on the communal farming areas of Omano go Ndjamba village approximately 4 km west of Obervatory S42 (Ogongo). The main landuse system of the community is agro-silvo-pastoralism, based primarily on millet (Mahangu) cultivation and communal grazing. Topographically, the area is an extensive plain at about 1100 m a.s.l., which is partly flooded by watercourses (locally known as 'oshanas', see the grey-green and whitish "channels" mainly in the lower part of the image) and covered by sand on slightly elevated terraces. On 22 April 2003 near the end of the rainy season, most parts of the oshanas were covered by dense grass and herb cover (bright green tones), and some parts were filled with water (blue-grey tones). Another flooded area is situated in the northern part of the image (dark brown to black tones), where parts of a forest (red-brown tones) in a depression appear to be inundated.

Scene 180/72, acquisition date: 22 April 2003

The natural vegetation type of the region is the Mopane savanna, which is characterised by semi-deciduous tree species (brownish tones) as well as grasses and wetland species (in green tones). Only in the Ogongo Research Station, the original Mopane woodland was conserved (closed dark brown region). The North Central region of Namibia experiences high land use pressure, and the area is covered by dispersed settlements and by crop fields (small bright green patches) between patches of Mopane savanna and the oshanas.

MODIS time series

Temporal patterns of vegetation cover, and phenology



Responsible author: M. Keil & T. Labitzky

Climate

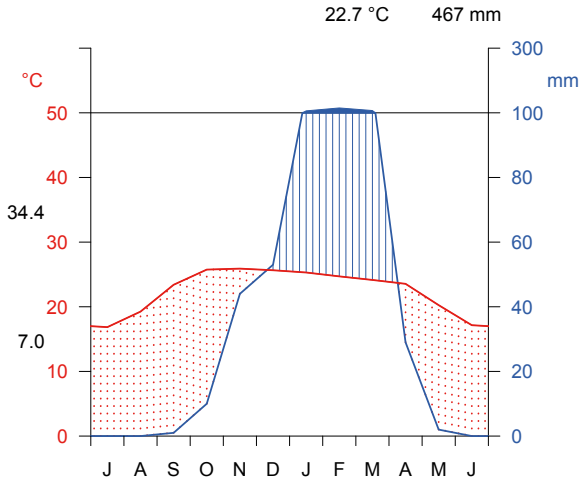
Modelled data

Mean temperature	Mean annual temperature range	Mean diurnal temperature range
22.6 (7.0–34.4) °C	9.1 °C	16.1 °C
Mean annual precipitation	**Precipitation seasonality**	**Percentage winter precipitation**
467 mm	113%	7% (strong summer)
Climate type	**Length of dry season**	**Aridity index (De Martonne)**
BSh	8 months	14.3 (semi-dry)

Only interpolated data from the WorldClim dataset is available for this Observatory. The climate at the Observatory is characterised by semi-arid conditions. Rainfall shows a strong seasonality with the major portion of rain falling during the summer season, peaking in February. The mean annual rainfall is 467 mm, which is fairly wet in comparison to the average rainfall recorded over the entire transect, but is intermediate for the Woodland Savanna. Near-surface air temperatures show a moderate seasonal cycle. The mean annual temperature is 22.7°C, which is intermediate for this biome.

Climate diagrams

Modelled data (WorldClim)



Responsible authors: K. Berger, A. Haensler & J. Luther-Mosebach

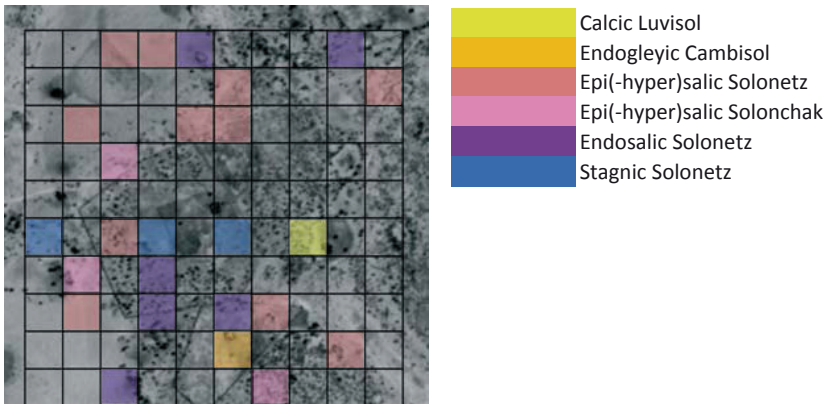
Soils

Year of sampling	Hectare plots sampled	SOTER unit
2008	25 (R1–25)	n.a.
Soilscape	**Dominant soil group(s)**	**Reference group richness**
Fluvisol	Solonetz	4
Soil unit richness	**Soil unit evenness**	**Soil ecotype richness**
15	0.791	n.a.
Parametric space	**pH**	**Electrical conductivity**
n.a.	6.4 (5.3–9.0)	41 (11–3100) µS·cm^{-1}
Organic carbon		
0.24% (0.07–1.96%)		

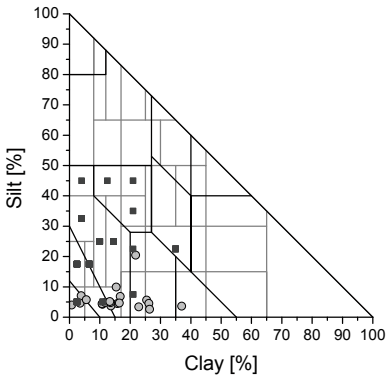
As the Observatory S42 (Ogongo), this Observatory is strongly influenced by water and salt enrichment. Shallow depressions, where the water remains for longer periods, show higher organic carbon content and finer texture than the surrounding soils. These depressions are the preferred habitat for plants with unique vegetation and high biomass production. This higher biomass results in stronger grazing impact on soil properties by trampling (bioturbation) and fertilization.

The reference groups of this Observatory are relatively the same as on Ogongo (S42). The Solonetz is even more dominant with 80%, followed by Solonchak (12%). Only two of the 25 profiles (8%) were classified as Luvisol and Cambisol, respectively. Like on Ogongo (S42), the variability of pH and electrical conductivity with depth is high; especially the pH is increasing significantly in deeper horizons. The silt content is sometimes slightly higher here than on Ogongo (S42).

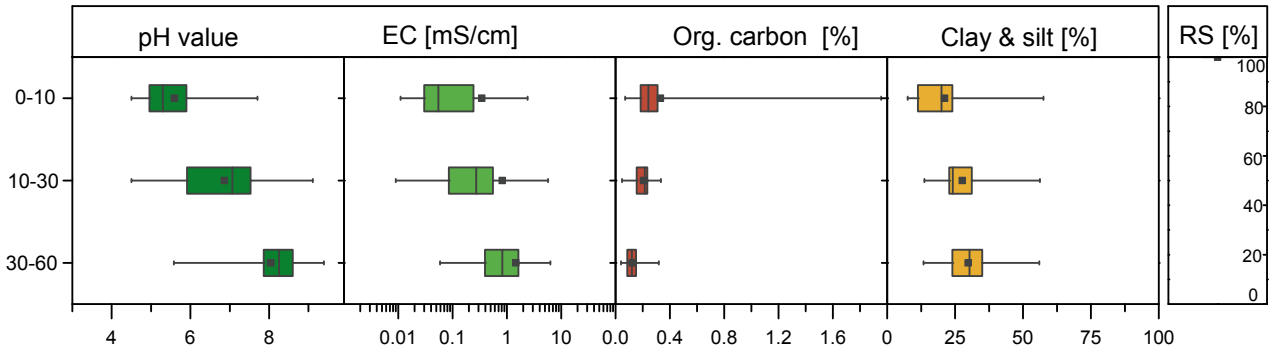
Map of soil profiles



Soil texture triangle

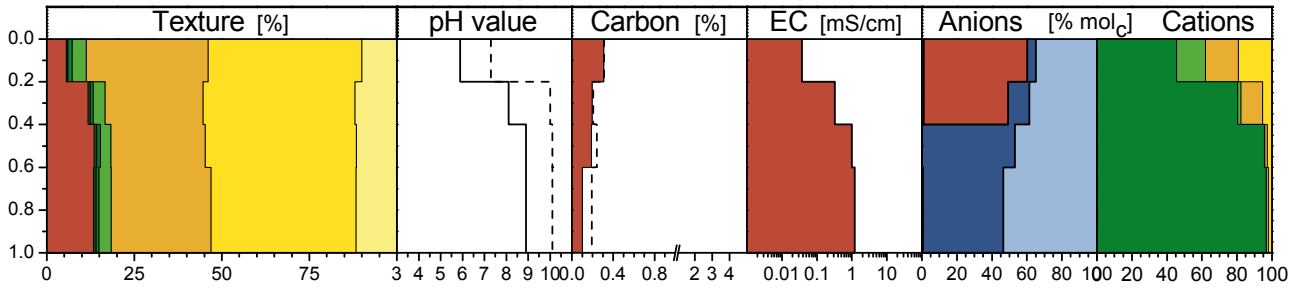


Soil characteristics



Reference profile (H61)

The **Episalic Solonchak (Sodic)** is an example of the salty soils of the region without the columnar structure described for the reference profile of Observatory S42 (Ogongo). No rock fragments can be found in the profile and the soil texture is dominated by sand, with slightly increasing contents of fine material with depth. Due to the high salt content, the electrical conductivity is high throughout the profile and increases with depth. Even without a distinct differentiation in soil structure, an abrupt increase in pH (7.3 to 10.0) and clay content (6% to 12%) in the second horizon is measured. In a depth of 40–60 cm, chloride (3.0 g l^{-1}) and sulphate (4.6 g l^{-1}) contents are extremely high. Sodium and calcium are high, but do not reach the levels of the Epihypersalic Solonetz (Albic, Abruptic) described for Ogongo (S42). The roots concentrate in the uppermost 20 cm, where excavation difficulty is low.



Texture

- Fine silt
- Medium silt
- Coarse silt
- Clay
- Fine sand
- Medium sand
- Coarse sand

- pH ($CaCl_2$)
- pH (H_2O)
- Organic carbon
- Inorganic carbon
- Electrical conductivity

Water soluble ions

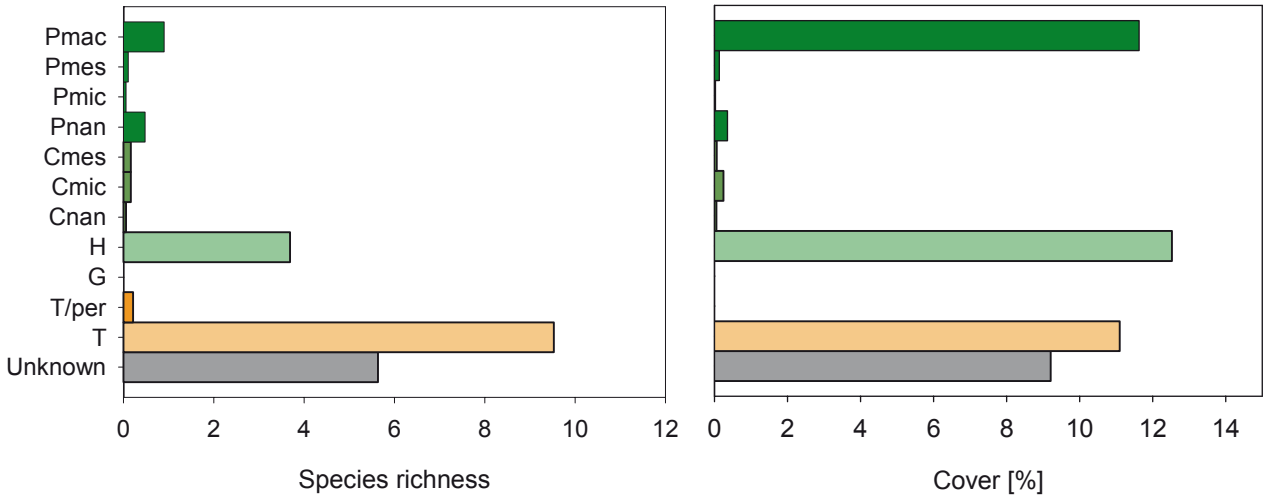
- Cloride
- Sulfate
- Nitrate
- Hydrocarbonate
- Fluoride, Bromide, Nitrite
- Calcium
- Magnesium
- Potassium
- Sodium

Responsible authors: U. Wisch, A. Petersen, A. Gröngröft & D. Mager

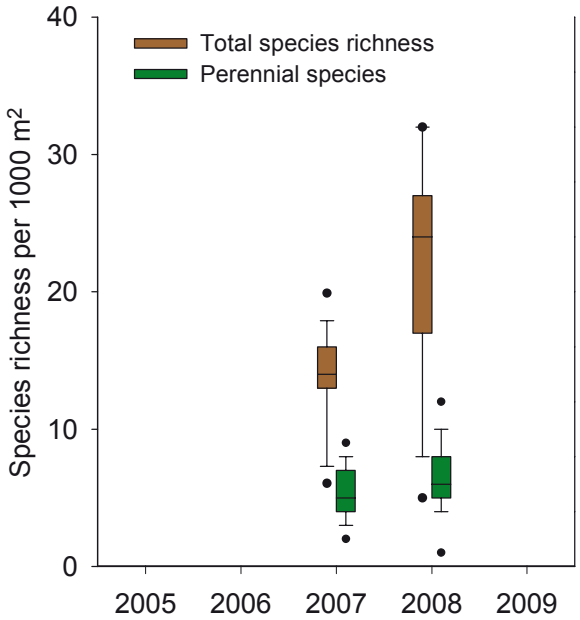
Vascular plants

Sampling period(s)	Hectare plots sampled	Biome
2007–2009	20 (R1–R20)	Woodland Savanna
Vegetation unit (level 1)	**Vegetation unit (level 2)**	**Identification rate**
Mopane Savanna	n.a.	90% – 91% – n.a.
Cumulative family richness	**Dominant families (cover)**	**Dominant families (richness)**
37	Poaceae, Fabaceae, Cyperaceae	Poaceae, Cyperaceae, Fabaceae
Cumulative species richness (1 km²)	**Species richness (1000 m²)**	**Species richness (100 m²)**
114 – 90	17.8 (5–32)	n.a.
***z*-value**	**Species richness change per year (1000 m²)**	**Evenness (1000 m²)**
n.a.	n.a.	0.718 (0.228–0.913)
Evenness (100 m²)	**Simpson (1000 m²)**	**Simpson (100 m²)**
n.a.	0.761 (0.141–0.915)	n.a.

Life forms



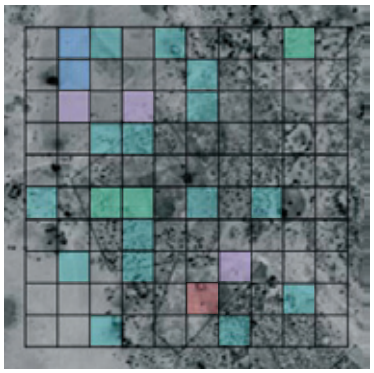
Species richness



Omano go Ndjamba, to the west of the Ogongo Agricultural College, is situated in the central western Cuvelai delta, which is a typical part of the Mopane savanna sensu Giess (1998). The landscape is characterised by shallow water courses (Oshanas) of the Cuvelai dissecting a relatively flat plain consisting of sandy-loam soils. The plains are covered with a moderately closed savanna dominated by *Colophospermum mopane* (Mopane), whilst the Oshana vegetation is a typical ephemeral wetland vegetation-type, which depends on the water in the Oshana. The depth of water in the Oshana is dependent on the strength of the "Efundja"—the annual floods from the Angolan Highlands.

The diversity of plant species is not very high here, which is typical for Mopane savannas (du Plessis 2001). This Observatory is part of a communal farming area, with intensive agro-sylvo-pastoralism as the dominant landuse. The farmers clear some of the Mopane savanna (up to 70% of the area according to Kangombe 2007)

Map of vegetation units



for crop fields. This contributes slightly to the biodiversity of the Observatory, both through the crop plants as well as the weeds commonly associated with cropping. However, biodiversity is depleted by activities such as the intensive use of timber from the Mopane savanna, the use of non-timber products, and the effects of intensive grazing by both cattle and goats. The Observatory therefore has less than 18 species per 1000 m², which is a figure very similar to many of the arid- and desert-environment Observatories along the transect. The species evenness (at the 1000 m² scale) at this Observatory is amongst the highest along the transect.

The Omano go Ndjamba Observatory is situated in the same ecosystem as the Ogongo Observatory, and thus possesses the same vegetation communities, with one exception being the crop fields, which are an additional community at Omano go Ndjamba.

The *Nymphaea nouchali-Nymphoides indica* association sensu Kangombe (2007) represents unit 1.1 and forms in deep ponds. Observatory ha 85 is characterised by such a pond, which is approximately 20 to 80 cm deep, depending on the height of flooding. *Nymphoides indica* occurs here as it is relatively shallow compared to the pond at Ongong. However, the deep-water species *Neptunia oleracea*, *Oryzidium barnardii*, and *Aeschynomene indica* are absent. As with other wetlands in the ecosystem, *Leptochloa fusca* (Swamp grass) is a dominant species in this community, as is the common water lily *Nymphaea nouchali*

Classification table (2007)

Column	Cover	All	1.1	1.2	2.1	2.2	2.3
Number of relevés		**25**	**1**	**2**	**3**	**3**	**16**
Mean cover [%]		49.6	*129*	27.0	46.5	24.3	52.8
Mean species richness (1000 m²)		17.7	*8.0*	8.0	18.7	10.7	21.8
Unit 1: Oshana wetlands							
Pycreus chrysanthus	23.00	16	*100*	100	.	.	6.3
Unit 1.1: Nymphaea nouchali-Nymphoides indica association sensu Kangombe							
Cyperus digitatus	2.00	4	*100*	.	.	.	.
Cynodon dactylon	0.50	4	*100*	.	.	.	.
Lagarosiphon cordofanus	0.50	4	*100*	.	.	.	.
Nymphoides indica	15.50	8	*100*	.	.	.	6.3
Leptochloa fusca	13.50	20	*100*	.	.	33	19
Nymphaea nouchali	0.67	12	*100*	50	.	.	6.3
Eragrostis rotifer	3.67	36	*100*	50	67	.	31
Unit 1.2: Leptocloa fusca-Aponogeton junceus community							
Crinum rautanenianum	0.67	12	.	100	.	.	6.3
Marsilea species	0.90	20	.	100	.	33	13
Aponogeton junceus	1.00	20	.	100	.	67	6.3
Eleocharis acutangula	0.50	4	.	50	.	.	.
Commelina subulata	0.79	28	.	100	33	33	19
Unit 2: Mopane savanna							
Colophospermum mopane	11.00	72	.	.	33	67	94
Monandrus squarrosus	0.58	72	.	.	67	33	94
Gisekia africana	0.59	68	.	.	33	33	94
Kohautia azurea	0.62	68	.	.	100	67	75
Willkommia sarmentosa	1.97	60	.	.	33	67	75
Chloris virgata	1.18	56	.	.	67	33	69
Mollugo cerviana	0.54	56	.	.	100	.	69
Eragrostis trichophora	9.02	84	.	50	67	67	100
Unit 2.1: Pennisetum glaucum-Amaranthus thunbergii community							
Pennisetum glaucum	33.33	12	.	.	100	.	.
Dactyloctenium aegyptium	0.83	36	.	.	100	.	38
Amaranthus thunbergii	0.75	8	.	.	67	.	.
Hermbstaedtia argenteiformis	1.25	8	.	.	67	.	.
Portulaca oleracea	0.50	8	.	.	67	.	.
Eragrostis cylindriflora	0.75	8	.	.	67	.	.
Cleome gynandra	0.50	8	.	.	67	.	.
Sesuvium sesuvioides	0.65	40	.	.	100	33	38
Eragrostis viscosa	0.60	20	.	.	67	.	19
Cyperus obtusiflorus	0.50	12	.	.	67	33	.
Kohautia aspera	0.50	4	.	.	33	.	.
Sesamum triphyllum	0.50	4	.	.	33	.	.
Citrullus lanatus	2.00	4	.	.	33	.	.
Dichrostachys cinerea	0.50	4	.	.	33	.	.
Pogonarthria fleckii	1.50	40	.	.	67	.	50
Unit 2.2: Hyphaene petersiana-Acacia arenaria association sensu Kangombe							
Eragrostis cilianensis	0.70	20	.	.	.	67	19
Ledebouria cooperi	0.83	12	.	.	.	67	6.3
Hyphaene petersiana	0.50	4	.	.	.	33	.
Ziziphus mucronata	1.00	4	.	.	.	33	.
Combretum imberbe	2.00	4	.	.	.	33	.

continued on next page

Classification table (continued)

Column	Cover	All	1.1	1.2	2.1	2.2	2.3
Number of relevés		**25**	**1**	**2**	**3**	**3**	**16**
Unit 2.3: Colophospermum mopane-Eragrostis trichophora association sensu Kangombe							
Limeum myosotis	2.53	64	.	.	.	.	100
Anthephora schinzii	5.67	60	.	.	.	.	94
Brachiaria xantholeuca	2.68	44	.	.	.	.	69
Justicia exigua	0.94	36	.	.	.	.	56
Aristida stipoides	3.50	32	.	.	.	.	50
Eragrostis porosa	6.00	32	.	.	.	.	50
Urochloa brachyura	0.92	24	.	.	.	.	38
Hibiscus sidiformis	0.58	24	.	.	.	.	38
Indigofera charlieriana	0.50	24	.	.	.	.	38
Hirpicium sp.	0.50	20	.	.	.	.	31
Most frequent companions							
Bulbostylis hispidula	0.81	72	.	.	67	33	88
Cyperus schinzii	0.63	48	.	50	.	33	63
Acacia nilotica	1.25	32	.	.	.	33	44
Ipomoea coptica	0.50	24	.	.	33	.	31
Dicoma tomentosa	0.70	20	.	.	33	.	25
Asparagus suaveolens	0.70	20	.	.	.	33	25
Chamaesyce inaequilatera	0.50	20	.	.	.	.	31
Tragus racemosus	1.00	16	.	.	.	.	25
Achyranthes aspera v. sicula	0.63	16	.	.	.	.	25
Cyperus compressus	0.63	16	.	.	33	33	13
Kyllinga intricata	0.67	12	.	.	.	.	19
Aristida rhiniochloa	0.67	12	.	.	.	.	19
Geigeria ornativa	0.67	12	.	.	.	.	19
Tribulus terrestris	0.50	12	.	.	33	.	13
Portulaca hereroensis	0.50	12	.	.	.	.	19

at the centre of the pond. The sedge community along the edges of these ponds is variable and dependant on the depth of the water, with *Cyperus digitatus* and *Pycreus chrysanthus* being dominant.

The *Leptochloa fusca-Aponogeton junceus* community (unit 1.2) is representative of the deep-water Oshanas. Water depth ranges between 20 and 50 cm in most places. A dense cover of the water grass *Leptochloa fusca* in association with other water grasses such as *Eragrostis rotifer* (Vlei Love-grass) and *E. cilianensis* is typical of this community. *Willkommia sarmentosa* (Brackarmgras) is a widespread grass in this area, and also populates the Oshanas. This grass becomes more important in the dry season when it acts as a ground cover. Other hydrophytes occurring in this community are the geophytic species *Crinum rautaneni-anum* and *Aponogeton junceus*, the water ferns of the genus *Marsilea*, as well as the sedge *Pycreus chrysanthus*. These Oshanas generally covered by grasses throughout the wet season.

The crop fields represent the *Pennisetum glaucum-Amaranthus thunbergii* community (unit 2.1), which are dominated by the local staple crop *Pennisetum glaucum* (Pearl Millet or Mahangu), as well as other crops such as Water Melon (*Citrulus lanatus*). Most woody plants are removed although large trees (like at Ha 8 – *Colophospermum mopane*) are occasionally left standing. The common herbs are generally removed, whilst other weedy herbs do persist. The seeds of these weeds are typically dispersed by tilling, cattle and/or together with crop seeds. Some of these weeds, such as *Amaranthus thungerbii* and *Cleome gynandra*, are used as a food source (as a type of wild spinach).

Unit 2.2 represents the *Hyphaene petersiana-Acacia arenaria* association sensu Kangombe (2007). This community forms a transition between the deep Oshanas and the dry Mopane savannas. Depending on the intensity of the "Efundja", this community may occasionally become flooded, resulting in a relative low tree and shrub cover, but high grass cover. At the Observatory, the tree layer is characterised by *Hyphaene petersiana* (Makalani Palm), and scattered Mopane trees (*Colophospermum mopane*) also occur. *Acacia arenaria* (Sand Acacia) was not recorded within the sample plots but is present on the Observatory. The grass sward is dominated by *Willkommia sarmentosa* and *Eragrostis rotifer*. The low-growing *Eragrostis cilianensis* also occurs here. This combination, which also occurs in the Oshanas, is indicative of the wetland nature of this community.

Unit 2.3 represents the *Colophospermum mopane-Eragrostis trichophora* association sensu Kangombe (2007). Four different subassociations were recognised, with this community forming part of the *Colophospermum mopane-Willkommia sarmentosa* subassociation. The presence of the grasses *Eragrostis rotifer* and *Willkommia sarmentosa* are indicative of the temporarily waterlogged soils of this community. Other typical grasses associated with moist soils occurring here are *Chloris virgata* (Feather-top Chloris) and *Brachiaria xantholeuca.* The grass sward is fairly sparse, even though the land is only lightly utilised for grazing, which is typical of many Mopane-dominated savannas.

Unit 1.1, 2008. Photo: F.N. Kangombe.

Unit 1.2, 2006. Photo: B.J. Strohbach.

Unit 2.1, dominated by the local staple crop *Pennisetum glaucum* (Pearl Millet or Mahangu). Photo: B.J. Strohbach.

Unit 2.2, 2006. Photo: B.J. Strohbach.

Unit 2.3, 2006. Photo: B.J. Strohbach.

Responsible authors: B.J. Strohbach, F.N. Kangombe & J. Luther-Mosebach

Site-specific studies

Vegetation of the Ogongo Agricultural College and surrounding communal farming areas

► *See* **S42.01**

Photo: J. Deckert

Thornbush Savanna

Boundaries
- International Boundary
- Provincial Border

Hydrography
- River
- Periodical River
- Salt Pan
- Lake
- Wetland

Contour Levels
- up to 300 m
- up to 600 m
- up to 900 m
- up to 1200 m
- up to 1500 m
- up to 1800 m
- more than 1800 m

Communications
- Motorway
- Road
- Railway

Populated Places
- City
- Provincial Capital
- Capital

- Transect
- S32 Elandsberg — BIOTA Observatory

0 250 500 km

Uwe Ulrich Jäschke & Karen Langner • HTW - University of Applied Sciences Dresden

Savanna landscape on the farm Rooisand. Photo: J. Deckert.

Thornbush Savanna

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II.3.7 Alpha (S17) 300

Savannas, which are characterised by an extensive cover of grasses with scattered trees, cover almost one third of the land surface of the earth and 40% of Africa. In southern Africa, savannas are home to growing human populations and most people depend on the ecological resources these systems offer. The main landuse practices in the Thornbush Savanna are farming with cattle and—increasingly so—game for trophy hunting. Increasing landuse pressure due to population growth, as well as landuse change as a consequence of political and socio-economic development have led to ongoing processes of savanna degradation, namely shrub encroachment, species shifts and losses, and soil erosion. These factors are likely to be further aggravated by projected climatic changes, enhancing the risk of desertification. This biome was therefore a special focus within the BIOTA Southern Africa project.

Seven Observatories were established in the Thornbush Savanna Biome. These Observatories represent different landuse types including commercial cattle farming (S05 Otjiamongombe), game farming (S04 Toggekry) and communal cattle farming (S06 Okomboro). They also cover the climatic gradient from the coastal desert in the west to the sub-humid interior in the east (S37 Rooisand, S38 Claratal, S41 Sandveld) as well as the unique Kalahari Desert (S17 Alpha). [U. Schmiedel]

General data

Number	Name	Alternative name(s)
S04	Toggekry	Omatako Ranch
Implementation	Country	Province/ region
2001	Namibia	Otjozondjupa
District/ constituency	Locality	Farm name
Okahandja	Omatako Ranch	Omatako Ranch
Latitude	Longitude	Altitude
21.501438 S	16.729326 E	1519 m a.s.l.
Rainfall season	Biome	WWF Ecoregion
Summer	Thornbush Savanna	AT1309 Kalahari xeric savanna
Agro-Ecological Zone	Relative intensity of land use	Tenure
CPL2	Medium	Private
Type and history of landuse	Land owner	
Farming with game for hunting	Private	

Toggekry (S04)

Mound of the fungus-growing termite species *Macrotermes michaelseni*. Photo: J. Deckert.

The BIOTA Observatory Toggekry (commonly named Omatako) is situated approximately 60 km northwest of Okahandja in the Otjozondjupa region. The mean altitude is 1519 m a.s.l. and the topography is flat to gently undulating. The soils are sandy to loamy and differ in colour from grey to reddish. The open Thornbush Savanna is dominated by *Acacia* species and grasses, and bush encroachment by *Acacia mellifera* occurs in some areas. From 2001 to 2009 Toggekry received an average annual rainfall of 346 mm mainly during the summer months from September to April.

Over the last two decades, the farming system has changed from a commercial cattle farm to a hunting farm, and the area of the farm has increased to approximately 15,000 ha. The "Omatako Hunting Ranch" is a family business and is host to species such as Sable Antelope, Common Eland, Black- and Blue Wildebeest, Mountain- and Burchell's Zebra, Giraffe, and Black Rhinoceros. Mounds built by the termite *Macrotermes michaelseni* are a widespread feature of the landscape on the farm and in the region.

The BIOTA Observatory was established to monitor changes induced by intensive game farming in comparison to cattle farming on the BIOTA Observatory Otjiamongombe, about 24 km to the south-east. The Observatory is regarded as typical for the central Namibian Thornbush Savanna and covers areas with different proportions of woody

species, grasses, and herbs. The monitoring of climate induced changes and bush encroachment needs to be addressed in this area.

Responsible authors: A. Gröngröft, C. Grohmann & D.H. Haarmeyer

Remote sensing and landscape

Geomorphology	Geological units	Lithological units
Red, yellow, pale, sandy soils	Swakop Group in Damara Supergroup and Gariep Complex	Schists and dolomites
Mean EVI	**EVI absolute range**	**Mean leaf area index**
0.171 (0.122–0.305)	0.114 (2001)–0.412 (2008)	0.59

Grid map of Observatory

	0	1	2	3	4	5	6	7	8	9
0	44	90	83	89	72	14	9	79	35	74
1	97	81	88	47	67	25	95	8	19	41
2	64	18	40	36	62	42	43	60	30	46
3	11	7	29	57	52	31	78	87	13	70
4	59	6	39	99	20	3	58	55	24	50
5	38	69	85	66	93	82	94	51	2	65
6	54	75	77	91	86	37	84	71	73	45
7	80	10	61	1	56	100	26	96	4	28
8	48	63	21	92	53	34	76	22	33	16
9	15	32	98	23	68	12	17	27	5	49

1 Dense Acacia-dominated thornbush savanna on loamy, red soils
2 Open Acacia-dominated thornbush savanna on loamy, red soils
3 Open Acacia-dominated thornbush savanna on loamy, yellow to pale soils
4 Open grass-dominated thornbush savanna on sandy soils
5 Open disturbed thornbush savanna with pioneer vegetation on sandy soils

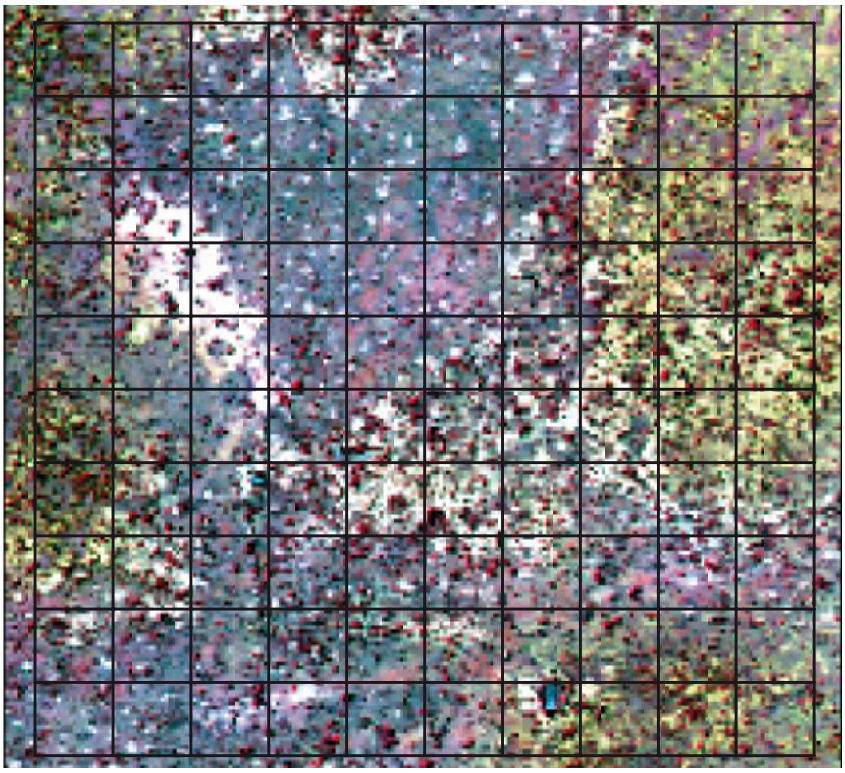
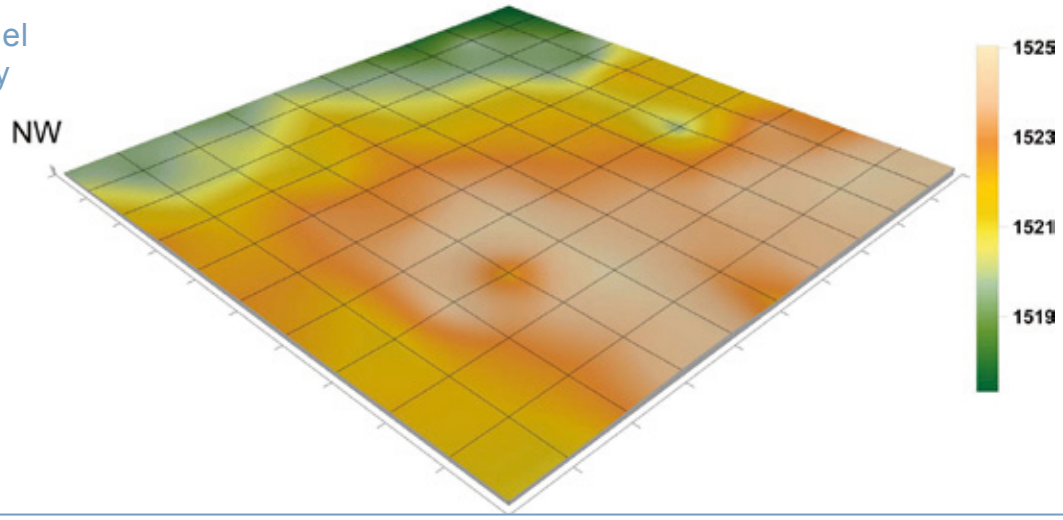


Image: HYMAP, 12 April 2004

Elevation model of Observatory



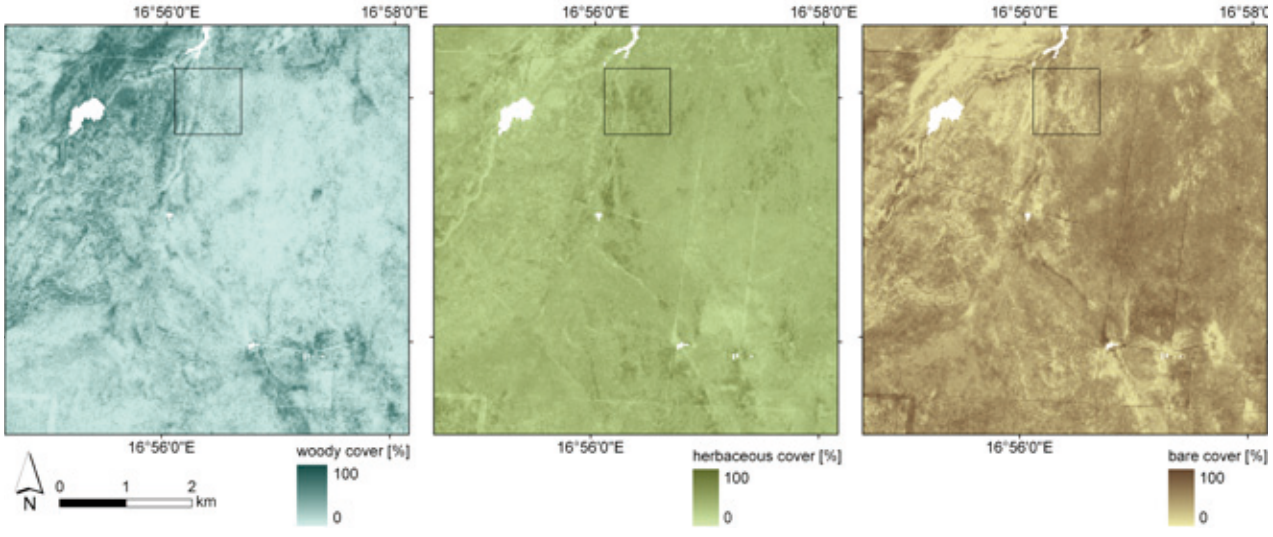
Landsat image

The Observatory Toggekry is located in the central Namibian mixed Thornbush Savanna. The topography of the area is almost flat to gently undulating. About 2 km south-west of the Observatory, three small pans, approximately 2 km south-west of the Observatory, appear to be filled with water (nearly black) at the time the aerial image was taken, which was at the end of the rainy season.

The landscape is a mosaic of patches with high tree and shrub densities (red) and patches dominated by grassy vegetation (green to blue grey). Grass density may vary over time. Recent grazing impacts are visible as brighter or bluish patches which depict areas of lower vegetation density. The white spot (approximately 300 m by 100 m in size) in the western part of the Observatory indicates a nearly bare soil surface.

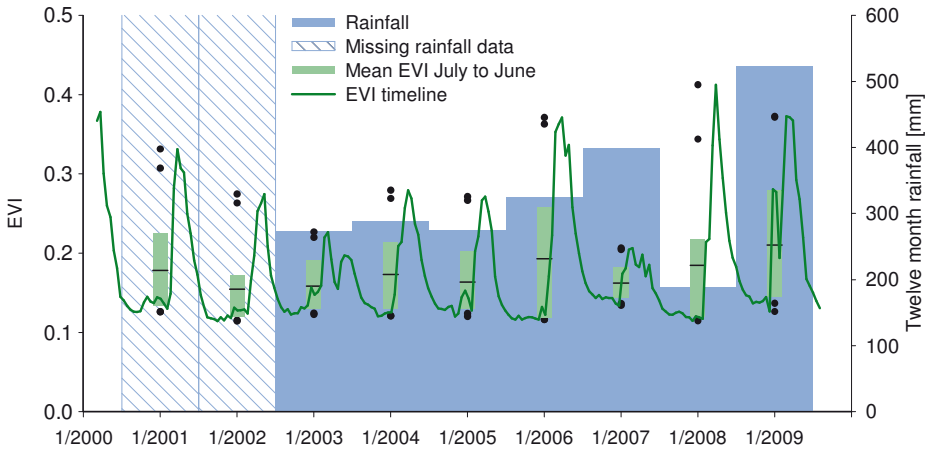
Scene 178/75, acquisition date: 24 April 2006

Fractional cover image



MODIS time series

Temporal patterns of annual rainfall, vegetation cover, and phenology



Responsible authors: M. Keil & T. Labitzky

Climate

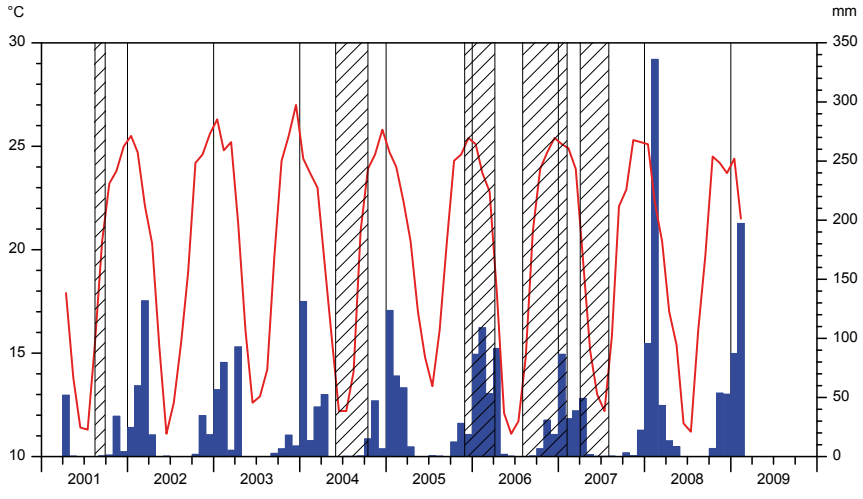
Data from BIOTA weather station

Location	Recorded period	Mean temperature
Toggekry (S04)	2001–2009	20.6 (-4.5–40.0) °C
Mean solar radiation	**Mean wind speed**	**Mean annual precipitation**
640 (313–1458) MJ·m^{-2}·month^{-1}	1.8 (5.9) m·s^{-1}	346 (270–298) mm
Mean annual potential evapotranspiration	**Interannual precipitation variability**	**Mean relative humidity**
1732 mm	149%	45% (22–86%)
Aridity index (UNEP)		
0.20 (arid)		

Modelled data

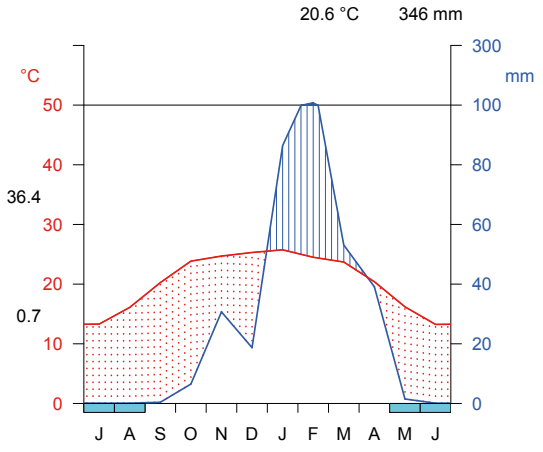
Mean temperature	Mean annual temperature range	Mean diurnal temperature range
19.1 (3.9–31.9) °C	9.8 °C	17.5 °C
Mean annual precipitation	**Precipitation seasonality**	**Percentage winter precipitation**
394 mm	110%	11% (strong summer)
Climate type	**Length of dry season**	**Aridity index (De Martonne)**
BWh	9 months	13.5 (semi-dry)

Time series: rainfall and temperature

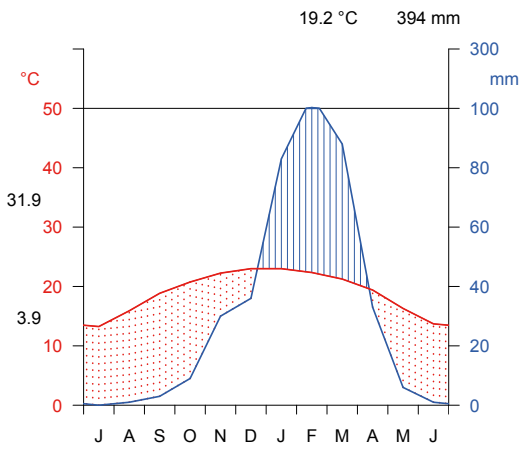


Climate diagrams

Recorded data (BIOTA)

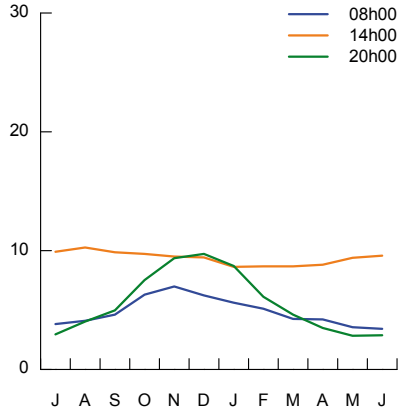


Modelled data (WorldClim)

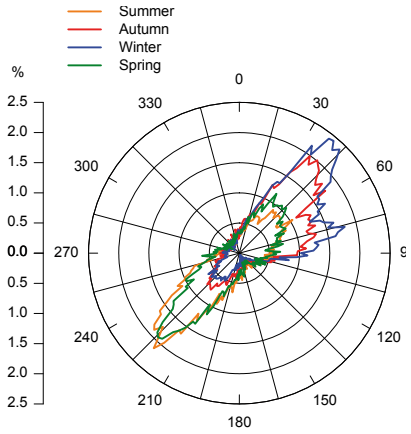


Wind diagrams

Speed



Directions



The climate at the Observatory is characterised by semi-arid conditions. Rainfall shows a strong seasonality with almost all rain falling during the summer season, peaking in February. The mean annual rainfall over the observation period was 346 mm, which is wetter than the average rainfall recorded at all Observatories, and at the Observatories within the Thornbush Savanna. However, substantial interannual variability is evident. Observed near-surface air temperatures show a moderate seasonal cycle. The mean annual temperature is 20.6°C, which is the approximate average for this biome. The observed mean minimum temperature is above the freezing point, but there is still a possibility of the occurrence of frost during the months of May to August. Compared to the interpolated long-term data taken from the WorldClim dataset, only minor differences in mean annual temperatures are evident. However, the station records of extreme temperatures deviate substantially from the WorldClim data, showing warmer maximum and colder minimum temperatures. For precipitation, mean annual rainfall is lower at the BIOTA weather station compared to the WorldClim data. Additionally, the station data shows a small secondary rainfall maximum in early summer that is not evident in the WorldClim data.

The observed near-surface winds at the Observatory are mainly constituted of south-westerly flows during the spring and summer seasons, but also shows a weak north-easterly component. This circulation is reversed during the autumn and winter seasons, with a major north-easterly flow component. Mean wind speed is highest during early afternoon, reaching about 10 km/h. Winds during that time of the day stay fairly constant throughout the year, whereas a pronounced annual cycle is evident for the mean wind speed recorded during the morning and evening.

Responsible authors: K. Berger, A. Haensler & J. Luther-Mosebach

Soils

Year of sampling	Hectare plots sampled	SOTER unit
2001	41 (R1–40, R70)	NA56
Soilscape	**Dominant soil group(s)**	**Reference group richness**
Luvisol/Arenosol	Cambisol, Arenosol, Luvisol	3
Soil unit richness	**Soil unit evenness**	**Soil ecotype richness**
9	0.633	5
Parametric space	**pH**	**Electrical conductivity**
2.61	5.1 (4.4–7.0)	32 (10–59) $\mu S \cdot cm^{-1}$
Organic carbon		
0.29% (0.06–2.35%)		

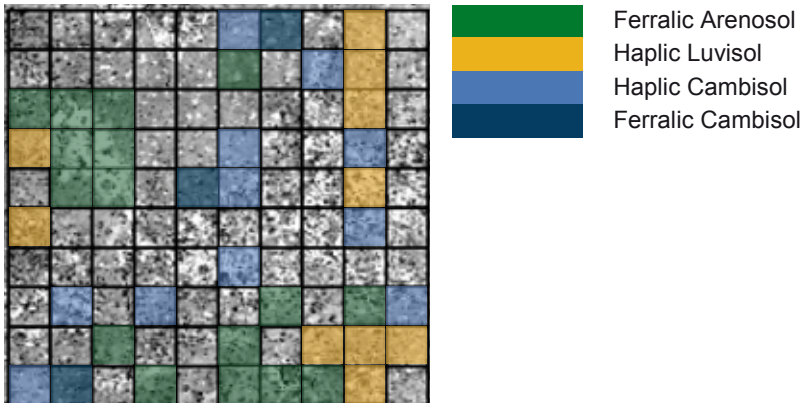
On this Observatory, the soil reference groups Arenosol, Cambisol and Luvisol occur. Approximately one third of the profiles are Arenosols which are predominantly found in and around habitat 5 (i.e. open disturbed Thornbush Savanna with pioneer vegetation on sandy soils) and in some sandier areas in the southern part of the Observatory. A soil unit bridging to the Luvisols is the Hypoluvic Arenosol, showing signs of weak clay enrichment in the subsoil horizons. Luvisols are exclusively found in habitats 1 and 2, here associated with Cambisols, which are mostly classified as 'Eutric'. In contrast, the yellowish to pale coloured Cambisols in habitats 3 and 4 are in most cases more sandy and 'Dystric'. In nearly all profiles the rooting depth is deeper than 1 m; in few sites limitations caused by saprolithic bedrock occur.

The most frequent qualifiers Eutric, Dystric, Ferralic, Arenic, and Chromic reflect the variability regarding base saturation, pH value, cation exchange capacity, texture, and substrate colour, properties, which can roughly be correlated to the different habitats. Often the influence of termites on the soil properties overrides the effects of the soil genesis and original substrate properties. Transport of subsoil material in combination with changes in the geochemical properties (see Petersen 2008) creates a small scale variety within a relatively homogenous substrate.

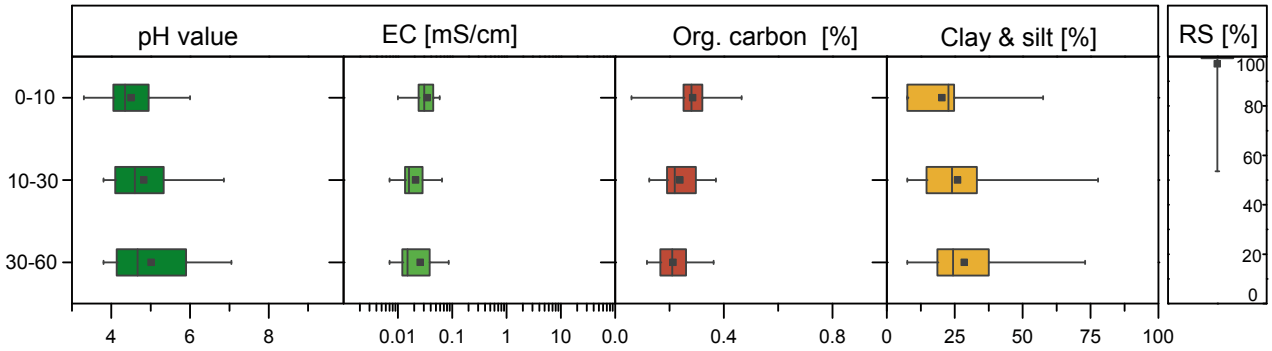
The pH values show a relatively wide variability with depth. The electrical conductivity is very low with little variation and with slightly higher values in the topsoil. These low contents of soluble salts, comparable with the nutrient status of rainwater, indicate a deep drainage of the soils. Within the topsoil layer, the total range of organic carbon is large whereas the majority of its values have only small ranges in each dataset and show a slight decrease in median values with depth. In contrast, the percentage of fine particles (clay and silt) increases with depth and varies significantly. Except for a few profiles in contact with the underlying bedrock, the rooting space is near 100% in all investigated profiles. The topsoil nutrients indicate a restricted availability of phosphorous and potassium and most likely also of nitrogen, although the total reserves are in a medium range.

Texture ranges from sand to sandy clay, and only few samples have higher silt contents. This clay-sand mixture without a silt fraction is a typical feature of these savanna soils. With regard to the sand fractions, the samples have a fairly constant amount of coarse sand (~ 20%) and typically slightly more medium than fine sand contents. High coarse sand proportions indicate that the substrate is not strongly influenced by wind blown sands. This influence becomes more important towards the eastern direction of the region (Kalahari Sands). More likely, the differences in substrates within the Observatory are a result of the heterogeneity of the underlying bedrock material, i.e. the lithology of the area. During the survey (in 2001) three different kinds of rock were found in the profiles or on the surface as a result of burrowing animals: (i) pegmatic granites with large minerals, (ii) 'standard' granites, and (iii) granites that are fine-structured like sandstones. We assume that these bedrocks have influenced the substrate genesis by different weathering behaviour. Moreover, the massive transport of soil parent material during the landscape evolution might also have been an important factor for substrate differentiation. The stratification within habitat 4 is a result of these processes.

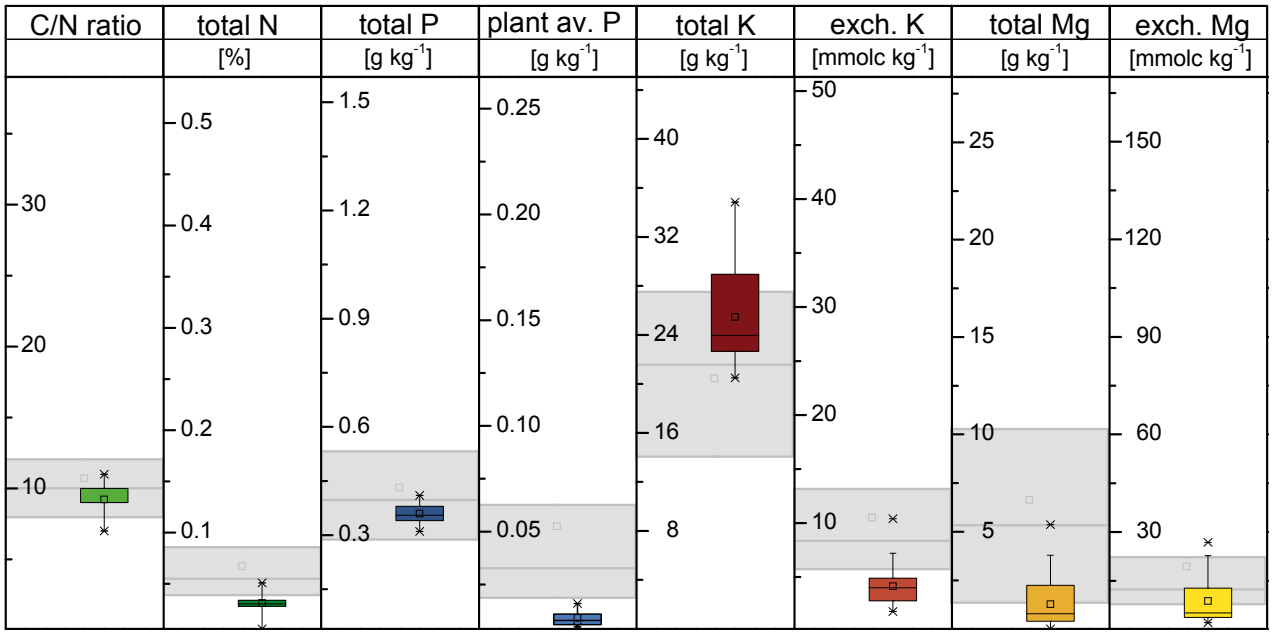
Map of soil profiles



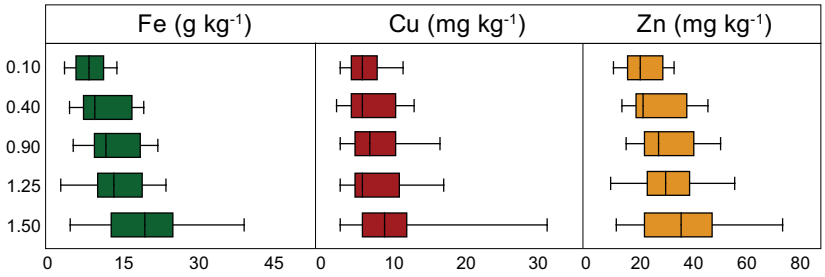
Soil characteristics



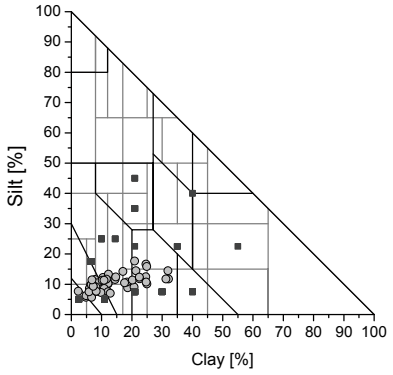
Soil nutrients



Soil micronutrients



Soil texture triangle



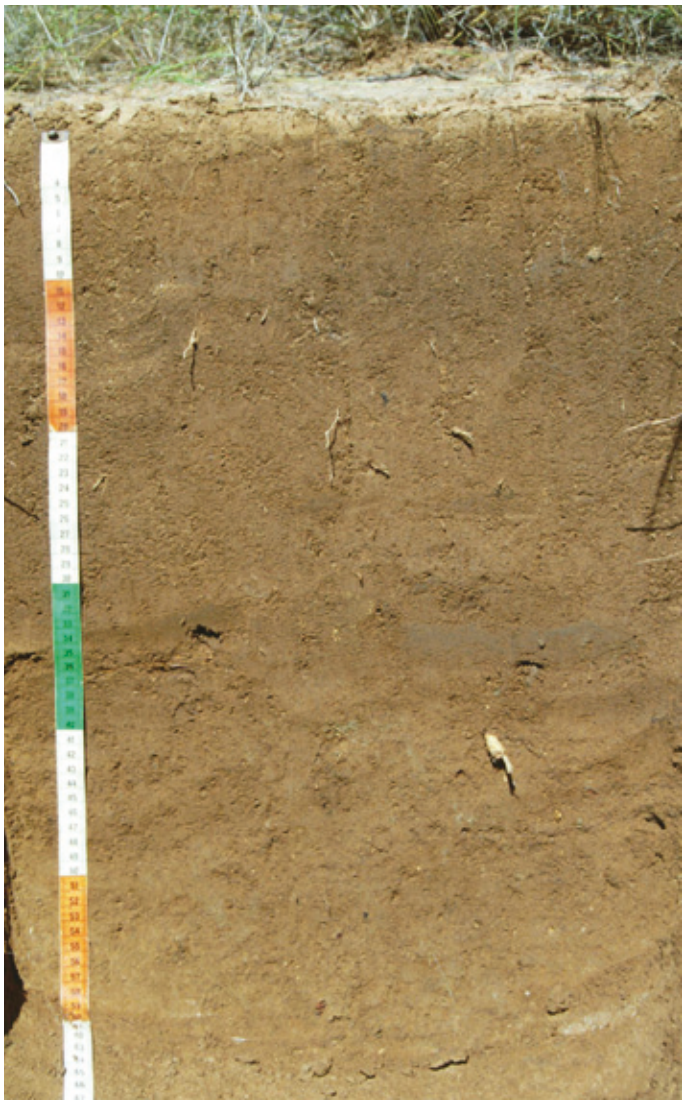
The variability of soil properties is not only a result of differences between habitats and soil units, but is additionally promoted by termite activity, which correlates to small scale changes in pH, electrical conductivity and texture.

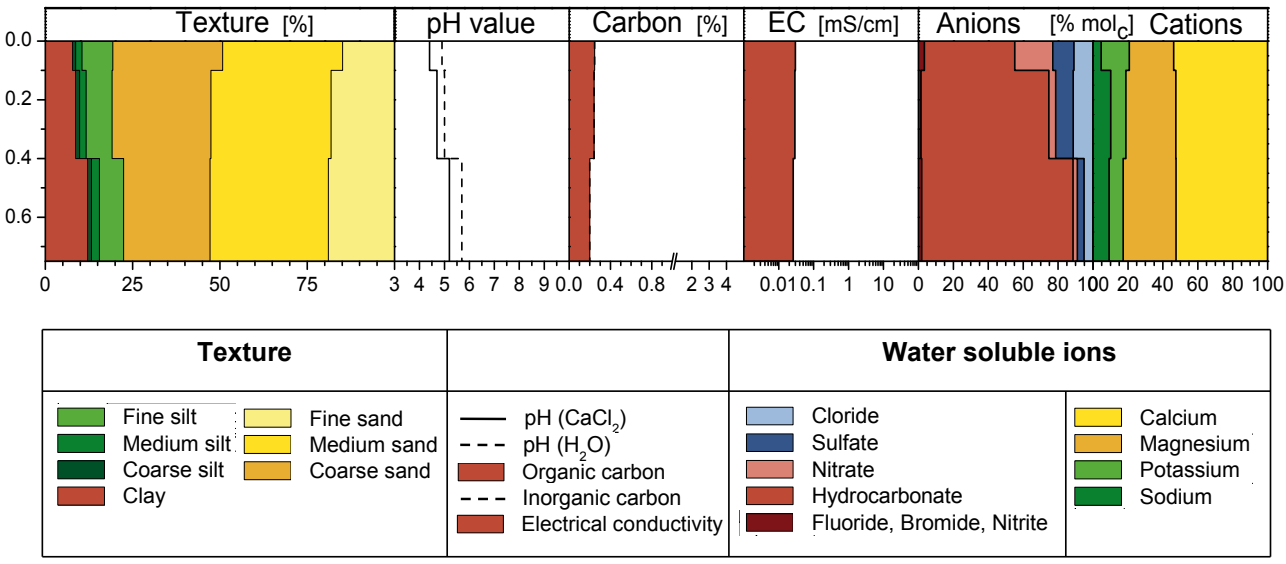
The vegetation distribution patterns of high tree and bush densities in habitat 1 and 2, more open grasslands in habitat 3 and scattered trees in habitat 4 correlates with soil texture and cation exchange capacity. Nutrient availability, on the other hand, is probably not the dominant factor responsible for this vegetation distribution pattern. More likely, this differentiation is driven by the sequence from pure sands in habitat 5 to sandy clay loam in habitat 1, which may cause a large variation in water supply.

Reference profile (H45)

Within habitat 3, **Cambisols** are the typical soil unit. The soils have developed in yellowish brown loamy sand to sandy loam substrates with a subangular, blocky structure. The texture shows only a slight increase in clay with depth, and in the sand fraction the coarse sand fraction is smaller than in other soils on the Observatory. The bulk density is comparably high (1.6–1.7 g cm^{-3}), and under dry conditions the subsoil have a massive concrete-like character, resulting in high excavation difficulty.

The reaction is strongly acid in the topsoil and slightly acid in the subsoil. The organic carbon and the electrical conductivity are very low. The content of pedogenic iron oxides is relatively low (40–50%) compared to other soils in the region, indicating a moderate weathering status. The cation exchange capacity correlates with the clay content with values of 22–35 $mmol_c$ kg^{-1}. The content of water soluble ions is very low.





Responsible authors: U. Wisch, A. Petersen, A. Gröngröft & D. Mager

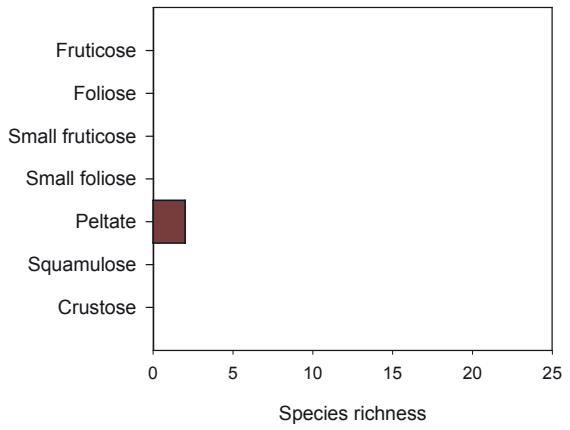
Lichens

Sampling period(s)	Hectare plots sampled	Cover
2001, 2004	10 (R1−R10)	0.1% (0−0.6%)
Total species richness	**Species richness on soil [1 km²]**	**Species richness on rock [1 km²]**
3	2 (67%)	n.a.
Species richness on plants [1 km²]	**Species richness on soil [1000 cm²]**	
1 (33%)	0.1 (0−1)	

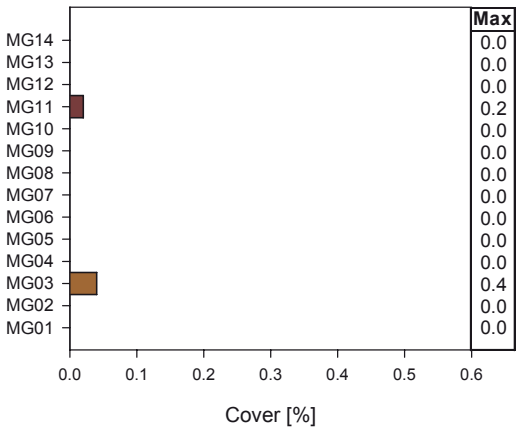
Lichens are infrequent at this Observatory, although the site is climatically suitable for lichen growth due to the relatively high rainfall. Each of the substrates hosted only a few species (although epiphytic and saxicolous lichens were not examined in detail). Only two terricolous cyanolichen species with peltate and small fruticose thalli were found. The low richness of soil-inhabiting lichens is probably due to the acidic soils, with very low calcium carbonate contents, and the sandy texture of the soils in some of the hectare plots.

Only one investigated hectare plot contained lichens, with a low average cover of less than 1%. Only two morphological groups (MG03 and MG11) are present, both with an average cover of less than 0.1%. The low and patchy cover of lichens can be attributed to the spatial heterogeneity of soils, which are unsuitable for lichen growth in many plots.

Growth forms



Morpho groups



List of taxa

Terricolous (on soil):

Heppia despreauxii
Peccania cf. subnigra

Saxicolous (on rock):

No records

Epiphytic (on plants):

Caloplaca citrina

Peccania cf. *subnigra*.
Photo: L. Zedda & G. Rambold.

Responsible authors:
L. Zedda & G. Rambold

Vascular plants

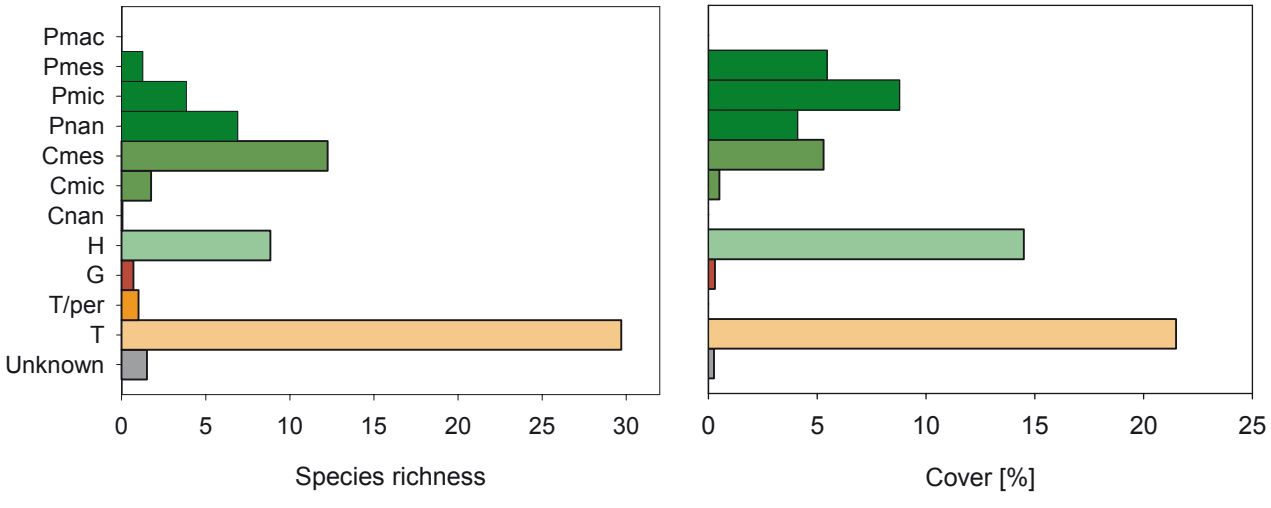
Sampling period(s)	Hectare plots sampled	Biome
2001–2009	20 (R1–R20)	Thornbush Savanna
Vegetation unit (level 1)	**Vegetation unit (level 2)**	**Identification rate**
Thornbush Savanna (Tree and Shrub Savanna)	n.a.	78% – 96% – 97%
Cumulative family richness	**Dominant families (cover)**	**Dominant families (richness)**
50	Poaceae, Fabaceae, Solanaceae	Poaceae, Fabaceae, Asteraceae
Cumulative species richness (1 km²)	**Species richness (1000 m²)**	**Species richness (100 m²)**
334 – 185	54.5 (0–101)	34.3 (14–61)
***z*-value**	**Species richness change per year (1000 m²)**	**Evenness (1000 m²)**
0.200 (0.102–0.525)	1.78	0.603 (0.278–0.878)
Evenness (100 m²)	**Simpson (1000 m²)**	**Simpson (100 m²)**
0.553 (0.208–0.804)	0.773 (0.332–0.955)	0.701 (0.210–0.920)

The vegetation of the Observatory Toggekry (S04) belongs to the Thornbush Savanna Biome. It is a typical savanna with alternating patches of open, grassy areas, with *Stipagrostis uniplumis* (Blinkhaarboesmangras) dominating, and patches of dense woody cover. There is no orographic structure—the whole Observatory area is flat without any specific geomorphological peculiarities. A prominent feature is the high abundance of mounds of the termite *Macrotermes michaelseni*. With heights of up to four metres, they are important landscape features that strongly influence nutrient cycling, soil and vegetation patterns. This is why parts of the Thornbush savanna are sometimes referred to as "termite mound savannas". During times of high rainfall, shallow depressions are waterlogged for short periods of time, and wildlife such as Warthog, Wildebeest, and Kudu use these depressions as watering points and cause slight disturbance around these areas through grazing and trampling. Five different habitat types (defined mainly according to soil properties) and three different vegetation units occur at the Toggekry Observatory.

The *Acacia hebeclada-Sida cordifolia* community (unit 1) occurs on loose sandy substrates. The part of the Observatory where this community occurs is a preferred area for burrowing animals such as Porcupine or Aardvark. Antelope are also attracted to this area. The loose substrates and the disturbance caused by animals results in sparse vegetation cover in this community, which is dominated by annual species and, depending on rainfall, a high proportion of bare soil. Spatio-temporal rainfall patterns exerts control over the species germinating from the soil seed bank, which can lead to a totally different appearance of the vegetation in different years. Besides some deeper rooted woody species such as *Acacia hebeclada* (Candle Thorn) and *Boscia albitrunca* (Shepherd's Tree), prostrate annuals such as *Requienia sphaerosperma* and *Indigofera alternans* are representative of this community.

The *Aptosimum lineare-Acacia tortilis* community (unit 2) covers the largest part of the Observatory. This unit possesses the highest woody cover compared to the other communities. Dominant woody species are the potential encroacher spe-

Life forms

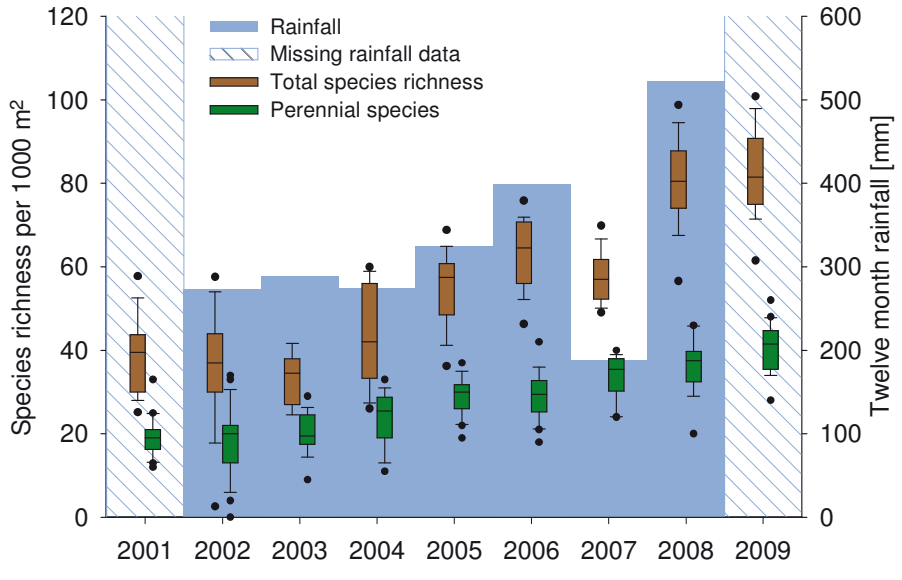


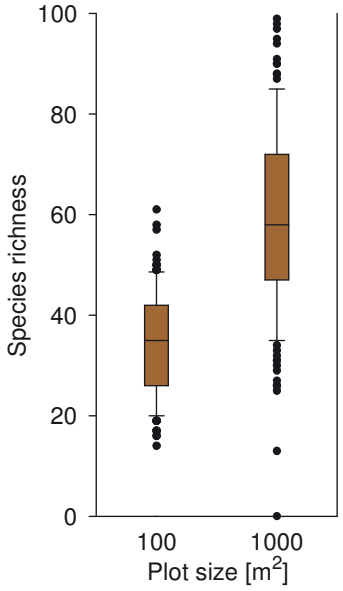
cies *Acacia mellifera* (Swarthaak) and *Acacia reficiens* (Rooihaak), as well as the tree *Albizia anthelmintica,* which is a valuable browse species for game and livestock. The grass layer is dominated by *Stipagrostis uniplumis*, the most important perennial grass in the whole area, and by *Eragrostis porosa* (Windgras) an annual grass occurring in high abundances during good rainfall years. The weak perennial herb *Aptosimum lineare* and the dwarf shrub *Monechma genistifolium* can occur in greater numbers in overgrazed patches. Many species which prefer moist damp places in the shadow (e.g. *Hibiscus calyphyllus* and *Pavonia burchellii)* occur in this community due to the relatively high cover of shrubs and trees.

The *Crotalaria heidmannii-Dichrostachys cinerea* community (unit 3) represents the

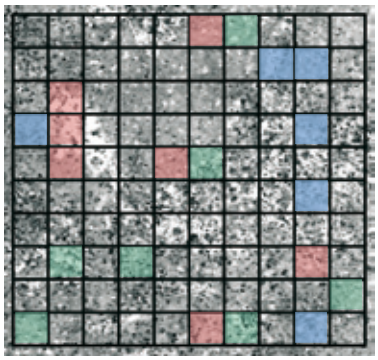
The Omatako Ranch is a game farm, 2007. Photo: D. Wesuls.

Species richness





Map of vegetation units



more open parts of the savanna landscape, although the woody cover of *Acacia mellifera* and *Acacia reficiens* can still be substantial. The dominant perennial grasses in this community are *Stipagrostis uniplumis* and *Eragrostis rigidior*. The name of the latter species refers to its rigid growth form. It can always be found where the soil is more sandy. Another typical species is the aromatic dwarf shrub *Ocimum americanum var. americanum*. This plant exudes a unique odour at the time of flowering. It can be used for the preparation of a herbal tea. The shrub *Dichrostachys cinerea* can be a potential encroacher species. This is rarely the case in this area because the winter frosts that occur at these latitudes cause a regular dieback of the topmost vegetative parts. Individuals of *D. cinerea* with a high proportion of dead wood are visible signs of this phenomenon.

Classification table (2009)

Column		Cover	All	1	2	3
Number of relevés			**20**	**7**	**6**	**7**
Mean cover [%]			68.5	59.1	81.5	66.7
Mean species richness (1000 m²)			82.5	77.4	79.2	90.4
Mean soil pH			4.31	4.20	4.78	4.00
Mean electrical conductivity [µS·cm^{-1}]			39	42	40	36
Organic carbon [%]			0.27	0.25	0.28	0.27
Nitrogen [%]			0.03	0.03	0.03	0.03
Fine material [%]			90.0	87.0	95.2	88.6
Gravel [%]			6.6	11.6	2.5	5.0
Unit 1: Acacia hebeclada-Sida cordifolia community						
H	Chamaecrista biensis	0.10	30	86	.	.
H	Xenostegia tridentata ssp. angustifolium	0.16	35	86	.	14
Cmes	Hermannia tomentosa	0.21	35	86	.	14
H	Requienia sphaerosperma	15.00	20	57	.	.
T/per	Sida cordifolia	0.83	40	86	17	14
Pmic	Acacia hebeclada ssp. hebeclada	1.43	30	71	.	14
H	Indigofera alternans	0.10	30	71	.	14
Pnan	Neorautanenia mitis	0.31	50	86	33	29
Unit 2: Aptosimum lineare-Acacia tortilis community						
Cmes	Aptosimum tragacanthoides	0.10	40	.	100	29
n.a.	Petalidium sp. 129561	0.40	20	.	67	.
T	Limeum argute-carinatum	0.14	50	.	100	57
T/per	Phyllanthus maderaspatensis	0.10	35	.	83	29
Cmes	Tribulus zeyheri	0.16	35	.	83	29
T	Indigofera charlieriana	0.25	55	.	100	71
n.a.	Heliotropium steudneri	0.10	60	.	100	86
Cmic	Leucosphaera bainesii	0.56	60	14	100	71
Pnan	Monechma genistifolium	0.61	60	14	100	71
Pmes	Acacia tortilis ssp. heteracantha	0.45	30	.	67	29
T	Geigeria acaulis	0.23	30	.	67	29
T	Mollugo cerviana	0.10	45	14	83	43
H	Blepharis integrifolia var. integrifolia	0.10	45	14	83	43
T	Tragus berteronianus	0.10	45	.	83	57
Unit 3: Crotalaria heidmannii-Dichrostachys cinerea community						
H	Crotalaria heidmannii	0.10	50	29	17	100
T	Lotononis platycarpa	0.10	20	.	.	57
T	Monsonia angustifolia	0.10	30	14	.	71
H	Chascanum pinnatifidum	0.10	60	57	17	100
T/per	Portulaca kermesina	0.10	25	14	.	57
T	Hirpicium gorterioides	0.10	65	57	33	100
Most frequent companions (2009)						
H	Stipagrostis uniplumis	10.76	100	100	100	100
Pmic	Acacia mellifera ssp. detinens	6.73	100	100	100	100
Cmes	Albizia anthelmintica	2.27	100	100	100	100
T	Melinis repens	1.76	100	100	100	100
Pmic	Boscia albitrunca	0.92	100	100	100	100
Cmes	Lycium eenii	0.87	100	100	100	100
Pnan	Grewia flava	0.73	100	100	100	100
T	Pupalia lappacea	0.59	100	100	100	100
T	Commelina benghalensis	0.29	100	100	100	100
H	Pollichia campestris	0.28	100	100	100	100
T	Cucumis anguria var. longaculeatus	0.24	100	100	100	100
T	Felicia smaragdina	0.17	100	100	100	100
Cmes	Solanum cf. dinteri	0.16	100	100	100	100
T	Eragrostis porosa	9.75	95	86	100	100
T	Pogonarthria fleckii	3.10	95	100	100	86
Pnan	Lycium oxycarpum	1.31	95	86	100	100

continued on next page

Unit 1, H21, 2007. Photo: J. Möller.

Unit 2, H30, 2008. Photo: J. Fleiner.

Classification table (continued)

Column		Cover	All	1	2	3
Number of relevés			**20**	**7**	**6**	**7**
H	Chloris virgata	1.18	95	86	100	100
H	Aristida congesta	0.56	95	100	83	100
T	Enneapogon cenchroides	0.52	95	86	100	100
T	Urochloa brachyura	0.38	95	86	100	100
Cmes	Ptycholobium biflorum	0.16	95	86	100	100
Pmes	Acacia reficiens	5.90	90	71	100	100
Pnan	Phaeoptilum spinosum	0.92	90	71	100	100
Pmic	Dichrostachys cinerea	0.71	90	86	83	100
T	Geigeria ornativa	0.46	90	86	83	100
Cmes	Tetragonia calycina	0.46	90	71	100	100
T	Ipomoea sinensis	0.36	90	86	83	100
H	Ipomoea obscura	0.23	90	100	67	100
T	Gisekia africana	0.12	90	86	83	100
T	Eragrostis biflora	0.12	90	100	83	86
Cmes	Acrotome fleckii	0.12	90	100	83	86
T	Nelsia quadrangula	0.64	85	100	83	71
H	Achyranthes aspera var. sicula	0.57	85	71	100	86
H	Ocimum americanum var. americanum	0.54	85	71	83	100
T	Crotalaria podocarpa	0.15	85	100	50	100
T	Aristida adscensionis	0.73	80	43	100	100
H	Indigofera vicioides	0.46	80	100	33	100
T	Kyphocarpa angustifolia	0.10	80	71	67	100
H	Eragrostis rigidior	0.81	75	100	17	100
H	Evolvulus alsinoides	0.69	75	86	33	100
Pnan	Ehretia rigida	0.35	75	86	83	57
H	Cenchrus ciliaris	0.27	75	71	100	57
T	Cleome rubella	0.13	75	100	33	86
T	Bulbostylis hispidula	0.10	75	86	33	100
H	Cyperus fulgens	0.10	75	43	100	86
T	Dactyloctenium aegyptium	0.10	75	86	67	71
T/per	Tephrosia burchellii	0.43	70	100	17	86
Cmes	Indigofera rautanenii	0.39	70	71	33	100
Cmes	Hibiscus calyphyllus	0.30	70	43	100	71
Cmes	Barleria lanceolata	0.24	70	29	100	86
Pnan	Hibiscus micranthus	0.16	70	57	100	57
T	Digitaria velutina	0.10	70	43	100	71
Cmes	Hermannia modesta	0.10	70	57	67	86
T/per	Talinum arnotii	0.10	70	57	83	71
T	Crotalaria sphaerocarpa	0.22	65	86	17	86
T	Chenopodium amboanum	0.16	65	71	100	29
T/per	Kohautia cynanchica	0.13	65	57	50	86
T	Oxygonum alatum	0.10	65	71	33	86
T	Eragrostis cylindriflora	1.89	60	86	33	57
T	Crotalaria pisicarpa	0.44	60	57	33	86
Cmes	Pavonia burchellii	0.20	60	43	67	71
Cmic	Aptosimum angustifolium	0.18	60	29	67	86
Pmic	Maerua schinzii	0.13	60	29	83	71
T	Aristida rhiniochloa	0.51	55	29	83	57
n.a.	Fabaceae sp. 14250	0.17	55	57	50	57
H	Hibiscus fleckii	0.10	55	57	17	86
Cmic	Dicoma tomentosa	0.10	55	71	33	57
H	Tricholaena monachne	0.14	50	57	17	71
H	Hermbstaedtia odorata	0.10	50	57	17	71
H	Corallocarpus dissectus	0.10	50	29	67	57
H	Eragrostis jeffreysii	0.10	50	14	83	57
H	Aristida effusa	0.23	45	57	50	29
T/per	Phyllanthus pentandrus	0.96	40	57	17	43
H	Helichrysum candolleanum	0.26	40	57	.	57
Cmes	Felicia clavipilosa	0.10	40	.	67	57
H	Schmidtia pappophoroides	0.10	40	43	17	57

Unit 3, H5, 2005. Photo: D. Lübsen.

A typical savanna on Omatako Ranch, 2005. Photo: D. Wesuls.

Responsible authors: D. Wesuls & J. Luther-Mosebach

Termites

Taxon richness	Abundance index	Dominant (sub-) family
8	68	Termitidae (Macrotermitinae)

Species belonging to the Macrotermitinae are by far the most common termites at this Observatory. *Macrotermes michaelseni* is particularly abundant with an average of 2.5 inhabited and 1.8 uninhabited mounds per hectare (see also Site-Specific Study [spatial patterns]). A total of six different *Macrotermes* species occur in southern Africa. They build massive mounds which are an important feature of many African landscapes. *M. michaelseni* builds the tallest mounds of all *Macrotermes* species in southern Africa, most of them exceeding 1.5 m in height. A large amount of energy is invested in building and maintaining the mounds in order to achieve a constant temperature and humidity within the nest (see also Site-Specific Study [temperature]). The size and shape of the termitaria vary between and within species. The *M. michaelseni* mounds are usually inclined towards the north, and the centralised nest with its fungus gardens and

Opened termite mound of *Macrotermes michaelseni* with clearly visible fungus gardens and air channels. Photo: C. Grohmann.

Queen of *Macrotermes michaelseni* in her opened cell with major soldier (e.g., in front), minor soldier (e.g., at top, right) and worker (e.g., at the queen's right side). Photo: C. Grohmann.

List of taxa

Taxon	(Sub-)family	Frequency Index	Feeding substrate
Macrotermes michaelseni	Termitidae (Macrotermitinae)	0.91	f (g, l, w)
Hodotermes mossambicus	Hodotermitidae	0.45	g
Odontotermes sp. 1	Termitidae (Macrotermitinae)	0.27	f (g, l, w)
Trinervitermes	Termitidae (Nasutitermitinae)	0.27	s, w, g, l, m
Microtermes	Termitidae (Macrotermitinae)	0.18	f (g, l, w)
Rhadinotermes	Termitidae (Nasutitermitinae)	0.09	s, w, g, l, m
Angulitermes	Termitidae (Termitinae)	r	s, w, g
Allodontermes	Termitidae (Macrotermitinae)	r	f (g, l, w)

Responsible authors: C. Grohmann & K.E. Linsenmair

the queen cell is located beneath the central chimney. Most commonly, one queen and one king can be found in the queen cell, but two or more queens may also occur. The queens are physiogastric, which means that their abdomens are enlarged, resulting in a greatly increased fecundity but less mobility. Egg-laying rates vary considerably between individual queens, but can reach up to 18,000 eggs per day (Kaib et al. 2001).

Like most other *Macrotermes* species, *M. michaelseni* forages beneath clay canopies (so called "soil sheetings") on dry grass, leaf litter, herbivore dung and dead wood. The ingested food passes through the gut rapidly without digestion, and this "primary faeces" is deposited onto fungus combs. These combs are built by the termites with their primary faeces and are pervaded by the mycelium of the basidiomycete fungus *Termitomyces*. The fungus degrades the cellulose and lignin within the comb. New material is added to the top of the combs by the termites, and they consume the material which was decayed by the fungus from the bottom for their nutrition (Rouland-Lefèfre 2000).

After heavy rains, the fungus produces sexual fruiting bodies which are called "omajova" in Namibia.

Macrotermitinae are able to decompose large amounts of plant material via this obligate symbiosis. For example, Buxton (1981) found that 90% of the wood in a Kenyan savanna was removed by fungus-cultivating termite species.

Odontotermes okahandjae, which occurs on the twin Observatory S05 (Otjiamongombe), was not found here. This is most likely due to the absence of riviers at this Observatory.

Fruiting bodies of the termite fungus *Termitomyces* on a *Macrotermes* mound. Photo: C. Grohmann.

Cell of a *Macrotermes michaelseni* queen, located in a block of compact soil within the fungus garden. Photo: C. Grohmann.

Worker of *Macrotermes michaelseni* awaiting eggs from the queen. Photo: C. Grohmann.

Close-up of a fungus comb of *Macrotermes michaelseni*. Photo: C. Grohmann.

True bugs

Sampling period(s)	Methods	Family richness
2001/ IV; 2003/ III, V, X; 2004/ II; 2007/ I; 2008/ IV, 2009/III	Trapping (light, pitfall traps, yellow pan, Malaise); beating of plants; hand collecting	22
Species richness	**Individuals sampled**	**Fisher's alpha diversity**
149	945	49.73

Phytophagous species of the Miridae, Pentatomidae, Rhyparochromidae, Alydidae, Lygaeidae, and Coreidae constitute 67% of all collected species at Toggekry Observatory. The second-largest group was the family Reduviidae with 12% of all species. About 45% of the species were collected only as a single specimen. The Nabidae and Saldidae are each represented by a single species and specimen. Both of these families were not collected at S05 (Otjiamongombe). The majority of the species (except ten species—Miridae species were not considered) were also recorded on the neighboring Observatory S05 (Otjiamongombe). All common species recorded at the Observatory are typical of the Thornbush Savanna. They are often widely distributed, such as the grass-feeding *Teracrius namaquensis* (Pachygronthidae). Species typical of the Karoo are rare. For instance, *Leptodemus irroratus* (Oxycarenidae), which is common at the southern Observatories (especially in S10, S11, S21) was collected only as a single specimen while net sweeping. All identified species recorded at Toggekry are already known from the other parts of Namibia.

Species abundances

Light traps

Species	Family	*N*	%
Corixidae spec. 1	Corixidae	53	10
Brotheolus pugnax	Coreidae	48	9
Miridae spec. 1	Miridae	31	6
Miridae spec. 2	Miridae	28	5
Carbula spec.	Pentatomidae	25	5
Nariscus spinosus	Alydidae	24	4
Camptocoris rostratus	Lygaeidae	21	4
Nysius spec.	Lygaeidae	17	3
Tenosius proletarius	Alydidae	16	3
Corixidae spec. 2	Corixidae	16	3
Miridae spec. 3	Miridae	16	3
Miridae spec. 4	Miridae	16	3
Cletus pusillus	Coreidae	14	3
Miridae spec. 5	Miridae	12	2
Elasmolomus transversus	Rhyparochromidae	12	2
Others (75)		190	35
Total		**539**	**100**

Pitfall traps

Species	Family	*N*	%
Tenosius proletarius	Alydidae	5	24
Carbula spec.	Pentatomidae	5	24
Eupododus spec.	Pentatomidae	3	14
Metacanthus concolor	Berytidae	1	5
Nysius ericae	Lygaeidae	1	5
Miridae spec.	Miridae	1	5
Reduviidae spec. 1	Reduviidae	1	5
Reduviidae spec. 2	Reduviidae	1	5
Edocla quadrimaculata	Reduviidae	1	5
Peliochrous nigrimaculatus	Rhopalidae	1	5
Rhyparochromidae spec.	Rhyparochromidae	1	5
Total		**21**	**100**

Species richness

Family	S	Family	S
Miridae	52	Mesoveliidae	2
Pentatomidae	18	Notonectidae	2
Reduviidae	18	Pachygronthidae	2
Rhyparochromidae	15	Scutelleridae	2
Lygaeidae	7	Tingidae	2
Alydidae	6	Anthocoridae	1
Coreidae	4	Berytidae	1
Corixidae	4	Nabidae	1
Rhopalidae	4	Oxycarenidae	1
Cydnidae	2	Pyrrhocoridae	1
Geocoridae	2	Saldidae	1
		Total	**148**

Responsible author: J. Deckert

Butterflies and moths

Sampling period(s)	Number of samples (moths)	Species richness (total)
2003/II; 3007/I; 2008/IV	3	127
Species richness (butterflies)	**Species richness (all moths)**	**Species richness (Microlepidoptera)**
28	99	31
Species richness (Pyraloidea)	**Species richness (Macrolepidoptera)**	**Species richness (Noctuidae)**
20	18	30
Individuals sampled (moths)	**Fisher's alpha diversity (moths)**	
284	59.9	

Butterflies

The observed butterflies are common and widespread species of open savannas. The commonly occurring *Acacia* trees are host-plants for the caterpillars of the two *Azanus* species (see Photo). *Belenois aurota aurota* is the dominant species in all years. A rare species is *Lepidochrysops glauca*, which was collected only once (a single male on the 11 January 2007).

Transect analysis of butterflies

Sampling period: 11 January 2007. The sampling was conducted after a short rainy period in December 2006.
Description of transect: The transect of 1000 m length lies in the southern part of the Observatory. The transect follows the trail which starts on the road west of the Observatory and crosses it in a north-easterly direction. **Species richness:** 10, **Number of individuals:** 83

Abundance

Species	N	Proportion
Belenois aurota aurota	51	61.4%
Colotis evagore antigone	8	9.6%
Azanus jesous jesous	8	9.6%
Pinacopteryx eriphia eriphia	6	7.2%
Colotis agoye bowkeri	6	7.2%

Moths

The proportion of species represented by single individuals was 55% (= 55 species). Several species of the genus *Athrips* (Gelechiidae) are the most abundant moths among the Microlepidoptera. The Pyraloidea are represented by 20 species with *Achyra nudalis* (Crambidae: Pyraustinae) being the dominant pyralid moth. Abundant macro-moths are *Isturgia deerraria*, *Holoterpna errata* (see Photos) and *Allocrostes* sp. (all Geometridae). The Noctuidae is the most species-rich family with *Centrarthra* sp. being the most abundant species.

Azanus ubaldus. Photo: W. Mey.

Male of *Holoterpna errata*. Photo: W. Mey.

Butterfly species and main food plants

Hesperiidae	
Spialia colotes transvaaliae	Hibiscus (Malvaceae)
Spialia spio	Hermannia, Hibiscus, Pavonia (Malvaceae)
Spialia mafa mafa	Hermannia, Hibiscus, Pavonia (Malvaceae)
Coeliades pisistratus	Sphedamnocarpus, Triaspis, Indigofera (Fabaceae)
Lycaenidae	
Deudorix antalus	Haplocoelum, Schotia, Faidherbia (Fabaceae)
Azanus jesous jesous	Acacia (Fabaceae)
Azanus ubaldus	Acacia (Fabaceae)
Cigaritis phanes	Acacia (Fabaceae), Ximenia (Olacaceae)
Tarucus sybaris linearis	Zizyphus (Rhamnaceae)
Leptotes pirithous pirithous	Plumbago (Plumbaginaceae), Indigofera (Fabaceae), Burkea (Caesalpiniaceae)
Lepidochrysops glauca	Ocimum, Lantana (Verbenaceae)
Zizeeria knysna	Tribulus (Zygophyllaceae), Amaranthus (Amaranthaceae), Medicago (Fabaceae)
Chilades trochylus	Indigofera, Heliotropium (Fabaceae)
Nymphalidae	
Danaus chrysippus aegyptius	Asclepias, Stapelia, Cynanchum (Asclepiadaceae)
Junonia hierta cebrene	Asystasia, Adhatoda, Barleria, Ruellia (Acanthaceae)
Pieridae	
Eurema brigitta brigitta	Hypericum (Hypericaceae), Chamaecrista (Caesalpiniaceae)
Catopsilia florella	Senna (Caesalpiniaceae)
Pinacopteryx eriphia eriphia	Boscia, Maerua (Capparaceae)
Belenois aurota aurota	Boscia, Capparis, Maerua (Capparaceae)
Colotis eris eris	Boscia (Capparaceae)
Colotis agoye bowkeri	Boscia, Cadaba (Capparaceae)
Colotis antevippe gavisa	Boscia, Capparis, Maerua (Capparaceae)
Colotis celimene pholoe	Boscia, Capparis (Capparaceae)
Colotis subfasciatus subfasciatus	Boscia (Capparaceae)
Colotis evagore antigone	Capparis, Maerua (Capparaceae)
Colotis evenina evenina	Boscia, Capparis (Capparaceae)
Colotis vesta mutans	Maerua (Capparaceae)
Colotis ione	Boscia, Capparis (Capparaceae)

Taxonomic spectrum of moths

Collection period: III/2003

Family	***S***	***N***
Tineidae	4	5
Nepticulidae		
Yponomeutidae	1	1
Coleophoridae	1	1
Ethmiidae	1	4
Scythrididae	4	6
Gelechiidae	20	67
Microlepidoptera	**31**	**84**
Pyralidae	16	25
Crambidae	4	16
Pyraloidea	**20**	**41**
Limacodidae	1	1
Lasiocampidae	2	8
Lymantriidae	1	4
Geometridae	13	62
Arctiidae	1	1
Noctuidae	30	83
Macrolepidoptera	**48**	**159**
Total	**99**	**284**

Responsible author: W. Mey

Vertebrates

Total species richness	Reptile species richness	Bird species richness
15	n.a.	15
Large mammal species richness	Small mammal species richness	
n.a.	n.a.	

Birds

Passeriformes	**Perching birds**
Batis pririt	Pririt Batis
Passer diffusus	Southern Grey-headed Sparrow
Bradornis mariquensis	Marico Flycatcher
Cercotrichas paena	Kalahari Scrub-Robin
Mirafra africanoides	Fawn-coloured Lark
Pycnonotus nigricans	Black-fronted Bulbul
Uraeginthus granatinus	Violet-eared Waxbill
Laniarius atrococcineus	Crimson-breasted Gonolek
Parisoma subcaeruleum	Chestnut-vented Tit-Babbler
Prinia flavicans	Black-chested Prinia
Sporopipes squamifrons	Scaly-fronted Weaver
Coraciiformes	**Kingfishers and relatives**
Merops hirundineus	Swallow-tailed Bee-eater
Columbiformes	**Doves and pigeons**
Streptopelia capicola	Ring-necked Dove
Piciformes	**Woodpeckers and relatives**
Tricholaema leucomelas	Acacia Pied Barbet
Galliformes	**Fowl-like birds**
Coturnix coturnix	Common Quail

Black-fronted Bulbul (*Pycnonotus nigricans*). Photo: J. Deckert.

Responsible authors: J. Deckert, A. Hoffmann & A. Mills

Impact of harvester ants (*Messor* sp.) on seed dispersal in the central Namibian Thornbush Savanna (S04.01)

[C. Grohmann & K.E. Linsenmair]
Seed-collecting ants have a significant influence on plant communities through their foraging activities. Harvester ants such as the genus *Messor* (Hymenoptera, Formicidae) play an important role in seed dispersal, especially in arid regions. In this study, it was analysed what kind of seeds are preferred by these ants and what behavioural patterns they exhibit during forays between the nest and food sources. Field work was conducted over a six week period from February to April 2006 at the Observatory. The observed ants showed a clear preference for mature and dry seeds. In total, the seeds of eleven different herb and grass genera were carried back to nests by the ants. However, ant nest storage chambers were dominated by a few seed species only, in particular, those that can be collected easily from the immediate vicinity of the nest. The ants showed different behavioural patterns outside of their nests. Most of the time was invested in the search for food. Nearly half of all collected seeds were lost while the ants were returning to their nests. This suggests that *Messor* ants may have a considerable effect on the distribution of grass species in the central Namibian savanna.

Siegel, K. (2006): Die Rolle der Ameisengattung *Messor* bei der Samenausbreitung in der Dornbuschsavanne Namibias. – Unpublished report. Würzburg: Department of Animal Ecology and Tropical Biology, University of Würzburg.

Yearly variation of temperature within nests of the termite *Macrotermes michaelseni* (S04.02)

[C. Grohmann & K.E. Linsenmair]
It is assumed, that the termite species *Macrotermes michaelseni* (Isoptera, Macrotermitinae) builds its massive mounds to maintain a constant temperature and/or moisture within its nest and at the same time ensure the essential exchange of CO_2 and O_2. This study examined temperature at different locations inside termite mounds. iButtons® (small temperature sensors which measure and store temperature data) were installed in several places inside six *M. michaelseni* termite mounds. Each iButtons® has its own battery and they could be left isolated for more than one year inside the mounds. Their small size (diameter: 16 mm, height: 5 mm) allowed them to be installed inside the mounds without massive destructions using a drill. At the Observatory S04 (Toggekry), the sensors were embedded in three different mounds in early 2006. Another three mounds were monitored at the Observatory S05 (Otjiamongombe) in 2008. Results show that the temperature varies over the year at the outer parts of the fungus gardens, but is relatively constant (± 2°C) around the inner part of the gardens near the queen's cell. The data show that—intended or not—one of the results of the massive nest construction by *M. michaelseni* is that the temperature is constant in the centre of their nests.

Spatial patterns of mounds built by the termite *Macrotermes michaelseni* (S04.03)

[C. Grohmann & K.E. Linsenmair]
In general, spatial patterns are generated by certain ecosystem processes, but at the same time each pattern in turn has an influence on ecosystem processes. This is especially true for those patterns generated by species which play important roles in ecosystem functioning, such as termites for example. Large parts of the central Namibian savanna are dominated by the large mounds built by the fungus-growing termite species *Macrotermes michaelseni* (Isoptera, Macrotermitinae). In 2007, the positions of all *Macrotermes michaelseni* mounds at the Observatory were recorded and their distribution pattern analysed. In total, 256 inhabited and 188 uninhabited mounds were counted. We found that inhabited mounds taller than 0.7 m were regularly distributed, presumably as a result of intraspecific competition. The heights of inhabited mounds taller than 0.7 m were correlated positively with the inter-mound distances of these mounds, such that on a spatial scale of less than approximately 50 m, the mounds tended to be smaller than average. This suggests that intraspecific competition for foraging areas influences the distribution and size of these termite colonies.

Grohmann, C., Oldeland, J., Stoyan, D., Linsenmair, K.E. (2010): Multi-scale pattern analysis of a mound building termite species. – Insectes Sociaux. DOI: 10.1007/s00040-010-0107-0.

Mapping of Thornbush Savanna soils using Landsat satellite data (S04.04)

[N. Classen]
Within the BIOTA framework, our investigation aimed at a regionalisation of soil properties with Landsat-TM 5 satellite imagery data for the area of two farms in the central Namibian savanna (total 236 km²) comprising the Observatories S04 and S05.

It could be shown that the distribution of two soil types (Vertisols, Leptosols, 6% of sampled profiles) could be accurately predicted from the Landsat-TM

data directly. For the dominant remaining proportion of the soils, the total predictability of soil properties like pH, elemental composition, and salinity was lower than 22%. Based on a Landsat scene from a rainy season, a rough estimate of vegetation coverage and biomass production was possible.

The different plant communities within the Thornbush Savanna, which are structurally similar, could not be differentiated satisfactorily. Thus, the approach to indirectly identify soil features by vegetation mapping has failed and the use of Landsat-TM data for the mapping of soil properties in the plain savannah region of central Namibia is inappropriate.

Classen, N. (2005): Überprüfung von Verfahren zum Up-scaling von Bodeneigenschaften in der Dornbuschsavanne Namibias. – Diplom thesis in Soil Science. Hamburg: University of Hamburg.

Does using species abundance data improve estimates of species diversity from remotely sensed spectral heterogeneity? (S04.05)

[J. Oldeland, D. Wesuls & N. Jürgens]

Different approaches for the assessment of biodiversity by means of remote sensing were developed over the last decades. A new approach, based on the spectral variation hypothesis, proposes that the spectral heterogeneity of a remotely sensed image is correlated with landscape structure and complexity, which also reflects habitat heterogeneity which itself is known to enhance species diversity. In this context, previous studies only applied species richness as a measure of diversity. The aim of this paper was to correlate species richness and an abundance-based diversity measure with spectral heterogeneity and compare the results at two scales. At three different BIOTA Observatories in central Namibia, Toggekry (S04), Otjiamongombe (S05) and Okamboro (S06), percentage cover of vascular plants species was sampled at two scales—100 m² and 1000 m². Hyperspectral remote sensing data were collected for the study sites, and spectral variation, expressed as the mean Euclidean distance to the centroid, was calculated at plot level. Correlations between two alpha diversity measures and spectral heterogeneity were tested using Pearson's correlation coefficient. We used species richness as a richness measure and the Shannon index as an abundance-based measure of species diversity. We found that the Shannon index consistently achieved higher correlation values and statistical significances at both sampling scales and at all test sites. Even when all sites where pooled together, Shannon index was still significantly correlated with spectral variation. We suggest incorporating abundance-based diversity measures in studies of correlations between ecological and spectral heterogeneity. The fact that the Shannon index combines richness and evenness of species makes it a more realistic measure for such comparisons. Furthermore, our analyses demonstrate that correlations were significantly better at 1000 m², suggesting that studies on diversity of savanna vegetation should make use of this plot size. We appreciate the contribution made by the high spectral and spatial resolution of the sensor to our results. Spectral variation may become a valuable source of information on biodiversity to interpret remotely sensed data for science and conservation management.

Oldeland, J., Wesuls, D., Rocchini, D., Schmidt, M., Jürgens, N. (2010): Does using species abundance data improve estimates of species diversity from remotely sensed spectral heterogeneity? – Ecological Indicators **10**: 390–396.

Mapping bush encroaching species by seasonal differences in hyperspectral imagery (S04.06)

[J. Oldeland, W. Dorigo, D. Wesuls & N. Jürgens]

Bush encroachment is a form of land degradation that occurs worldwide, but is particularly prominent in semi-arid areas. In this study, we mapped the spatial distribution of the two encroacher species *Acacia mellifera* and *A. reficiens* in central Namibia, based on their different phenological behaviour. The study was conducted on and around the Observatory Toggekry (S04) and comprised a total area of 19 km² with the Observatory in the center. We collected information on plant species composition and percentage cover on 127 vegetation plots of 25 m × 25 m size. We used constrained principal curves to extract a one-dimensional gradient of phenological change from two hyperspectral images taken in different seasons. Field measurements of species composition and cover values were statistically related to bi-temporal differences in hyperspectral vegetation indices in a direct gradient analysis. The extracted gradient reflected the relationship between species composition and cover values, and the phenological pattern as captured by the image data. Cover values of four dominant plant species were mapped and species responses along the phenological gradient were interpreted. Cover information provided by the twenty 20 m × 50 m permanent plots from the Observatory S04 served as an independent validation dataset.

Oldeland, J., Dorigo, W., Wesuls, D., Jürgens, N. (2010): Mapping bush encroaching species by seasonal differences in hyperspectral imagery. – Remote Sensing **2**: 1416–1438.

Diversity measures in comparative rangeland studies: application and advantages of SADs and diversity profiles (S04.07)

[J. Oldeland, N. Dreber & D. Wesuls]

Biodiversity consists of the two components richness and evenness. Diversity indices such as the Shannon or Simpson index are commonly used to describe diversity patterns for sampled habitats or plant communities. However, these indices are ineffective for comparing richness and evenness at the same time, what might lead to a biased interpretation of actual diversity patterns. With this article, we aim at describing two alternative approaches for comparing diversity patterns, which, in combination, allow an effective visualisation of those patterns: curves for ranked species

abundance distributions (SADs) and diversity profiles. In a case study, we compare biodiversity measurements within and between the Thornbush Savanna and the Nama Karoo biomes. The study was conducted on the BIOTA Observatories Toggekry (S04) and Otjiamongombe (S05) representing the Thornbush Savanna and on Niko North (S08) and Niko South (S09) representing the Nama Karoo. As an important outcome of this study, we emphasise the importance of taking abundance into consideration when diversity between different habitats is compared. We briefly discuss possible applications of these methods in rangeland and restoration ecology.

Oldeland, J., Dreber, N., Wesuls, D. (2010): Diversity measures in comparative rangeland studies: application and advantages of SADs and diversity profiles. – Dinteria **31**: 50–66.

The role of mound-building termites for the soil structure and nutrient patterns

► *See* **'The role of mound building termites' in Subchapter IV.2.4.**

Influence of soil features on soil lichen diversity in the summer-rainfall biomes

► *See* **S03.02**

Further studies

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General data

Number	Name	Alternative name(s)
S05	Otjiamongombe	Erichsfelde
Implementation	**Country**	**Province/ region**
2001	Namibia	Otjozondjupa
District/ constituency	**Locality**	**Farm name**
Okahandja	Erichsfelde	Otjiamongombe West 44
Latitude	**Longitude**	**Altitude**
21.596834 S	16.935106 E	1495 m a.s.l.
Rainfall season	**Biome**	**WWF Ecoregion**
Summer	Thornbush Savanna	AT1309 Kalahari xeric savanna
Agro-Ecological Zone	**Relative intensity of land use**	**Tenure**
CPL2	Medium	Private
Type and history of landuse	**Land owner**	
Farming with cattle and game for hunting	Private	

Otjiamongombe (S05)

Typical Thornbush Savanna on the farm Erichsfelde. Photo: J. Deckert.

The BIOTA Observatory Otjiamongombe (commonly called Erichsfelde) is located approximately 40 km north of Okahandja in the Otjozondjupa region. It lies 24 km southeast of the BIOTA Observatory Toggekry at a mean altitude of 1495 m a.s.l. and, similar to Toggekry, the topography is almost flat. The Observatory is slightly inclined towards the north and is dissected by a small rivier. The unconsolidated substrates are mainly loamy in their texture. Adjacent to the rivier, a calcrete layer is exposed at the soil surface. The vegetation of this predominantly open Thornbush Savanna is dominated by *Acacia* species and grasses. Depending on the habitat and the intensity of disturbance by grazing and trampling animals, annuals can dominate over perennial climax grasses in the herbaceous layer. From 2001 to 2009 the neighbouring Observatory Toggekry received an average annual rainfall of 346 mm mainly during the summer months from September to April.

The 13,000 ha farm is privately owned and used for cattle farming, with a small proportion of income coming from hunting. Large herds of games species (e.g. Oryx, Kudu, Eland, and Warthog) occur on the farm, which is typical in this region. Mounds built by the termite *Macrotermes michaelseni* are widespread at this Observatory, as they are in the whole region.

The BIOTA Observatory was established to monitor changes induced by intensive cattle farming in comparison to

the game farming on the BIOTA Observatory Toggekry. Both Observatories are regarded as typical for the central Namibian Thornbush Savanna, where the monitoring of climate induced changes and bush encroachment need to be addressed.

Responsible authors: A. Gröngröft, C. Grohmann & D.H. Haarmeyer

Remote sensing and landscape

Geomorphology	Geological units	Lithological units
Red soils, rivier	Damara Granite intrusions	Granites
Mean EVI	**EVI absolute range**	**Mean leaf area index**
0.172 (0.123–0.307)	0.115 (2004)–0.373 (2006)	0.67

Grid map of Observatory

	0	1	2	3	4	5	6	7	8	9
0	84	29	52	2	39	54	81	53	78	96
1	26	25	3	36	90	64	85	34	70	72
2	11	8	60	98	87	61	1	80	62	27
3	95	93	20	86	94	99	6	44	47	32
4	92	89	33	65	7	58	15	42	23	10
5	74	51	12	66	24	41	31	73	46	38
6	50	19	37	91	30	100	48	43	18	9
7	68	76	4	63	82	83	88	17	57	49
8	35	5	16	13	79	22	55	69	67	28
9	71	21	97	75	56	77	40	45	14	59

1 Open to dense Acacia-dominated thornbush savanna on loamy, red soils
2 Dense Acacia-dominated thornbush savanna with intersection of rivier

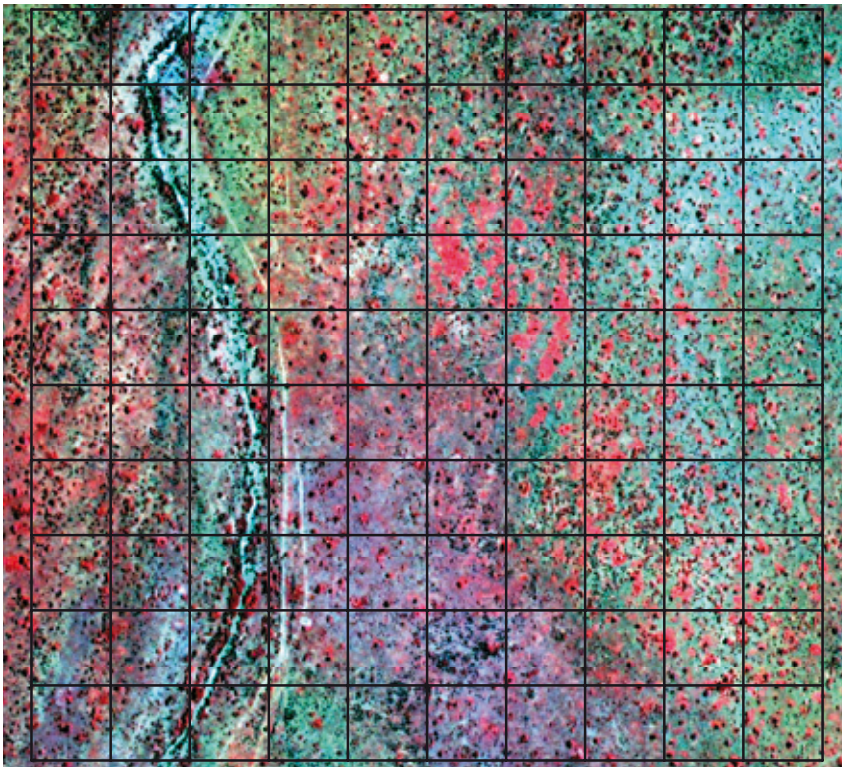
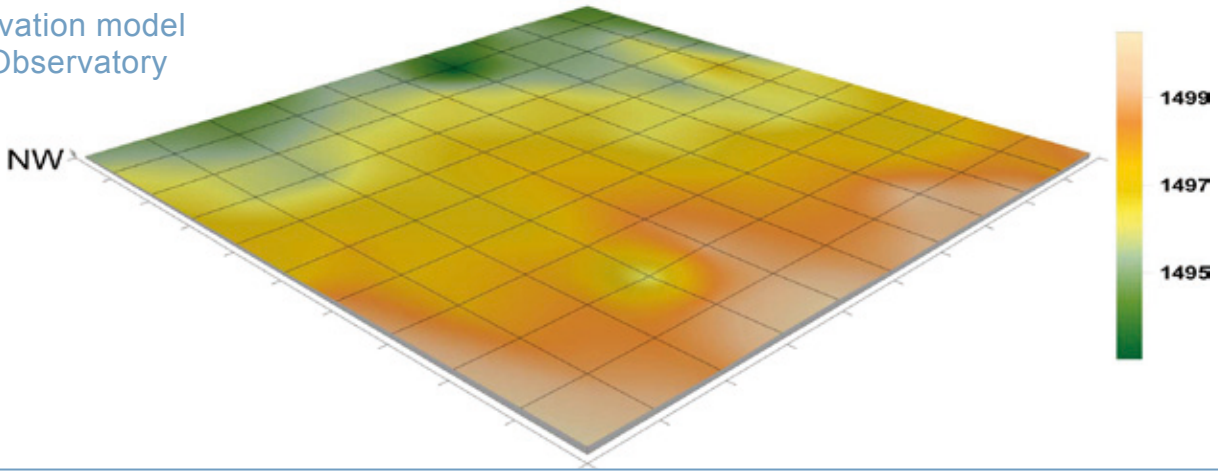


Image: IKONOS, 24 March 2008

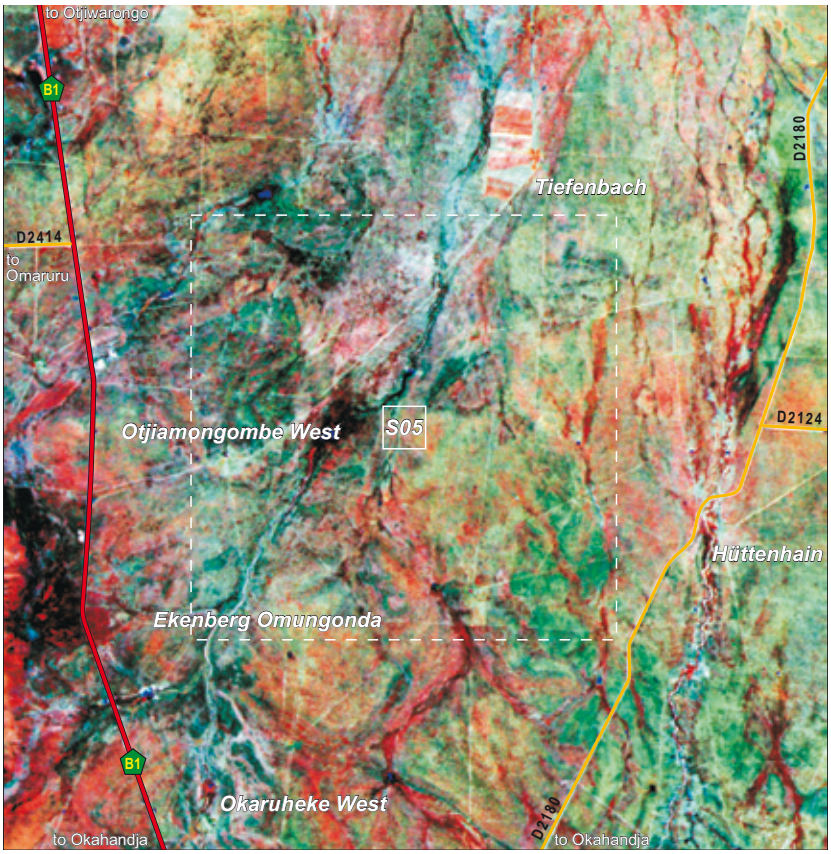
Elevation model of Observatory



Landsat image

The western part of the Observatory is dissected in a south-north direction by a small river (Herero: omuramba), which meets with another omuramba north of the Observatory and drains to the north. West of the Observatory, this river has been dammed (water showing in blue). Dark red patterns indicate the occurrence of thickets (e.g. stands with the highest woody plant densities in the subscene) to the north of, and surrounding, this dam.

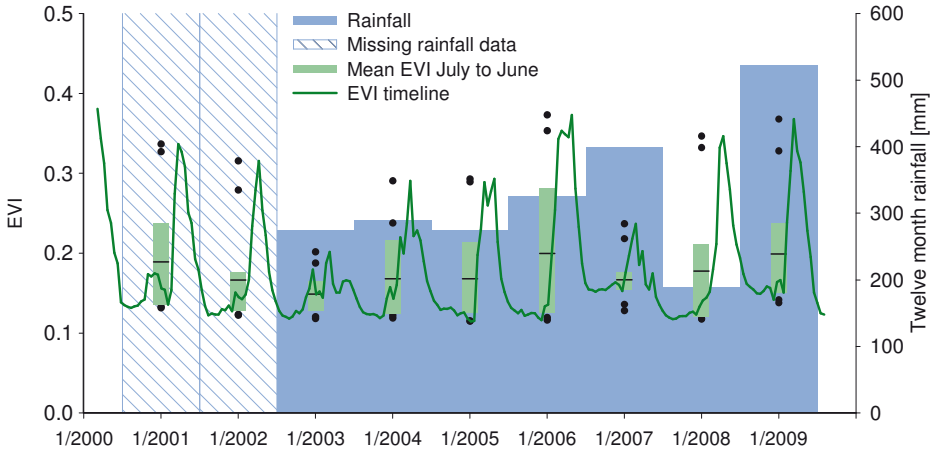
The landscape is a mosaic of patches with high tree and shrub densities (red) and patches dominated by grassy vegetation (green to blue grey). Recent grazing impacts are visible as brighter or bluish patches, which depict areas of lower vegetation density. Near the western edge of the image, several tracks intersect near the houses of the farm Erichsfelde. Nearby, some overgrazed cattle enclosures show in white.



Scene 178/75, acquisition date: 24 April 2006

MODIS time series

Temporal patterns of annual rainfall, vegetation cover, and phenology



Responsible authors: M. Keil & T. Labitzky

Climate

Data from BIOTA weather station

Location	Recorded period	Mean temperature
Toggekry (S04)*	2001–2009	20.6 (-4.5–40.0) °C
Mean solar radiation	**Mean wind speed**	**Mean annual precipitation**
640 (313–1458) MJ·m^{-2}·month^{-1}	1.8 (5.9) m·s^{-1}	346 (270–298) mm
Mean annual potential evapotranspiration	**Interannual precipitation variability**	**Mean relative humidity**
1732 mm	149%	45% (22–86%)
Aridity index (UNEP)		
0.20 (arid)		

Modelled data

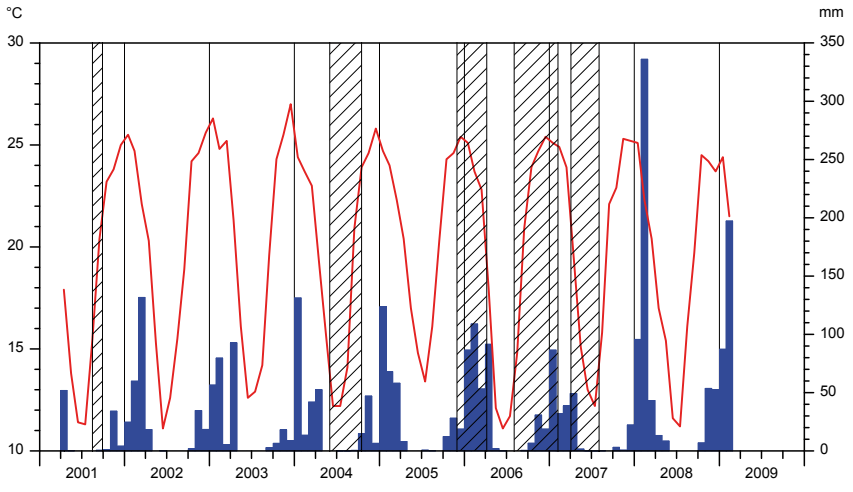
Mean temperature	Mean annual temperature range	Mean diurnal temperature range
19.3 (3.9–32.0) °C	9.8 °C	17.6 °C
Mean annual precipitation	**Precipitation seasonality**	**Percentage winter precipitation**
396 mm	106%	12% (strong summer)
Climate type	**Length of dry season**	**Aridity index (De Martonne)**
BWh	9 months	13.5 (semi-dry)

**23 km west-northwest of the Observatory Otjiamongombe*

The climate at the Observatory is characterised by semi-arid conditions. Rainfall shows a strong seasonality with almost all rain falling during the summer season, peaking in February. The mean annual rainfall over the observation period was 346 mm, which is wetter than the average rainfall recorded at all Observatories, and at the Observatories within the Thornbush Savanna. However, substantial interannual variability is evident. The observed near-surface air temperatures show a moderate seasonal cycle. The mean annual temperature is 20.6°C, which is the approximate average for this biome. The observed mean minimum temperature is above the freezing point, but there is still a possibility of the occurrence of frost during the months of May to August. Compared to the interpolated long-term data taken from the WorldClim dataset, only minor differences in mean annual temperature are evident. However, the station records of extreme temperatures deviate substantially from the WorldClim data, showing warmer maximum and colder minimum temperatures. For precipitation, mean annual rainfall is lower at the BIOTA weather station compared to the WorldClim data. Additionally, the station data shows a small secondary rainfall maximum in early summer that is evident in the WorldClim data.

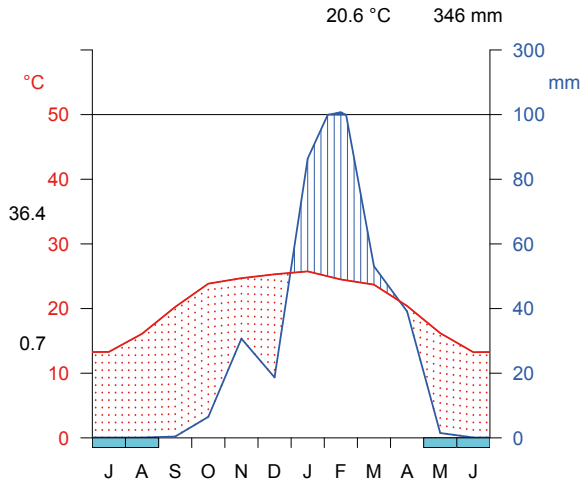
The observed near-surface winds at the Observatory are mainly constituted by south-westerly flows during the spring and summer seasons, but also show a weak north-easterly component. During the autumn and winter seasons the circulation is reversed, with a major north-easterly flow component. Mean wind speed is highest during the early afternoon, reaching about 10 km/h. Winds during that time of the day stay fairly constant throughout the year, whereas a pronounced annual cycle is visible for the mean wind speed recorded during the mornings and evenings.

Time series: rainfall and temperature

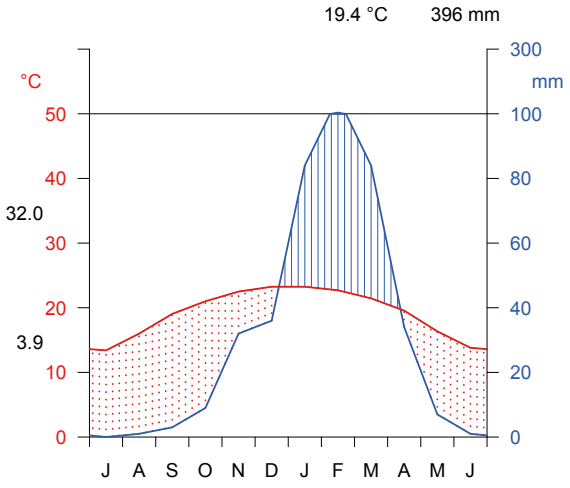


Climate diagrams

Recorded data (BIOTA)

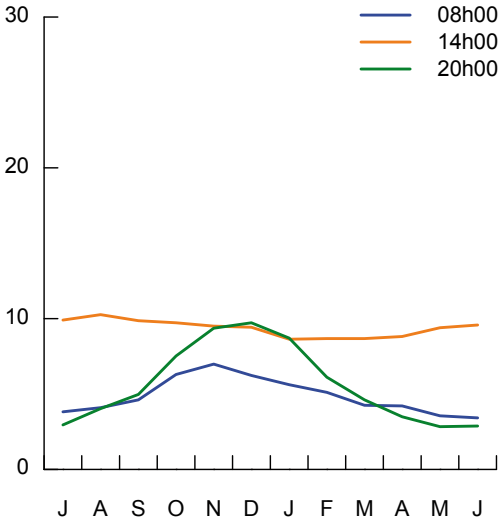


Modelled data (WorldClim)

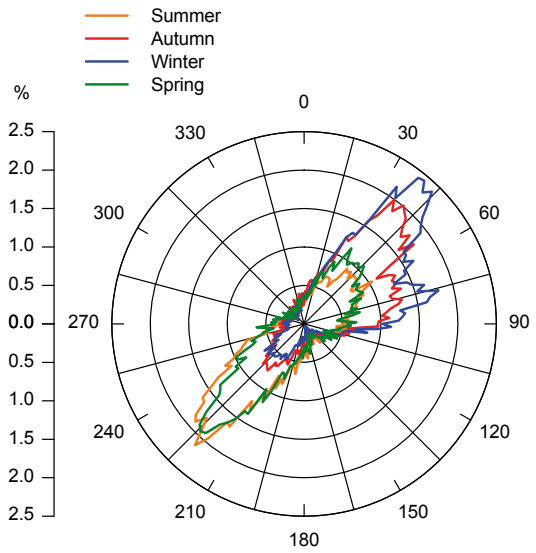


Wind diagrams

Speed



Directions



Responsible authors: K. Berger, A. Haensler & J. Luther-Mosebach

Soils

Year of sampling	Hectare plots sampled	SOTER unit
2001	26 (R1–25, R39)	NA56
Soilscape	**Dominant soil group(s)**	**Reference group richness**
Luvisol/Calcisol	Luvisol, Calcisol	3
Soil unit richness	**Soil unit evenness**	**Soil ecotype richness**
13	0.752	10
Parametric space	**pH**	**Electrical conductivity**
4.00	6.6 (4.8–8.0)	30 (11–131) $\mu S \cdot cm^{-1}$
Organic carbon		
0.44% (0.09–1.82%)		

The soilscape of the Observatory can be subdivided into three areas: (i) the eastern part with deeply developed reddish clayey Luvisols, which are slightly acid and have very low nutrient content, (ii) the western part with loamier Calcisols and Cambisols with high pH values, dark brown colour and higher content of organic carbon, and (iii) the direct vicinity of the dry river with shallow Calcisols, which are restricted in their rooting depth and have neutral to alkaline soil reaction. Electrical conductivity and organic carbon are higher in the Calcisols but the availability of some elements such as phosphorous might be limited due to the high pH values. Additional small scale variations of soil properties across all soil units are ascribed to the activity of the mound-building termite *Macrotermes michaelseni* (see Sections Termites of S04 and S05), except for the very shallow Epipetric Calcisols. A common feature of all carbonate-rich soils is the strongly developed biological soil crust (see section Biological soil crusts). In the carbonate-free substrates in the eastern part of the Observatory, these crusts are only weakly developed or absent. Another typical feature of most soils is the presence of a thin layer of coarse sand that can be regarded as the residual of rain-splash induced erosive processes. Additionally, a vesicular layer in the first top centimetres occurs frequently.

With the exception of electrical conductivity, the variability of most soil properties in this Observatory is comparably high with an even distribution. For pH values and clay and silt percentages the variability is nearly constant with depth, whereas for electrical conductivity the values are increasing while decreasing for organic carbon. Vertical variation in organic carbon occurs within the profiles, decreasing with depth while clay and silt content reflect a typical increase.

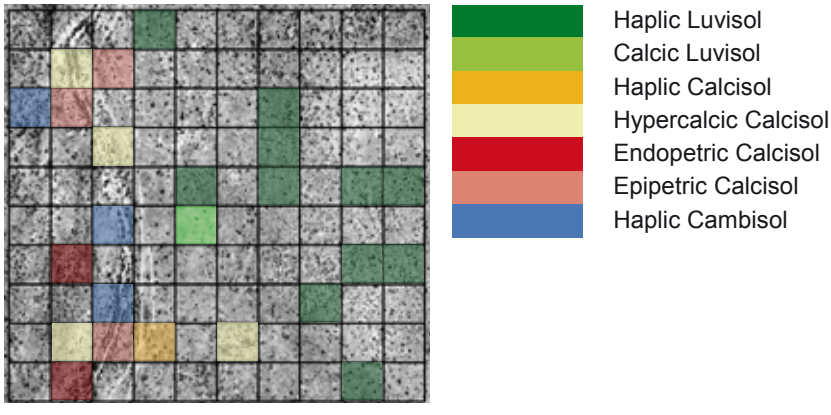
The rooting space shows a wide variation ranging from 100% in the deeply developed Luvisols down to only 3% in the very shallow Epipetric Calcisols. All restrictions of the rooting space are most likely caused by nodular or massive calcic horizons. The underlying saprolith was not excavated.

The sandy and clayey-sandy fraction is dominant; only few samples examined by finger tests showed silt content of more than 30%. However, due to the presence of finely distributed calcium carbonate, these tests were often difficult and may have overestimated the silt content. Partly, the clay content exceeds 30%, meeting one requirement for Vertic properties. X-ray diffraction analyses by Winterstein (2003) showed that the clay fraction contains only small amounts of smectite and is dominated by illite. Illite does not swell or shrink as smectites do and thus clay rich soils do not show deep cracks or slickensides. When these horizons are dry, they do not show any signs of aggregation but rather homogenous concrete-like blocks atypical for Vertisols.

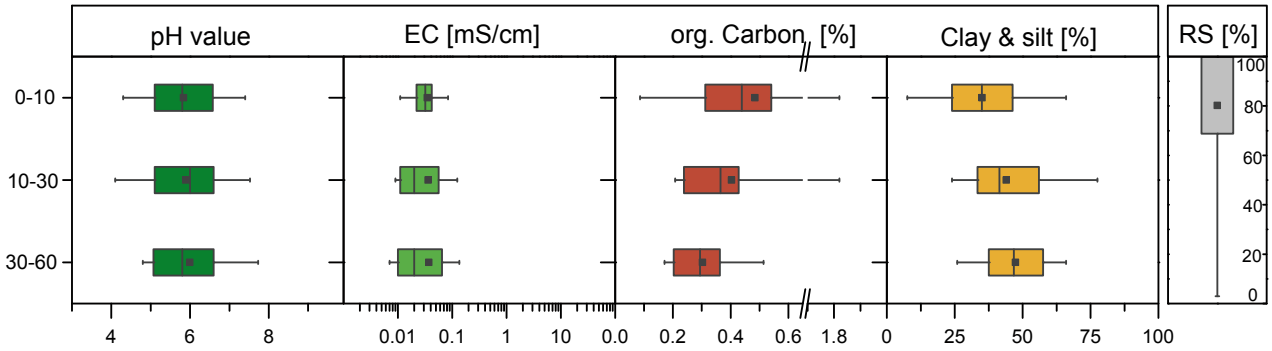
The high content of clay is also reflected in the high concentration of total potassium. Concentration of total phosphorus is within the inter-quartile range (mean 75%) of the total transect, but plant available phosphorus is below detection levels. The concentration of soil micronutrients (Fe, Cu, and Zn) is significantly below average (approximately 14 g·kg-1 and 11 mg·kg-1 and 27 mg·kg-1 in the topsoil, respectively).

The genesis of the profiles cannot be explained for certain, an inherent problem of the polygenetic landscapes with their variable climatic history and mass movements of soil parent material since the Tertiary.

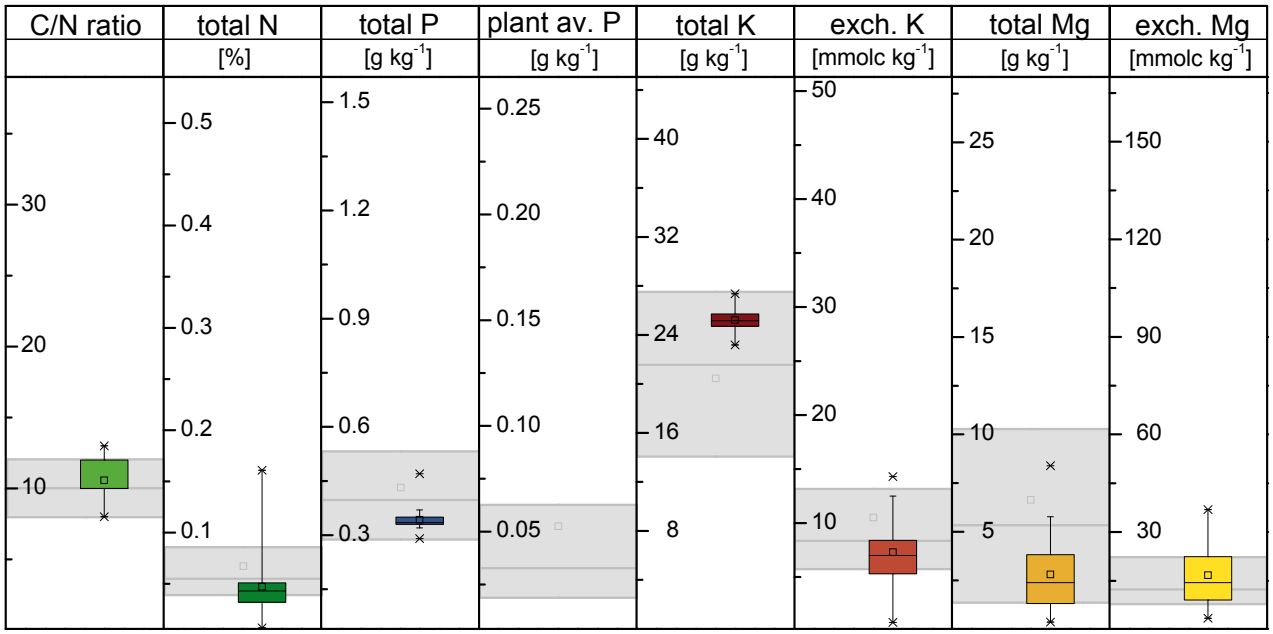
Map of soil profiles



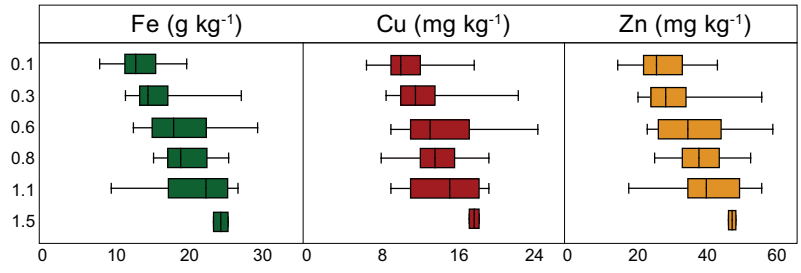
Soil characteristics



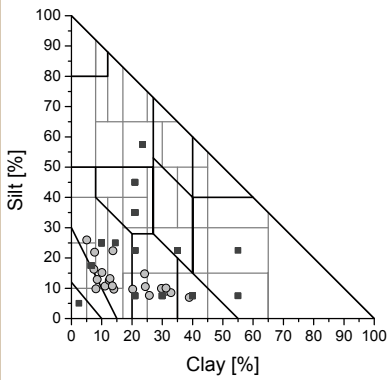
Soil nutrients



Soil micronutrients



Soil texture triangle



However, some observations and indications can be summarised in the following.

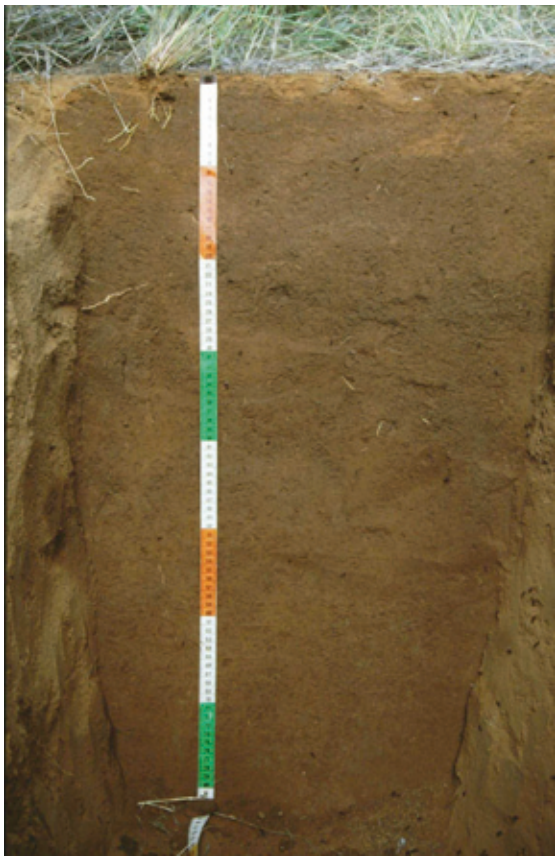
It can be assumed that the Luvisol association is developed in a granitic derived soil parent material and that dispersion and translocation of clay is continuing with present pH values and climatic conditions, appearing after strong rainfall events. Clay coatings have often been observed in the subsoil. Most likely, this translocation is also an important process in the further genesis of decaying termite mounds which initially exhibit homogenous clay content across the entire mound profile. At the landscape level, termite activity keeps nutrient levels in the soil compensating leaching losses.

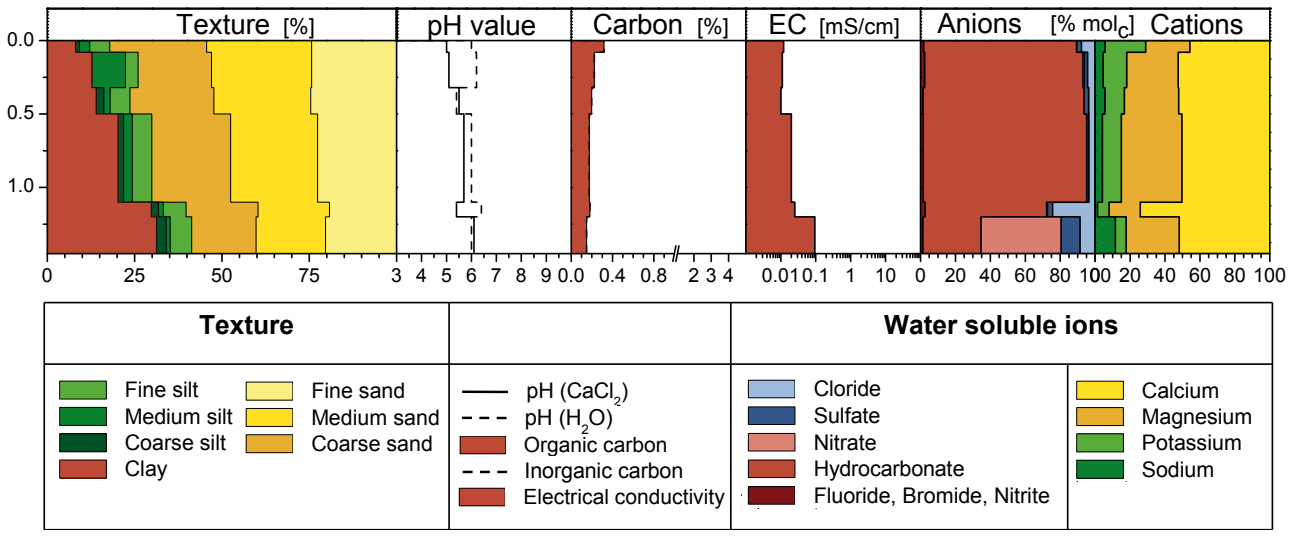
The profiles in the western part of the Observatory and adjacent to the dry river have higher and deeper accumulation of organic carbon leading to the assumption

that they were "fluvial" deposited. Nevertheless, the origin of this material is not clear. One possible explanation is the accumulation of eroded topsoil material from the surrounding area. Another possibility is the development of more stable humus complexes in soils with calcium carbonate and higher pH. During this study, higher humus content and darker colour were frequently found in soils influenced by calcareous material. Eitel & Eberle (2001, 2002) reported regions approx. 50 km north of the Observatory displaying considerable proportions of soils with dark, mollic epipedons, which they classified as Kastanozems. They assumed that these soils have been formed in earlier and more open and grass-dominated periods and are now subject to degradation processes. It is possible that soils with a similar genesis exist in the study area.

Reference profile (H26)

This **Luvisol** is a typical example for soils developed in the reddish loamy substrates without calcretes. The texture is dominated by a sand clay mixture with an even distribution of the different sand fractions and only little amounts of silt. Clay content increases with depth up to 30% and the mean bulk density is around 1.65 g cm^{-3}. The soil has a subangular, blocky structure; the excavation difficulty is high and so is the penetration resistance when the soil is dry. Soil reaction is slightly acid across the entire profile; the electrical conductivity is low with a marginal increase with depth. Total element content increases with profile depth, showing a clear correlation with the clay content. Pedogenic iron is around 40% of the total iron content indicating a moderate weathering status. The content of water soluble ions is very low with 3–10 $mmol_c\ kg^{-1}$. The cation exchange capacity is between 40 and 110 $mmol_c\ kg^{-1}$.





Responsible authors: U. Wisch, A. Petersen, A. Gröngröft & D. Mager

Biological soil crusts

Sampling period(s)	Hectare plots sampled	Types of soil crusts
2001, 2003	4 (R2, R3, R4, R12)	2, 3
Crust thickness	**Cover**	**Carbon [weight %]**
3–4 mm	up to 60%	1.523
Nitrogen [weight %]	**Chlorophyll *a* [mg/m²]**	**Chlorophyll *a+b* [mg/m²]**
0.036	15	22

Well-established cyanobacterial crusts occur preferentially under tree and shrub canopies (see Photo). Despite the low chlorophyll content of the crusts, the soil contains a significant amount of carbon, probably from dead plant material. The diversity of cyanobacteria and green algae is moderate in this Observatory.

Cyanobacteria
Leptolyngbya foveolarum
Phormidium sp. 1
Pseudanabaena cf. *minima*
Pseudanabaena cf. *starmachii*
Scytonema ocellatum
Scytonema sp.

Green algae
Bracteacoccus giganteus
Chlorolobion lunulatum
Chlorosarcinopsis cf. *variablis*
Pseudochlorococcum typicum

Well-established cyanobacterial crusts under shrub canopies and between grass tufts. Photo: B. Büdel.

Biological soil crust characteristics

	H03	H12	H52	H72
Soil characteristics	Dark brown silty sand with small stones	Red ferralitic sand with few small stones	Dark brown fine to silty sand; few small stones	Dark brown to grey sand with small stones
Crust characteristics	Thick crust with light to dark surface; biotic and abiotic crust	Black shiny crust surface; Biotic and abiotic crust	Encrusted with light coloured surface; BSC not obvious	Encrusted with lighter coloured surface; BSC not obvious
Chlorophyll a [mg/m²]	15.86	31.82	3.77	6.82
Chlorophyll a+b [mg/m²]	27.19	46.79	5.69	10.27
Carbon [weight %]	1.32	1.09	2.21	1.47
Nitrogen [weight %]	0.03	0.03	0.05	0.03

Responsible authors: B. Weber, K. Deutschewitz, S. Dojani, T. Friedl, T. Darienko, K. Mohr & B. Büdel

Lichens

Sampling period(s)	Hectare plots sampled	Cover
2001	4 (R1−R4)	0%
Total species richness	Species richness on soil [1 km²]	Species richness on rock [1 km²]
33	15 (45%)	3 (10%)
Species richness on plants [1 km²]	Species richness on soil [1000 cm²]	
15 (45%)	0	

This Observatory is one of the richest in terms of lichen species diversity in the Savanna Biome. 15 species are found on soils, with cyanolichens dominating (70%). The majority of taxa have a squamulose, peltate, small fruticose or small foliose growth habit, but all exhibit reduced growth. Rocks and boulders are uncommon on this site, but some lichen species occur on limestone (stones and pebbles). The number of epiphytic species is relatively high, especially in more closed woodland or shrubland stands. Five taxa from this Observatory were recorded for the first time in Namibia (*Caloplaca holocarpa*, *Hyperphyscia pruinosa*, *H. syncolla*, *Phaeophyscia hispidula* and *Xanthoria candelaria*) and two (*Caloplaca citrina* and *Opegrapha varia*) for the first time in southern Africa (Zedda et al. 2009).

Only four hectare plots were investigated at this Observatory by means of digital photography. Lichens were completely absent in the examined hectare plots, but were abundant in other plots. Such large differences between sites are mainly due to the patchy distribution of suitable soil types, but livestock grazing intensity may also influence lichen occurrence. Lichens are common and have a high cover on calcareous soils, while they are absent on most sandy soils.

List of taxa

Terricolous (on soil):

Collema coccophorum s.l.
Endocarpon cf simplicatum
Endocarpon cf pallidulum
Heppia adglutinata
Heppia despreauxii
Heppia cf. conchiloba
Lichinaceae sp.
Lichinella stipatula
Peccania sp.
Peltula radicata
Peltula patellata
Peltula sp.
Placidium lacinulatum
Placidium squamulosum
Placidium tenellum

Saxicolous (on rock):

Lichenothelia sp.
Peccania sp.
Peltula obscurans s.l.

Epiphytic (on plants):

Caloplaca citrina
Caloplaca holocarpa
Candelaria concolor
Collema occultatum
Flavoparmelia soredians
Flavopunctelia flaventior
Hyperphyscia adglutinata
Hyperphyscia pruinosa
Hyperphyscia syncolla
Opegrapha varia
Phaeophyscia hispidula
Physcia erumpens
Physcia poncinsii
Physcia undulata
Pyxine cocoes

Peltula radicata. Photo: M. Schultz, L. Zedda & G. Rambold.

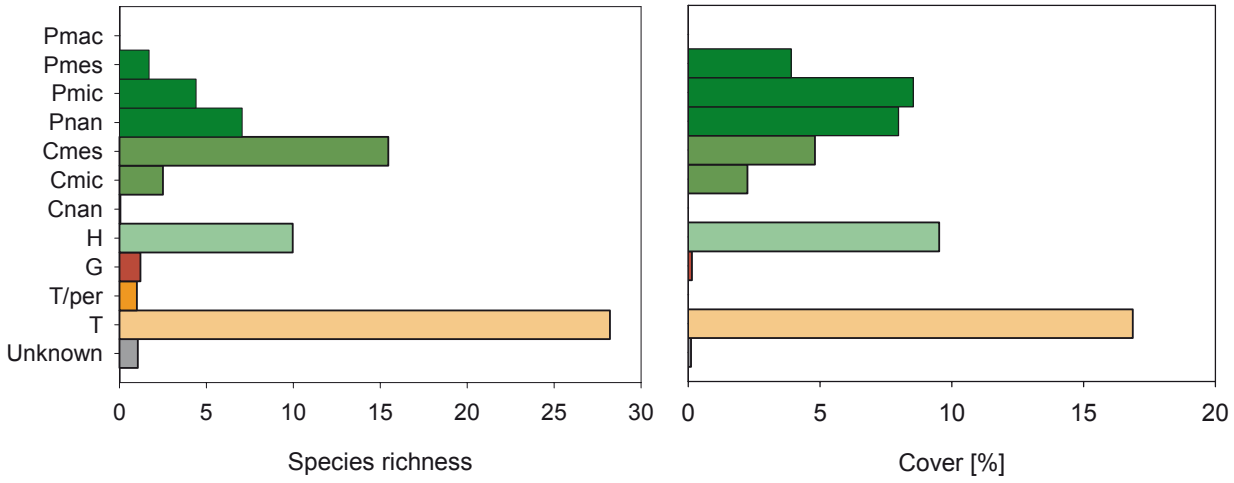
Heppia despreauxii. Photo: M. Schultz, L. Zedda & G. Rambold.

Responsible authors: L. Zedda & G. Rambold

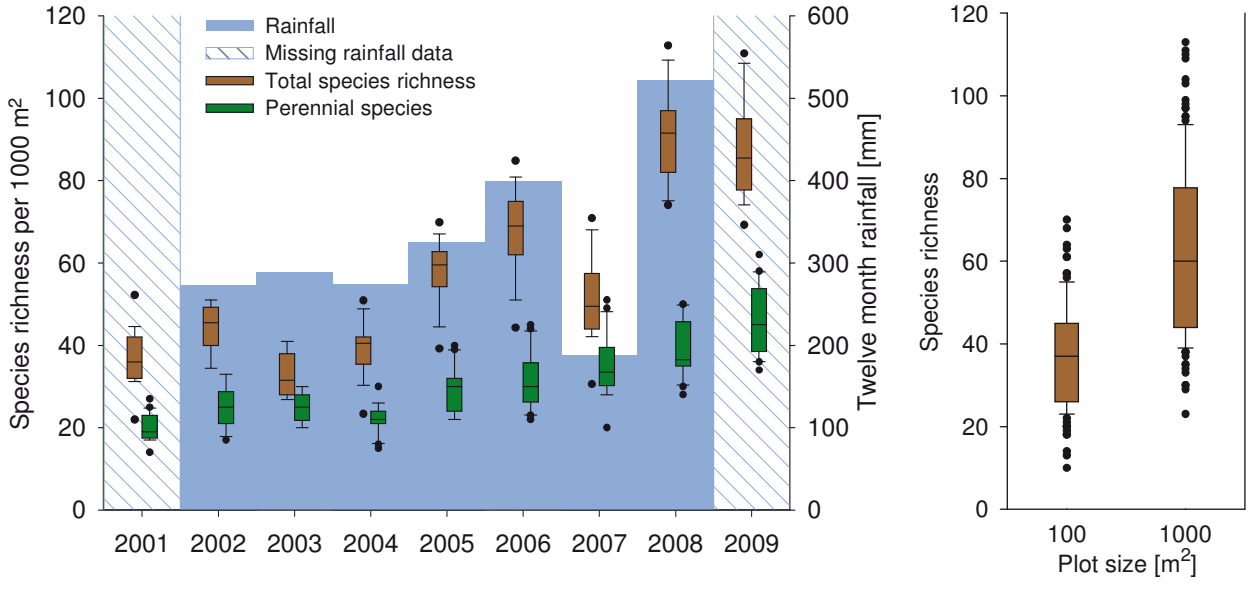
Vascular plants

Sampling period(s)	Hectare plots sampled	Biome
2004–2009	20 (R1–R20)	Thornbush Savanna
Vegetation unit (level 1)	**Vegetation unit (level 2)**	**Identification rate**
Thornbush Savanna (Tree and Shrub Savanna)	n.a.	78% – 96% – 98%
Cumulative family richness	**Dominant families (cover)**	**Dominant families (richness)**
53	Poaceae, Fabaceae, Acanthaceae	Poaceae, Fabaceae, Asteraceae
Cumulative species richness (1 km²)	**Species richness (1000 m²)**	**Species richness (100 m²)**
388 – 213	56.8 (21–113)	36.7 (10–70)
***z*-value**	**Species richness change per year (1000 m²)**	**Evenness (1000 m²)**
0.189 (0.097–0.477)	2.12	0.663 (0.431–0.877)
Evenness (100 m²)	**Simpson (1000 m²)**	**Simpson (100 m²)**
0.624 (0.349–0.825)	0.851 (0.499–0.953)	0.796 (0.428–0.928)

Life forms



Species richness

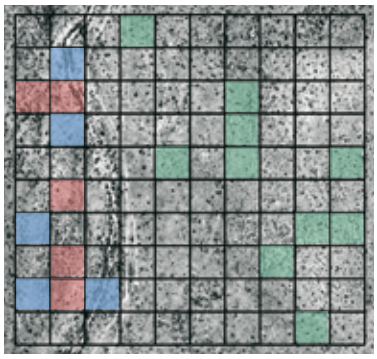


Classification table (2009)

Column		Cover	All	1	2	3
Number of relevés			**20**	**5**	**5**	**10**
Mean cover [%]			58.3	67.0	51.2	57.5
Mean species richness (1000 m²)			87.7	94.2	84.0	86.2
Mean soil pH			5.78	6.01	6.63	5.24
Mean electrical conductivity [µS·cm^{-1}]			57	49	38	70
Organic carbon [%]			0.44	0.48	0.48	0.40
Nitrogen [%]			0.04	0.04	0.04	0.04
Fine material [%]			77.0	73.6	75.4	79.5
Gravel [%]			9.4	11.0	8.2	9.2
Stones 2-6 cm [%]			0.2	0.8	0	0
Stones 6-20 cm [%]			0.1	0.4	0	0
Stones 20-60 cm [%]			0.1	0.4	0	0
Blocks [%]			0.05	0.2	0	0
Rock outcrops [%]			0.05	0.2	0	0
Unit 1: Bothriochloa radicans-Ziziphus mucronata community						
Cmes	Monechma spartioides	0.30	20	80	.	.
T	Setaria verticillata	0.56	25	80	.	10
Hper	Blepharis integrifolia var. integrifolia	0.10	40	100	20	20
Hper	Leucas glabrata	0.10	15	60	.	.
T	Acalypha indica	0.10	15	60	.	.
Cmes	Peristrophe hereroensis	0.10	30	80	.	20
T	Launaea intybacea	0.10	45	100	40	20
T/Hper	Vernonia fastigiata	0.17	30	80	40	.
H	Bothriochloa radicans	0.53	30	80	40	.
H	Eragrostis echinochloidea	0.26	50	100	80	10
Hper	Corchorus asplenifolius	0.10	20	60	20	.
Unit 2: Seddera suffruticosa-Melhania virescens community						
H	Monelytrum luederitzianum	0.23	15	.	60	.
Cmes	Melhania virescens	0.10	15	.	60	.
Cmes	Seddera suffruticosa	0.19	45	40	100	20
Unit 3: Eragrostis rigidior-Gisekia africana community						
T	Gisekia africana	0.10	40	.	.	80
T	Commelina forskaolii	0.10	55	.	40	90
T	Hirpicium gorterioides	0.10	55	40	.	90
Hper	Indigofera vicioides	0.26	65	20	40	100
Hper	Crotalaria heidmannii	0.10	25	.	.	50
T/Hper	Tephrosia burchellii	0.18	50	20	20	80
T	Bulbostylis hispidula	0.10	50	20	20	80
Hper	Ipomoea obscura	0.17	60	40	20	90
H	Eragrostis rigidior	0.21	35	.	20	60
Hper	Helichrysum candolleanum	0.10	35	20	.	60
Most frequent companions						
Pmic	Acacia mellifera ssp. detinens	6.40	100	100	100	100
T	Aristida rhiniochloa	4.01	100	100	100	100
Pmes	Acacia tortilis ssp. heteracantha	2.00	100	100	100	100
Cmes	Lycium eenii	1.13	100	100	100	100
T	Enneapogon cenchroides	1.05	100	100	100	100
Cmes	Indigofera rautanenii	0.88	100	100	100	100
T	Pupalia lappacea	0.47	100	100	100	100
T/Cmic	Talinum arnotii	0.30	100	100	100	100
Cmes	Acrotome fleckii	0.14	100	100	100	100
H	Aristida congesta	3.29	95	100	100	90
T	Melinis repens	2.79	95	100	80	100
Pnan	Grewia flava	2.16	95	100	100	90
H	Stipagrostis uniplumis	1.85	95	100	100	90
Pmic	Boscia albitrunca	1.02	95	100	100	90
T	Aristida adscensionis	0.65	95	100	80	100

continued on next page

Map of vegetation units



The vegetation of the Observatory Otjiamongombe (S05) is a Thornbush Savanna with patches of dense tree and thorny shrub cover alternating with more open grassland dominated by *Stipagrostis uniplumis* and scattered trees. Areas with a mix of grasses, dwarf shrubs, and dense woody vegetation occur along a small river (also called Rivier or omuramba). The two main habitat types are the plains and the river, which are quite distinct in vegetation structure and species composition. Changes in vegetation on the plains are mainly associated with the occurrence of a calcrete layer in the soil. Dwarf shrubs are more common on soils influenced by calcrete, which causes lower soil depths. Bush encroachment by *Acacia mellifera* occurs in some areas on the plain. The riverine vegetation can show strong interannual variability but permanently features a layer of relatively high trees and a dense shrub thicket. Three distinct vegetation units can be found on the Observatory.

The *Bothriochloa radicans-Ziziphus mucronata* community (unit 1) features the riverine vegetation of the "rivier" habitat type. The river that intersects the plain only bears water after strong rainfall. Nevertheless, the sandy riverbed and deeper soil layers act as a water reservoir and allow for the enhanced growth of trees such as *Ziziphus mucronata*, *Acacia reficiens* (Red Thorn), and *Acacia mellifera* (Swarthaak). A very species rich flora of ephemeral herb and grass species occurs in the moist understorey of thickets. Some perennial grasses such

as *Bothriochloa radicans* and *Eragrostis rotifer* are well adapted to moist conditions and can form dense stands along or within the riverbed.

The *Seddera suffruticosa-Melhania virescens* community (unit 2) is typically found in parts of the "plain" habitat where the soil possesses a calcrete layer. The soil type associated with this community is Calcisol, which is characterised by elevated concentrations of calcium carbonate. Both eponymous species of this community are known to indicate calcareous soils. The same applies to *Monelytrum luederitzianum*, a perennial grass of reasonable palatability, which can form dense stands through the formation of stolons. Other species characteristics of this community are *Enneapogon desvauxii*, a shallow rooted short grass, and the shrub *Catophractes alexandri* with its typical greyish leaves, which generally occurs throughout the area on shallow soils

The *Eragrostis rigidior-Gisekia africana* community (unit 3) covers most of the Observatory area. Although typical of sandy soils of the northern Kalahari, the densely tufted perennial grass *Eragrostis rigidior* can also be found on loamy, heavier soils such as those occurring on the Observatory. Other typical species of this community are annual herbs such as *Gisekia africana*, *Crotalaria heidmannii* and *Tephrosia burchellii,* which occur in large numbers after good rainfall but may be absent during bad rainfall years. Bush encroachment by *Acacia mellifera* and high abundances of grasses from the genus *Aristida* in some parts of this unit are visible signs of poor land-management in the past. However, many parts of this vegetation unit show a high diversity of non-encroacher woody species such as *Acacia fleckii*, *Acacia tortilis* (Umbrella Thorn), *Acacia hebeclada* and *Boscia albitrunca*.

Classification table (continued)

Column		Cover	All	1	2	3
Number of relevés			**20**	**5**	**5**	**10**
Cmes	Barleria lanceolata	0.42	95	100	100	90
T	Eragrostis porosa	0.27	95	100	100	90
Hper	Evolvulus alsinoides	0.21	95	100	80	100
T/Hper	Phyllanthus maderaspatensis	0.18	95	100	100	90
H	Chloris virgata	0.16	95	100	80	100
Pnan	Lantana angolensis	0.16	95	100	100	90
T	Indigofera charlieriana	0.16	95	100	100	90
Hper	Pollichia campestris	0.16	95	100	100	90
T	Commelina benghalensis	0.14	95	100	80	100
Cmes	Ptycholobium biflorum	0.10	95	100	100	90
H	Eragrostis jeffreysii	1.97	90	100	80	90
Cmic	Aptosimum angustifolium	1.84	90	80	80	100
T	Pogonarthria fleckii	0.83	90	80	80	100
Hper	Hermbstaedtia odorata	0.12	90	100	80	90
Cmes	Solanum cf. dinteri	0.12	90	100	80	90
Hper	Chascanum pinnatifidum	0.10	90	80	80	100
T	Kyphocarpa angustifolia	0.10	90	60	100	100
T	Mollugo cerviana	0.10	90	100	80	90
Pnan	Monechma genistifolium	4.90	85	80	100	80
Pnan	Lycium oxycarpum	1.07	85	100	100	70
Cmes	Hibiscus calyphyllus	0.26	85	100	60	90
Cmes	Blepharis pruinosa	0.22	85	100	80	80
T	Ipomoea sinensis	0.22	85	80	60	100
T	Nelsia quadrangula	0.15	85	100	80	80
T	Geigeria ornativa	5.24	80	80	80	80
Cmic	Leucosphaera bainesii	0.59	80	100	100	60
Cmes	Otoptera burchellii	0.53	80	60	100	80
H	Aristida effusa	0.53	80	80	40	100
Pmic	Dichrostachys cinerea	0.30	80	60	60	100
Hper	Ocimum americanum var. americanum	0.29	80	100	80	70
T	Nidorella resedifolia	0.18	80	80	80	80
Cmic	Dicoma tomentosa	0.15	80	60	60	100
Hper	Hermannia rautanenii	0.15	80	80	60	90
T	Urochloa brachyura	0.13	80	60	60	100
T	Felicia smaragdina	0.10	80	60	60	100
T	Lotononis platycarpa	0.10	80	60	60	100
H	Eragrostis trichophora	0.68	75	80	80	70
Pmic	Ziziphus mucronata	0.47	75	100	80	60
Cmes	Aptosimum tragacanthoides	0.45	75	100	100	50
T	Geigeria acaulis	0.13	75	60	80	80
H	Cyperus fulgens	0.10	75	80	60	80
H	Cenchrus ciliaris	0.89	70	100	100	40
T/Hper	Kohautia cynanchica	0.10	70	60	100	60
Pmes	Acacia reficiens	2.78	65	100	80	40
T/Hper	Ondetia linearis	1.86	65	80	80	50
H	Eragrostis rotifer	0.79	65	100	60	50
T	Chenopodium amboanum	0.26	65	100	100	30
Cmes	Pavonia burchellii	0.16	65	80	40	70
T	Cucumis anguria var. longaculeatus	0.13	65	80	20	80
T	Euphorbia inaequilatera	0.10	65	60	100	50
Pmic	Acacia hebeclada ssp. hebeclada	1.43	60	60	60	60
Pnan	Ehretia rigida	0.17	60	60	40	70
Hper	Achyranthes aspera var. sicula	0.10	60	60	60	60
Pnan	Solanum lichtensteinii	0.17	55	60	40	60
T	Indigofera holubii	0.31	50	60	40	50
Cmes	Peliostomum leucorrhizum	0.14	50	60	80	30
n.a.	Heliotropium steudneri	0.10	50	40	20	70
Hper	Hibiscus palmatus	0.10	50	40	60	50
T	Tragus berteronianus	0.10	50	60	40	50
T	Bidens pilosa	0.39	45	80	80	10

Unit 1, 2007. Photo: D. Wesuls.

Unit 2, 2005. Photo: D. Wesuls.

Unit 3, H46, 2008. Photo: J. Fleiner.

Flowering savanna, 2008. Photo: D. Wesuls.

Responsible authors: D. Wesuls & J. Luther-Mosebach

Millipedes

Sampling period(s)	Species richness
2003/III	3

This Observatory possessed the highest millipede species richness of all sampled Observatories. However, this finding may have been biased by the different times of the season spent at the different observatories. The very large species *Spirostreptus heros* (see Mile 46/S01) was found to occur here, along with another representative of the family Spirostreptidae, *Doratogonus rugifrons*. *Doratogonus rugifrons* is dark–brown in colour and is a medium-sized millipede attaining lengths of approximately 17 cm. Small protrusions on the final segment, or telopodit, are a characteristic morphological feature of this genus.

According to Samways & Hamer (2004) this species is also found in suburban areas and is therefore of least concern.

Another species occurring here is *Chaleponcus limbatus*, which is dark-brown, only 4.0–4.5 mm long, and belongs to the family Odontopygidae. This family probably originated in central Africa. In contrast to other millipedes, which defend themselves by curling their bodies into a tight curl, the agile odontopygids display an active defensive behaviour by writhing their bodies.

List of species

Species	Family	Relative frequency	Feeding group
Spirostreptus heros	Spirostreptidae	Frequent	Litter, fresh plant material
Doratogonus rugifrons	Spirostreptidae	n.a.	Litter
Chaleponcus limbatus	Odontopygidae	n.a.	Litter

Responsible author: K. Vohland

Termites

Taxon richness	Abundance index	Dominant (sub-)family
7	62	Termitidae (Macrotermitinae)

Odontotermes sp. 1 is one of the most common termite species occurring at this Observatory. In contrast to *Macrotermes* (see Observatory S04/Toggekry), the southern African species of *Odontotermes* usually do not build large mounds. Their mounds are rarely observed, and if they are visible they are usually low and flattened. The centralised nest cavity is accompanied by supplementary fungus chambers in the surrounding soil. *O. okahandjae* (see Photo) was collected from this Observatory exclusively. In Namibia, within the species-rich genus *Odontotermes*, only this species can be recognised easily in the field due to the remarkable dimorphism of the soldier cast. This species is always associated with heavier soils found for example on river floodplains and riverbanks. It was found along the rivier which crosses this Observatory.

List of taxa

Taxon	(Sub-)family	Frequency Index	Feeding substrate
Hodotermes mossambicus	Hodotermitidae	0.45	g
Macrotermes michaelseni	Termitidae (Macrotermitinae)	0.45	f (g, l, w)
Odontotermes sp. 1	Termitidae (Macrotermitinae)	0.45	f (g, l, w)
Microtermes	Termitidae (Macrotermitinae)	0.36	f (g, l, w)
Odontotermes okahandjae	Termitidae (Macrotermitinae)	0.18	f (g, l, w)
Trinervitermes	Termitidae (Nasutitermitinae)	0.18	s, w, g, l, m
Allodontermes	Termitidae (Macrotermitinae)	0.09	f (g, l, w)

Responsible authors: C. Grohmann & K.E. Linsenmair

Odontotermes okahandjae in their nest system surrounded by fungus combs; the soldiers vary remarkably in their size. Photo: C. Grohmann.

Major soldier of *Odontotermes okahandjae* on a fungus comb. Photo: C. Grohmann.

True bugs

Sampling period(s)	Methods	Family richness
2001/IV; 2002/III, IV, X; 2003/III, IV, V; 2004/II; 2007/I, II, III; 2008/II, IV, IX; 2009/II	Trapping (light, pitfall traps, yellow pan, Malaise); beating off plants; vacuum collector, hand collecting, soil and litter sifting	25
Species richness	**Individuals sampled**	**Fisher's alpha diversity**
264	2494	74.95

The species diversity at Otjiamongombe Observatory (S05) is much higher than at any other Observatory, followed by the species diversities of S04 (Toggekry) and S02 (Mutompo). The differences between these Observatories were probably caused by differences in collecting effort. Phytophagous species make up 82% of all collected species and belong to the families Miridae, Pentatomidae, Rhyparochromidae, Alydidae, Lygaeidae, and Coreidae. As with the other Observatories, a high percentage of species (45%) were recorded only as a single specimens. The majority of the species, particularly the common ones, are characteristic of the Thornbush Savanna. One specimen typical of the Nama Karoo biome, *Leptodemus irroratus* (Oxycarenidae), was collected by net sweeping.

A few species were recorded for the first time in Namibia, such as *Suffenus fusconervosus* and *Stygnocorisella linnavuori*. Both of these Rhyparochromidae species are widely distributed in Africa, although they are often overlooked because of their tiny size (about 2 mm). *Peliochrous globisternum* (Rhopalidae) and *Pontia misella* (Pentatomidae) are two other species that were recorded in Namibia for the first time. One species of Dipsocoromorpha was collected in a pitfall trap, and is the first record of this infra-order in Namibia.

Responsible author: J. Deckert

Species richness of families

Family	S
Miridae	127
Pentatomidae	21
Reduviidae	19
Rhyparochromidae	18
Lygaeidae	9
Alydidae	8
Coreidae	8
Rhopalidae	7
Tingidae	7
Micronectidae	6
Cydnidae	5
Notonectidae	5
Corixidae	4
Stenocephalidae	4
Anthocoridae	2
Geocoridae	2
Pachygronthidae	2
Pyrrhocoridae	2
Scutelleridae	2
Berytidae	1
Dipsocoromorpha	1
Enicocephalidae	1
Heterogastridae	1
Pleidae	1
Oxycarenidae	1
Total	**264**

Species abundances

Light traps

Species	Family	*N*	%
Micronecta scutellaris cf.	Corixidae	185	13
Micronecta spec.	Corixidae	125	9
Aethus perosus cf.	Cydnidae	110	8
Carbula abacta	Pentatomidae	75	5
Miridae spec. 1	Miridae	59	4
Sigara meridionalis	Corixidae	45	3
Orthotylus spec.	Miridae	43	3
Aethus sculptus	Cydnidae	42	3
Miridae spec. 2	Miridae	35	2
Oncylocotis nasutus	Enicocephalidae	35	2
Camptocoris rostratus	Lygaeidae	33	2
Miridae spec. 3	Miridae	32	2
Piezodorus purus	Pentatomidae	27	2
Acrosternum apicale	Pentatomidae	26	2
Nariscus cinctiventris	Alydidae	26	2
Dicranocephalus pseudotestaceus	Stenocephalidae	22	2
Dicyphus spec.	Miridae	22	2
Miridae spec. 4	Miridae	21	1
Miridae spec. 5	Miridae	20	1
Ectomocoris quadrimaculatus	Reduviidae	19	1
Miridae spec. 6	Miridae	17	1
Nysius ericae	Lygaeidae	17	1
Miridae spec. 7	Miridae	16	1
Miridae spec. 8	Miridae	15	1
Miridae spec. 9	Miridae	15	1
Cletus pusillus	Coreidae	15	1
Others (146)		344	24
Total		**1441**	**100**

Pitfall traps

Species	Family	*N*	%
Tenosius protelarius	Alydidae	29	29
Liorhyssus hessei	Rhopalidae	20	20
Nysius ericae	Lygaeidae	9	9
Liorhyssus natalensis	Rhopalidae	8	8
Centroplax melanosticta	Coreidae	5	5
Naphius apicalis	Rhyparochromidae	4	4
Euthetus leucostictus	Alydidae	3	3
Pephricus paradoxus	Coreidae	2	2
Menaccarus ciliosus	Pentatomidae	2	2
Peliochrous nigromaculatus	Rhopalidae	2	2
Others (16)		16	16
Total		**100**	**100**

Butterflies and moths

Sampling period(s)	Number of samples (moths)	Species richness (total)
2001/III; 2002/II; 2003/II–III; 2007/I–II, X; 2008/IV, XII	10	492
Species richness (butterflies)	**Species richness (all moths)**	**Species richness (Microlepidoptera)**
39	453	162
Species richness (Pyraloidea)	**Species richness (Macrolepidoptera)**	**Species richness (Noctuidae)**
111	53	127
Individuals sampled (moths)	**Fisher's alpha diversity (moths)**	
5323	97.6	

Butterflies

The butterfly fauna on this Observatory was studied in 2003 and repeatedly during 2007–2008. This Observatory possesses the highest number of recorded species along the BIOTA transects. The composition and abundances of the resident species can be regarded as typical for large parts of the Savanna Biome in Namibia. The species composition largely corresponds to that of the nearby Observatory S04 (Toggekry). The families Pieridae and Lycaenidae are dominant in terms of species diversity and abundance. *Papilio demodocus demodocus* were regularly observed flying close to the farm-house, but were not recorded at the Observatory. The abundance of butterflies is highest in January–February and they are either absent or their numbers are extremely low at the end of the dry season (November–December).

Transect analysis of butterflies

Sampling period: 11 January 2007. The sampling was conducted after a short rainy period in December.
Description of transect: The transect of 1000 m length lies in the eastern part of the Observatory. The transect follows the trail which crosses the Observatory in a north-west direction and ends at the fence to the neighbouring farm Tiefenbach.
Species richness: 10, **number of individuals:** 83

Abundance

Species	*N*	Proportion
Belenois aurota aurota	51	61.4%
Colotis evagore antigone	8	9.6%
Azanus jesous jesous	8	9.6%
Pinacopteryx eriphia eriphia	6	7.2%
Colotis agoye bowkeri	6	7.2%

Moths

Collecting moths by means of light traps is heavily influenced by weather conditions and moon phase. Low temperatures (below 14°C), rainy conditions, wind, no clouds, and a full moon tend to reduce moth capture success when using light traps. On 10 January, 2007 the conditions were optimal in all respects and the sample of moths collected turned out to be the largest and most diverse sample obtained in Namibia and South Africa during the project. Even some large *Heniocha dyops* (Saturniidae) individuals were trapped (see Photo). The results of the full sample are presented here and compared to a sample from the same plot a month later. The combined species numbers revealed a remarkably high diversity especially in the major Lepidoptera groups Microlepidoptera (with Gelechiidae, Scythrididae and Tineidae being the most species-rich families) and Pyraloidea with more than 100 species. The comparison also shows the occurrence of a pronounced seasonality, which is discernable as rapid species turnover from month to month.

Female of *Heniocha dyops*.
Photo: W. Mey.

Butterfly species and main food plants

Hesperiidae	
Spialia colotes transvaaliae	Hibiscus (Malvaceae)
Spialia spio	Hermannia (Sterculiaceae), Hibiscus, Pavonia (Malvaceae)
Spialia mafa mafa	Hermannia (Sterculiaceae), Hibiscus, Pavonia (Malvaceae)
Coeliades pisistratus	Sphedamnocarpus, Triaspis (Malpighiaceae), Indigofera (Fabaceae)
Lycaenidae	
Azanus jesous jesous	Acacia (Fabaceae)
Azanus ubaldus	Acacia (Fabaceae)
Cigaritis phanes	Acacia (Fabaceae), Ximenia (Olacaceae)
Leptotes babaulti	n.a.
Lepidochrysops plebeia	Lantana (Verbenaceae)
Lepidochrysops michellae	n.a.
Tarucus sybaris linearis	Zizyphus (Rhamnaceae)
Tuxentius melaena melaena	Zizyphus (Rhamnaceae)
Leptotes pirithous pirithous	Plumbago (Plumbaginaceae), Indigofera (Fabaceae), Burkea (Caesalpiniaceae)
Zintha hintza krooni	Zizyphus (Rhamnaceae)
Zizula hylax	Phaulopsis, Ruellia (Acanthaceae)
Chilades trochylus	Indigofera (Fabaceae), Heliotropium (Boraginaceae)
Nymphalidae	
Danaus chrysippus aegyptius	Asclepias, Stapelia, Cynanchum (Asclepiadaceae)
Acraea neobule	Adenia, Passiflora (Passifloraceae)
Acraea stenobea	n.a.
Hypolimnas misippus	Portulaca, Talinum (Portulacaceae)
Junonia hierta cebrene	Asystasia, Adhatoda, Barleria, Ruellia (Acanthaceae)
Junonia oenone oenone	Asystasia, Adhatoda, Barleria, Ruellia (Acanthaceae)
Vanessa cardui	Carduus, Arctotis, Berkheya (Asteraceae)
Pieridae	
Eurema brigitta brigitta	Hypericum (Hypericaceae), Chamaecrista (Caesalpiniaceae)
Catopsilia florella	Senna (Caesalpiniaceae)
Pinacopteryx eriphia eriphia	Boscia, Maerua (Capparaceae)
Belenois aurota aurota	Boscia, Capparis, Maerua (Capparaceae)
Colotis eris eris	Boscia (Capparaceae)
Colotis agoye bowkeri	Boscia,. Cadaba (Capparaceae)
Colotis antevippe gavisa	Boscia, Capparis, Maerua (Capparaceae)
Colotis celimene pholoe	Boscia, Capparis (Capparaceae)
Colotis subfasciatus	Boscia (Capparaceae)
Colotis evagore antigone	Capparis, Maerua (Capparaceae)
Colotis evenina evenina	Boscia, Capparis (Capparaceae)
Colotis evippe omphale	Boscia, Capparis, Maerua (Capparaceae)
Colotis regina	Boscia, Capparis (Capparaceae)
Colotis pallene	Capparis (Capparaceae)
Colotis lais	Boscia (Capparaceae)
Colotis ione	Boscia, Capparis (Capparaceae)

Taxonomic spectrum of moths

Collection period: I+II/2007

	10 Jan		12 Feb		Shared species	Total
Family	***S***	***N***	***S***	***N***	***S***	***S***
Nepticulidae	6	57	2	3	2	6
Tischeriidae	1	2				1
Tineidae	12	60	7	22	4	15
Eriocottidae	5	81	1	5	1	5
Psychidae	3	43	3	7	1	5
Bucculatricidae	5	22				5
Gracillariidae	2	8	2	2	2	2
Galacticidae	1	1				1
Yponomeutidae	2	3				2
Lyonetiidae	2	17				2
Coleophoridae	4	42	5	20	2	7
Xyloryctidae			1	1		1
Ethmiidae	5	33	5	19	4	6
Scythrididae	21	288	10	36	8	23
Oecophoridae	2	6	1	1		3
Lecithoceridae	2	11				2
Autostichidae	1	1	1	1	1	1
Chrysopeleidae	9	139	3	5	2	10
Cosmopterigidae	3	352	2	27	2	3
Gelechiidae	51	536	17	69	14	54
Gelechiidae, indet.		82				
Thyrididae			1	3		1
Tortricidae	4	5	2	5	2	4
Pterophoridae	2	2				2
Alucitidae	1	3	1	1	1	1
Microlepidoptera	**144**	**1794**	**64**	**227**	**46**	**162**
Pyralidae: Phycitinae	44	947	24	124	18	50
Pyralidae: Endotrichinae	1	4	1	5	1	1
Pyralidae: Galleriinae	2	2				2
Pyralidae: Pyralinae	9	31	6	33	5	10
Crambidae	31	444	25	144	18	48
Pyraloidea	**87**	**1428**	**56**	**306**	**42**	**111**
Limacodidae	2	9				2
Lasiocampidae	4	17	2	3	1	5
Saturniidae	1	1	1	1		2
Sphingidae	1	3	2	2		3
Geometridae	28	740	19	108	12	35
Arctiidae	3	5	2	4	2	3
Notodontidae	1	4				1
Lymantriidae	2	8	1	1	1	2
Noctuidae	109	1292	64	344	47	127
Noctuidae, indet.		22				
Macrolepidoptera	**151**	**2101**	**91**	**463**	**63**	**180**
Total	**382**	**5323**	**211**	**996**	**151**	**453**

Responsible author: W. Mey

Vertebrates

Total species richness	Reptile species richness	Bird species richness
65	n.a.	65
Large mammal species richness	Small mammal species richness	
n.a.	n.a.	

Abdim's Stork (*Ciconia abdimii*). Photo: J. Deckert.

European Bee-eater (*Merops apiaster*). Photo: J. Deckert.

Birds

Passeriformes	**Perching birds**
Bradornis mariquensis	Marico Flycatcher
Bubalornis niger	Red-billed Buffalo-Weaver
Calamonastes fasciolatus	Southern Barred Warbler
Cisticola sp.	Cisticola
Dicrurus adsimilis	Fork-tailed Drongo
Emberiza flaviventris	African golden-breasted Bunting
Hirundo rustica	Barn Swallow
Hirundo semirufa	Rufous-chested Swallow
Lamprotornis nitens	Cape Glossy Starling
Laniarius atrococcineus	Crimson-breasted Gonolek
Lanius collaris	Fiscal Shrike
Lanius collurio	Red-backed Shrike
Muscicapa striata	Spotted Flycatcher
Nectarinia mariquensis	Mariqua Sunbird
Nectarinia senegalensis	Scarlet-chested Sunbird
Parisoma subcaeruleum	Chestnut-vented Tit-Babbler
Passer griseus	Grey-headed Sparrow
Philetairus socius	Sociable Weaver
Plocepasser mahali	White-browed Sparrow-weaver
Ploceus intermedius	Lesser masked Weaver
Ploceus velatus	Southern masked Weaver
Prinia flavicans	Black-chested Prinia
Pririt batis	Pririt Puffback
Psophocichla litsipsirupa	Groundscraper Trush
Pycnonotus nigricans	Black-fronted Bulbul
Pytilia melba	Green-winged Pytilia
Sporopipes squamifrons	Scaly-fronted Weaver
Uraeginthus angolensis	Blue Waxbill
Accipitriformes	**Birds of prey**
Aquila rapax	Tawny Eagle
Buteo buteo vulpinus	Steppe Buzzard
Elanus caeruleus	Black-winged Kite
Melierax gabar	Gabar Goshawk
Milvus aegyptius	Yellow-billed Kite
Milvus migrans	Black Kite
Falconiformes	**Birds of prey**
Falco chicquera	Red-necked Falcon
Gruiformes	**Cranes, rails, coots, and allies**
Lophotis ruficrista	Red-crested Bustard
Afrotis afraoides	White-quilled Bustard
Afrotis afra	Black Bustrard
Ardeotis kori	Kori Bustard
Eupodotis afraoides	White-quilled Bustard
Eupodotis ruficrista	Red-crested Bustard
Cuculiformes	**Cuckoos and anis**
Chrysococcyx caprius	Dideric Cuckoo
Corythaixoides concolor	Grey go-away-Bird
Galliformes	**Fowl-like birds**
Francolinus swainsonii	Swainson's Spurfowl
Francolinus adspersus	Red-billed Francolin
Numida meleagris	Helmeted Guineafowl
Ciconiiformes	**Herons and storks**
Ciconia abdimii	Abdim's Stork
Coraciiformes	**Kingfishers and relatives**
Coracias naevia	Rufous-crowned Roller
Tockus erythrorhynchus	Red-billed Hornbill
Merops apiaster	European Bee-eater
Merops hirundineus	Swallow-tailed Bee-eater
Coracias caudata	Lilac-breasted Roller
Tockus leucomelas	Southern yellow-billed Hornbill
Tockus nasutus	African Grey Hornbill
Upupa epops africana	African Hoopoe
Coracias caudata	Lilac-breasted Roller
Coliiformes	**Mousebirds**
Colius colius	White-backed Mousebird
Caprimulgiformes	**Nightjars**
Caprimulgus rufigena	Rufous-cheeked Nightjar
Caprimulgus pectoralis	Fiery Necked Nightjar
Strigiformes	**Owls**
Otus senegalensis	African Scops-Owl
Piciformes	**Woodpeckers and relatives**
Dendropicos fuscescens	Cardinal Woodpecker
Tricholaema leucomelas	Acacia Pied Barbet
Columbiformes	**Doves and pigeons**
Turtur chalcospilos	Emerald Spotted Wood-Dove
Oena capensis	Namaqua Dove
Stigmatopelia senegalensis	Laughing Dove
Streptopelia capicola	Ring-necked Dove

Responsible authors: J. Deckert, A. Hoffmann & A. Mills

Site-specific studies

Photo SSS05.1: Savanna on deep sandy soils at Otjiamongombe (Erichsfelde) in 1956. Photo: O.H. Volk.

Impact of the termite *Macrotermes michaelseni* on plant growth (S05.01)

[A. Graiff, C. Grohmann & K.E. Linsenmair]

One aim of this study was to investigate how the building activities of the termite *Macrotermes michaelseni* (Isoptera, Macrotermitinae) affect the growth and nutrient content of plants in the Thornbush Savanna of Namibia and whether this was influenced by soil properties. In pot experiments, the plant growth and nutrient content of radish (*Raphanus sativus* subsp. *sativus*) and of sorghum (*Sorghum* sp.) were assessed and compared between specimens growing on (i) soil from *M. michaelseni* mounds (inhabited and uninhabited), (ii) *M. michaelseni* sheetings (soil constructions, which the termites build to protect themselves when they forage), and (iii) ambient savanna soil as the control. Field work was conducted from February to May 2008 at the Observatory. Plant growth was less vigorous on *M. michaelseni* mound soils than on ambient reference soils although the plants growing on mound soils possessed higher nutrient content. The high nutrient content of these plants can be attributed to the high mineral content of the mound soils. However the higher clay content, cation exchange capacity, and electrical conductivity appear to be responsible for the weaker plant growth on the nutrient-rich mound soils compared to the more sandy sheetings and reference soils.

Graiff, A. (2010): Der Einfluss der Termitentaxa *Macrotermes michaelseni* und *Odontotermes* sp. (Isoptera, Macrotermitinae) auf Pflanzenwachstum und Pflanzenzersetzung in der Dornbuschsavanne Zentralnamibias. – Diplom thesis in Biology. Würzburg: University of Würzburg.

Vegetation changes in the Thornbush Savanna since 1956 (S05.02)

[B.J. Strohbach & R. Austermühle]

Historic vegetation data collected by Prof O.H. Volk in 1956 (Photo SSS05.1) were compared to current vegetation composition (Photo SSS05.2) on a commercial cattle farm (S05) in the Thornbush Savanna in central Namibia. Savannas on deep sandy soils changed from grasslands or open bushlands to closed shrubland with varying degrees of bush encroachment. Shrublands on calcareous soils changed from typical low growing shrubs to a high bushland. In both cases a high degree of perennial grass cover was lost. Omirimbi (shallow water courses in the area, typically covered with grassland) changed to ephemeral rivers through rill erosion with a dense thicket along its embankments. These thickets cannot be differentiated from other riverine thickets.

An extended spell of heavy cattle stocking during periods of average or below average rainfall most probably initiated the change in the vegetation composition. 30 years later the resulting loss of grazing capacity (62%) has a major economical impact.

The value of keeping of datasets secure and available over generations is emphasised as a means to compare long-term vegetation composition changes,

Photo SSS05.2: The same site in a savanna on deep sandy soils at Otjiamongombe (Erichsfelde) as in Photo SSS05.1, 43 years later, i.e. in 1999. Photo: B.J. Strohbach.

especially regarding degradation/desertification studies.

Yearly variation of temperature within nests of the termite *Macrotermes michaelseni*

► *See* **S04.02**

Mapping of Thornbush Savanna soils using Landsat satellite data

► *See* **S04.04**

Does using species abundance data improve estimates of species diversity from remotely sensed spectral heterogeneity?

► *See* **S04.05**

Diversity measures in comparative rangeland studies: application and advantages of SADs and diversity profiles

► *See* **S04.07**

Influence of soil features on soil lichen diversity in the summer-rainfall biomes

► *See* **S03.02**

Further studies

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Classen, N., Gröngröft, A., Petersen, A. (2009): Identifikation von Bodenmustern mit LANDSAT Daten in der zentralen Savanne Namibias. – Zentralblatt für Geologie und Paläontologie, Teil I, **2007**: 199–215.

Gröngröft, A., Classen, N., Petersen, A. (2005): Identification of soil patterns with LANDSAT data in the central Namibian savannah region. – Mitteilungen der Deutschen Bodenkundlichen Gesellschaft **107**: 323–324.

Koch, F. (2005): The sawflies of the BIOTA-Southern Africa Project with description of a new species of Arge (Insecta, Hymenoptera, Symphyta). – Mitteilungen aus dem Museum für Naturkunde in Berlin, Zoologische Reihe **81**: 193–199.

Schütze, S.J. (2009): Towards a sustainable use of the Devil's Claw: results from a simulation model. – Diplom thesis in Geoecology. Potsdam: University of Potsdam.

Tietjen, B. (2009): Drylands under climate change – a novel ecohydrological modelling approach. – PhD thesis in Ecology. Potsdam: University of Potsdam.

Tietjen, B., Jeltsch, F., Zehe, E., Classen, N., Gröngröft, A., Schiffers, K., Oldeland, J. (2010): Effects of climate change on the coupled dynamics of water and vegetation in drylands. – Ecohydrology **3**: 226–237.

Weiß, M. (2008): Unterschiedliche Strategien in der Besiedelung eines Nahrungspatches bei den Termitenarten *Macrotermes michaelseni* und *Odontotermes* sp. in der Dornbuschsavanne Namibias. – Unpublished report. Würzburg: Department of Animal Ecology and Tropical Biology, University of Würzburg.

General data

Number	Name	Alternative name(s)
S06	Okamboro	Ovitoto
Implementation	**Country**	**Province/ region**
2001	Namibia	Otjozondjupa
District/ constituency	**Locality**	**Farm name**
Okahandja	Ovitoto	Ovitoto 55
Latitude	**Longitude**	**Altitude**
22.019179 S	17.062480 E	1490 m a.s.l.
Rainfall season	**Biome**	**WWF Ecoregion**
Summer	Thornbush Savanna	AT1309 Kalahari xeric savanna
Agro-Ecological Zone	**Relative intensity of land use**	**Tenure**
CPL3-6	High	Communal
Type and history of landuse	**Land owner**	
Farming with cattle, goats and sheep	Government of Namibia	

Okamboro (S06)

Dense thornshrub at Okamboro Observatory. Photo: G. Miehlich.

The BIOTA Observatory Okamboro (S06) is situated in the northern part of the Khomas Hochland (Central Highland) in Namibia, in the Ovitoto communal area next to the village of Okamboro, about 60 km north of Windhoek. The area is characterised by dissected plains and mountains with a height of up to 1700 m a.s.l. The vegetation is a transition between Thornbush and Highland Savanna dominated by thorny *Acacia* species and grasses. The mean annual precipitation in this summer rainfall area was 314 mm.

The Ovitoto communal land is inhabited by Herero pastoralists. Livestock farming with cattle is the most important type of landuse. The village Ovitoto lies next to a military base, which also covered the area of the Observatory until 2000. Since then new settlements have been built close to the Observatory and the number of free ranging cattle, and thus grazing pressure, increased considerably.

The Observatory was set up to monitor the impacts of climate and landuse changes in this communal area as opposed to commercial farmland, which makes up most of the area in this part of Namibia. Although a comparable nearby Observatory on commercial farmland has never been established, data from this communal farmland will contribute in documenting the influence of a very dynamic landuse change.

Responsible authors:
D. Wesuls & D.H. Haarmeyer

Remote sensing and landscape

Geomorphology	Geological units	Lithological units
Steep slopes, undulating plains, eroded slopes	Khomas Group in Damara Supergroup and Gariep Complex	Schists
Mean EVI	**EVI absolute range**	**Mean leaf area index**
0.151 (0.108–0.275)	0.101 (2001)–0.361 (2006)	0.61

Grid map of Observatory

	0	1	2	3	4	5	6	7	8	9
0	94	41	27	26	11	51	55	17	75	70
1	86	43	98	13	19	32	36	71	62	96
2	46	77	91	64	4	37	15	92	9	69
3	49	95	79	61	5	67	44	38	14	31
4	22	63	76	3	72	29	74	28	21	50
5	73	10	59	85	83	82	45	58	65	30
6	52	54	56	24	81	8	2	34	84	7
7	99	40	57	60	87	97	33	66	35	18
8	16	93	89	25	42	48	6	78	20	23
9	80	88	100	1	47	39	53	12	90	68

1 Acacia-dominated thornbush savanna on slopes
2 Acacia-dominated thornbush savanna on undulating plains
3 Acacia-dominated thornbush savanna on eroded plains
4 Acacia-dominated thornbush savanna on eroded slopes
5 Acacia-dominated thornbush savanna on slopes with intersection of rivier

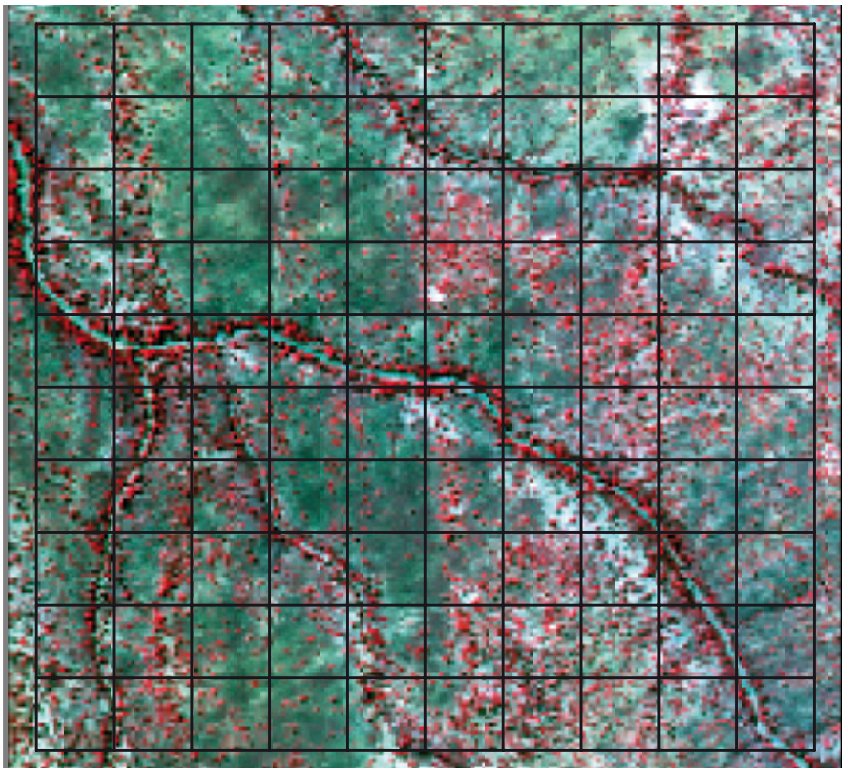
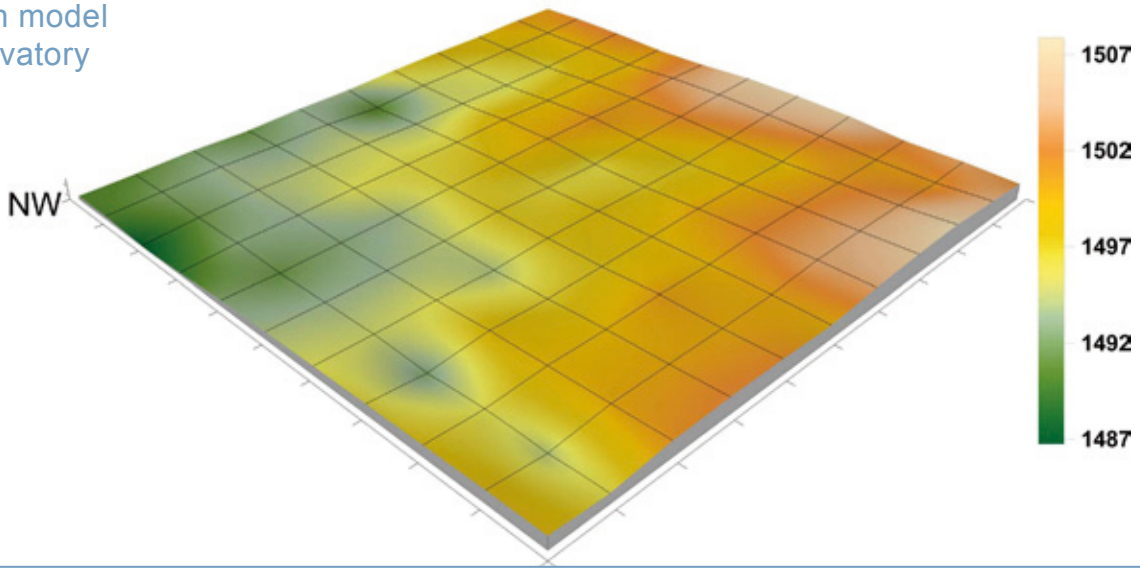


Image: HYMAP, 12 April 2004

Elevation model of Observatory



Landsat image

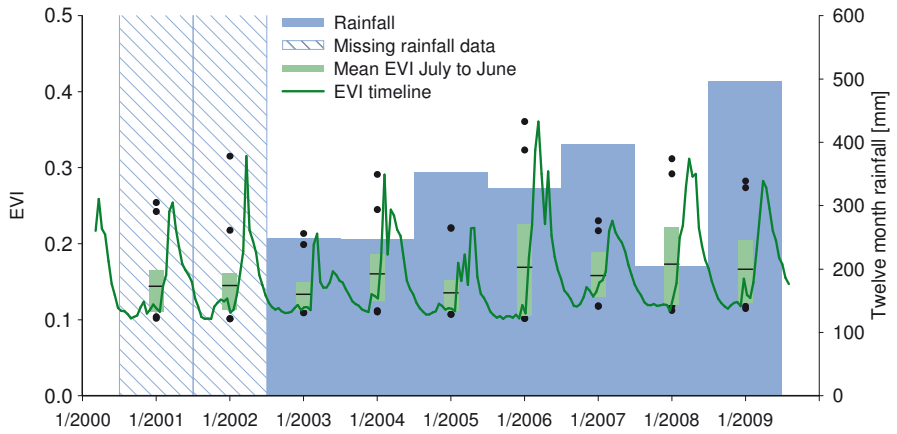
The image shows a few mountains rising above the dissected plains of the area. The western part of the image is dissected by a tributary of the Swakop River, draining to the north. The partly dry river beds are visible as white or bright blue lines.

The vegetation cover alternates between relatively dense grassy and herbaceous vegetation with small patches of woody vegetation (blue-green with some red patterns) and areas with a higher shrub coverage (predominantly red, e.g. in the western parts), indicating that the area is affected by bush encroachment (red). Communal settlements with concentrated high grazing impacts appear as white patches.

Scene 178/75, acquisition date: 24 April 2006

MODIS time series

Temporal patterns of annual rainfall, vegetation cover, and phenology



Responsible authors: M. Keil & T. Labitzky

Climate

Data from BIOTA weather station

Location	Recorded period	Mean temperature
Okamboro (S06)	2001–2009	22.2 (3.9–36.8) °C
Mean solar radiation	**Mean wind speed**	**Mean annual precipitation**
596 (423–826) MJ·m^{-2}·month^{-1}	2.1 (6.6) m·s^{-1}	314 (266–506) mm
Mean annual potential evapotranspiration	**Interannual precipitation variability**	**Mean relative humidity**
1769 mm	153%	39% (19–76%)
Aridity index (UNEP)		
0.18 (arid)		

Modelled data

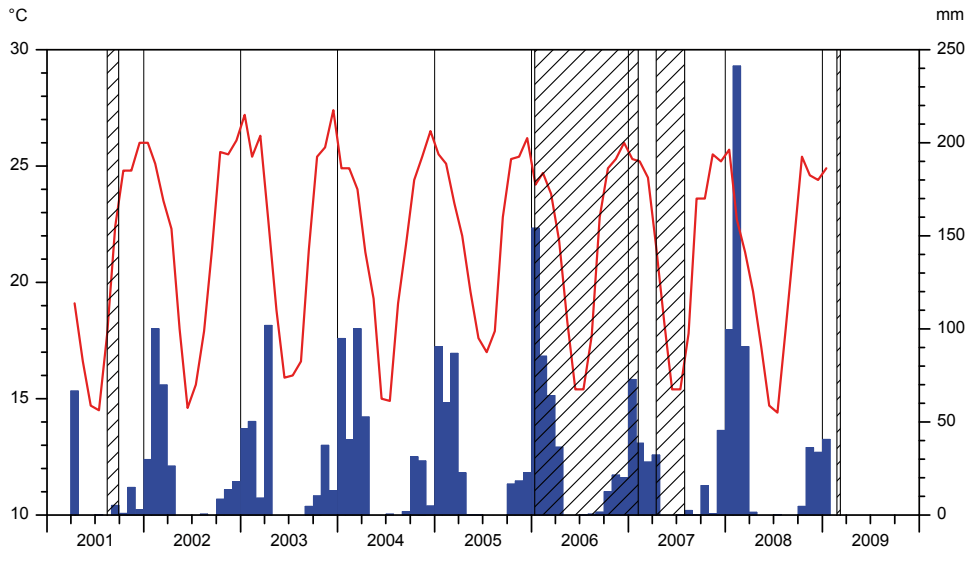
Mean temperature	Mean annual temperature range	Mean diurnal temperature range
19.7 (3.9–32.7) °C	10.5 °C	17.6 °C
Mean annual precipitation	**Precipitation seasonality**	**Percentage winter precipitation**
398 mm	106%	12% (strong summer)
Climate type	**Length of dry season**	**Aridity index (De Martonne)**
BSh	9 months	13.4 (semi-dry)

The climate at the Observatory is characterised by semi-arid conditions. Rainfall shows a strong seasonality with almost all rain falling during the summer season, peaking in February. The mean annual rainfall over the observation period was 314 mm, which is wetter than the average rainfall recorded along the entire transect and within the Thornbush Savanna. However, substantial interannual variability is evident. The observed near-surface air temperatures show a moderate seasonal cycle. The mean annual temperature is 22.2°C and is therefore slightly warmer than the mean temperature of this biome.

The observed mean minimum temperature is above the freezing point, but there is still a possibility of the occurrence of frost during the months of July and August. Compared to the interpolated long-term data taken from the WorldClim dataset, a noticeably warmer mean annual temperature was observed at the BIOTA weather station. Furthermore, the station records of extreme temperatures deviate substantially from the WorldClim data, showing warmer maximum and minimum temperatures. For precipitation, mean annual rainfall is markedly lower at the BIOTA weather station than the WorldClim data.

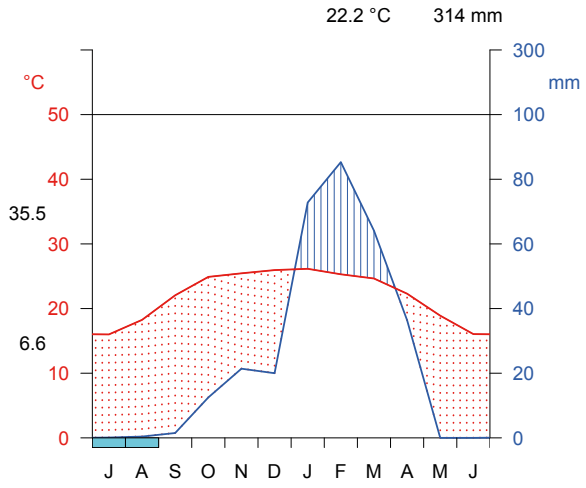
The observed near-surface winds at the Observatory are mainly constituted of west south-westerly flows during the spring and summer. During the autumn and winter seasons, the circulation is characterised by easterly and south-easterly flows. Mean wind speed recorded in the evening shows a pronounced annual cycle, peaking in mid-summer. Winds observed during the morning and early afternoon stayed fairly constant throughout the year, with higher wind speeds in the early afternoon reaching about 10 km/h.

Time series: rainfall and temperature

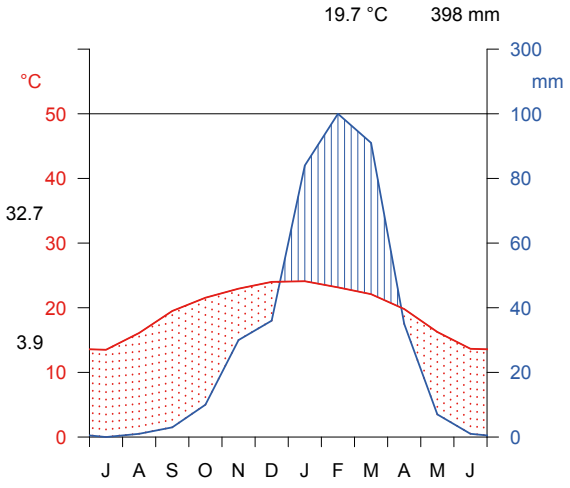


Climate diagrams

Recorded data (BIOTA)

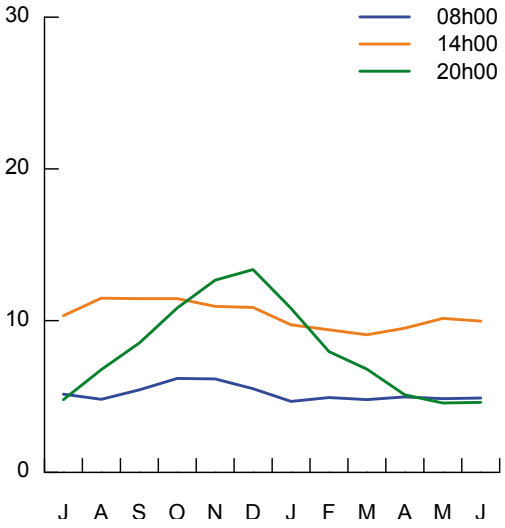


Modelled data (WorldClim)

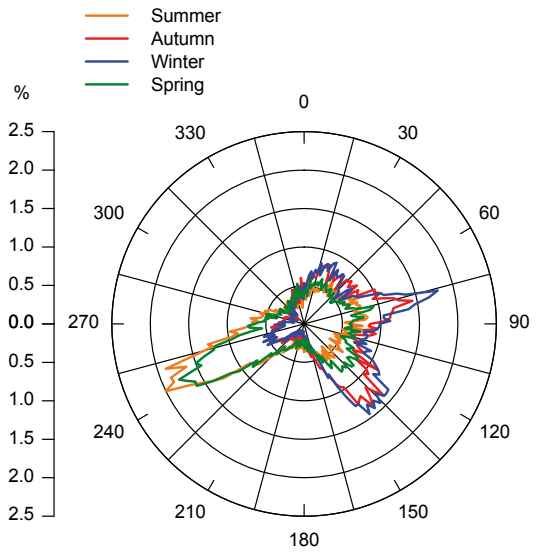


Wind diagrams

Speed



Directions

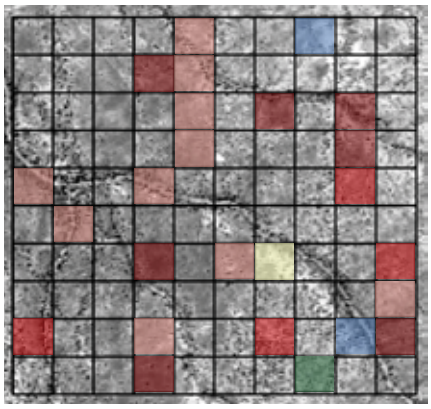


Responsible authors: K. Berger, A. Haensler & J. Luther-Mosebach

Soils

Year of sampling	Hectare plots sampled	SOTER unit
2004	27 (R1–25, R30, R50)	NA2
Soilscape	Dominant soil group(s)	Reference group richness
Regosol	Regosol	4
Soil unit richness	Soil unit evenness	Soil ecotype richness
13	0.728	10
Parametric space	pH	Electrical conductivity
3.56	7.1 (5.5–8.7)	42 (11–126) µS·cm^{-1}
Organic carbon		
0.35% (0.21–0.57%)		

Map of soil profiles



Haplic Regosol
Epileptic Regosol
Endoleptic Regosol
Endoleptic Cambisol
Endopetric Calcisol
Haplic Leptosol

On the Observatory the reference groups Regosol, Calcisol, Cambisol and Leptosol are found. With a proportion of 77%, Regosols are the most dominant soil units; the other reference groups are only represented by few profiles. The key factors for the soil properties and the classification units in this Observatory are the type of substrate, depth of the profiles and content of coarse rock fragments. Especially the latter two vary over short distances and are responsible for the almost random distribution of soil units. One visible trend in the dominating unit is the occurrence of Regosols (Endoskeletic, Arenic) in the north-western and central part of the Observatory, reflected by the lighter colours in the aerial photograph. In the eastern part, more shallow Leptic Regosols (Arenic) occur.

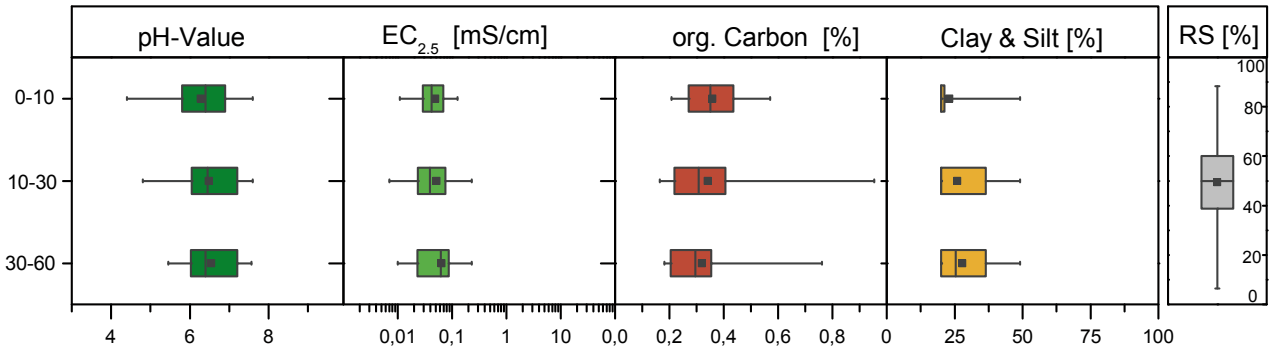
The high soil variability in this Observatory is also reflected by the chemical properties. The most important variations occur in the pH values and in the rooting space, which is driven by depth of the bedrock layer and the content of coarse rock fragments. For the topsoil the variability of fine-grained particles (clay and silt) is rather low. Also, only few vertical trends are evident, except for the slight decrease of organic carbon and the lower silt and clay contents in the topsoil which may be a result of deflation.

The topsoil's content of total magnesium and phosphorus are exceptionally high. Nevertheless, the contents of exchangeable magnesium and potassium are low. Also, the concentration of both iron and zinc are the highest among all the Observatories (approximately 40 g kg^{-1} and 115 mg kg^{-1} in the topsoil, respectively). The concentration of copper is the highest among all Observatories of the Thornbush Savanna.

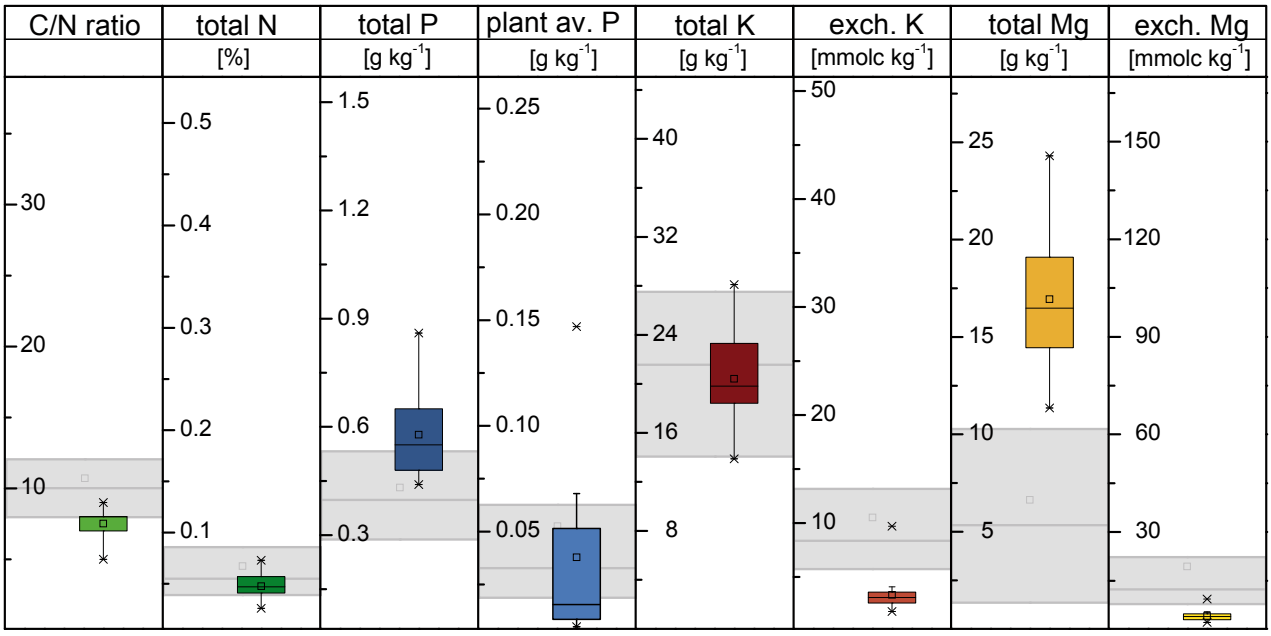
The sandy and silty fraction is dominant; only few samples of the Cambisols show more than 10% clay. With regard to the sand fractions, the ten analysed samples displayed a remarkable homogenous composition with a strong fine sand dominance. This is an indication of a very homogenous structure and weathering of the mica soil parent material. The content of coarse rock fragments and the depth of the bedrock may be the main differentiating factors for plant growth. The different states of soil reaction may be an additional ecologically important factor but the texture driven water supply seems to override this. An additional effect might be the microtopography and the depth of bedrock, which leads to small-scale run-off/run-on situations causing uneven water distribution. The grassy plains consist of a more homogenous soil structure, which provides a more even water availability. This might be responsible for the higher proportion of grasses.

The reduction of cover of perennial grass species leads, next to the problem of general rangeland degradation. Additionally, the fine sand and coarse silt-dominated textures are highly vulnerable to water erosion. Also the short distances to the dry rivers reduce the probability that the material will only be relocated within the area. Main erosion features visible are moderate rill and slight sheet erosion.

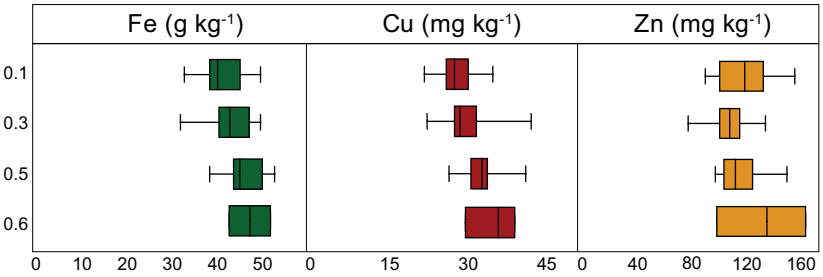
Soil characteristics



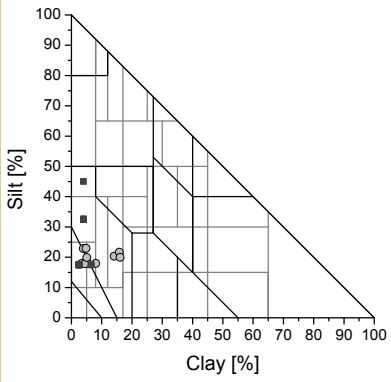
Soil nutrients



Soil micronutrients



Soil texture triangle

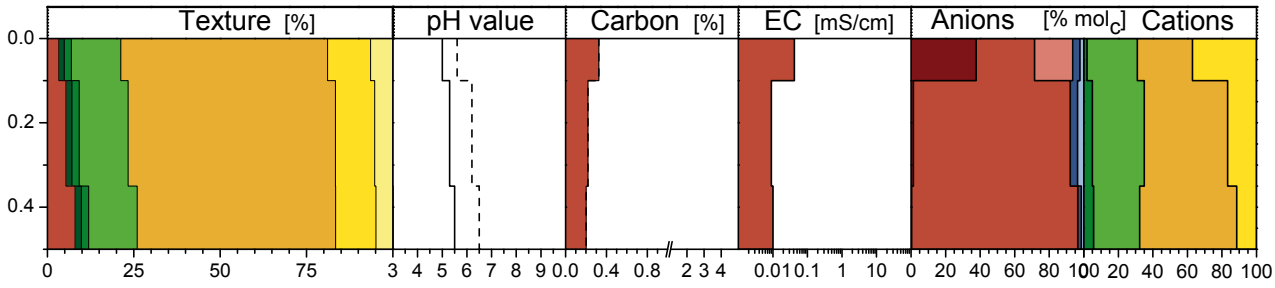


Reference profile (H34)

The **Haplic Regosol (Eutric, Episkeletic, Arenic)** is a typical example of the slightly deeper developed soils in the plain habitats. The transition zone to the saprolithed bedrock occurs at approx. 50 cm depth. In this profile, high quartz pebble content dominates the coarse rock fragments up to 70% in the subsoil. This is a typical residual of quartz veins that are part of the mica schists and resist weathering processes leading to an accumulation of quartzes in the soils as well as on the soil surfaces.

The texture of the fine earth is loamy sand, dominated by fine sand and coarse silt with a slight increase of clay content in the subsoil but still single grain structure. Rooting is intense over the whole profile with up to 50 roots dm^{-2}.

The soil reaction is slightly acid across the entire profile. The content of organic carbon is low and shows only a marginal decrease with depth. EC is low with highest values in the topsoil. Total element contents are constant across the profile depth and the total reserve of bases is relatively high with around 230 $cmol_c\ kg^{-1}$. The content of water soluble ions is very low with 3–5 $mmol_c\ kg^{-1}$ and the extractable bases reach highest values in the subsoil.



Texture

- Fine silt
- Medium silt
- Coarse silt
- Clay
- Fine sand
- Medium sand
- Coarse sand

- pH ($CaCl_2$)
- pH (H_2O)
- Organic carbon
- Inorganic carbon
- Electrical conductivity

Water soluble ions

- Cloride
- Sulfate
- Nitrate
- Hydrocarbonate
- Fluoride, Bromide, Nitrite
- Calcium
- Magnesium
- Potassium
- Sodium

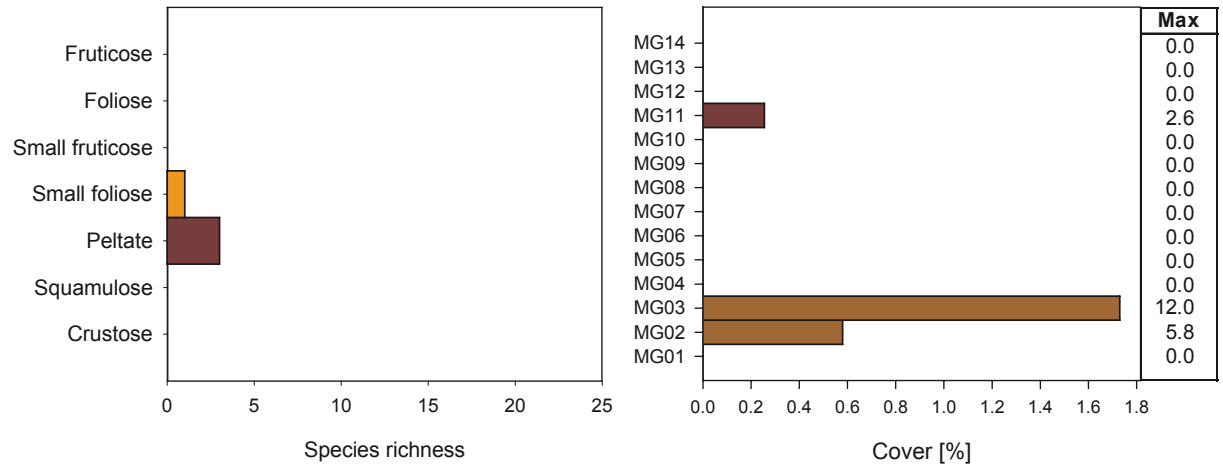
Responsible authors: U. Wisch, A. Petersen, A. Gröngröft & D. Mager

Lichens

Sampling period(s)	Hectare plots sampled	Cover
2001, 2004	10 (R1−R10)	2.6% (0−12%)
Total species richness	**Species richness on soil [1 km²]**	**Species richness on rock [1 km²]**
5	4 (80)	1 (20%)
Species richness on plants [1 km²]	**Species richness on soil [1000 cm²]**	
n.a.	0.7 (0−3)	

Only a few cyanobacterial lichen species occur at this Observatory. Epiphytic and saxicolous lichens were not examined in detail. Despite the presence of sandy soils, the occurrence of terricolous lichens is supported by the relatively high content of calcium carbonate in some plots (i.e. H28 and H86) and the resulting higher soil pH. However, the high cover of pebbles or stones here appears to be unfavourable for lichen growth. Furthermore, mechanical disturbance is also likely to play a major role in limiting lichen cover, which is typically rather low at this Observatory. Only ubiquitous taxa are found with a predominantly peltate growth habit.

Growth forms



List of taxa

Terricolous (on soil):

Collema coccophorum s.l.
Heppia despreauxii
Peltula patellata
Peltula radicata

Saxicolous (on rock):

Peltula obscurans s.l.

Epiphytic (on plants):

No records

Peltula obscurans var. *obscurans*. Photo: M. Schultz, L. Zedda & G. Rambold.

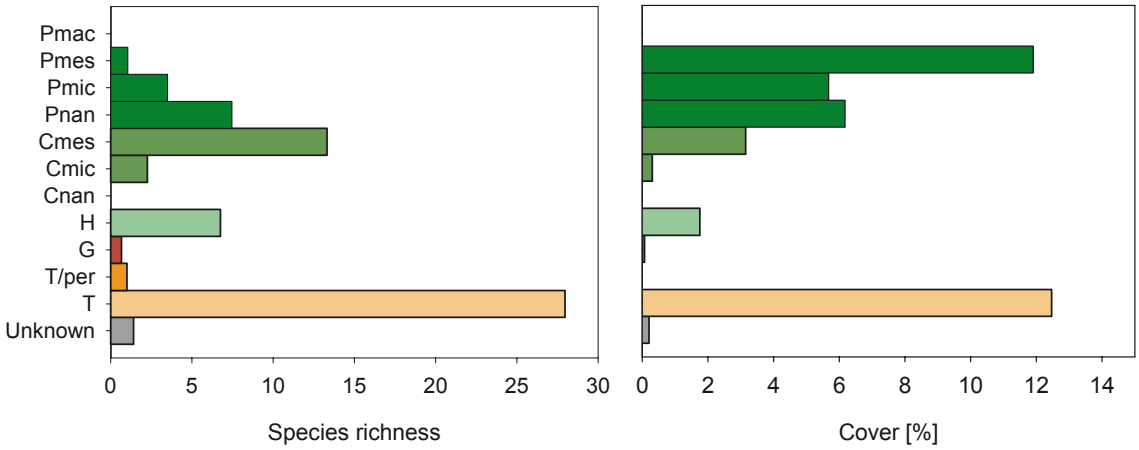
Responsible authors:
L. Zedda & G. Rambold

Vascular plants

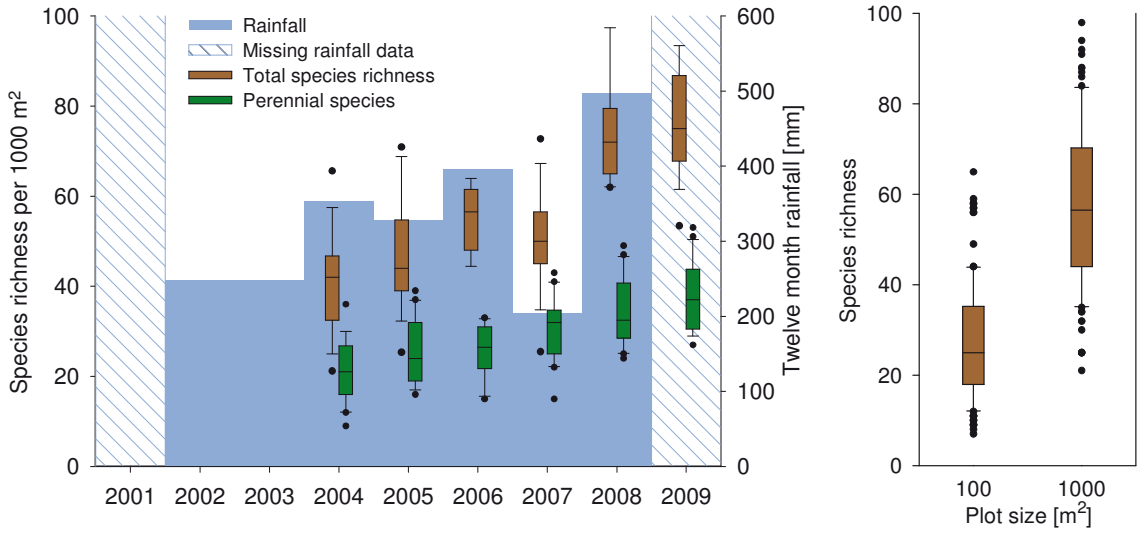
Sampling period(s)	Hectare plots sampled	Biome
2004–2009	20 (R1–R20)	Thornbush Savanna
Vegetation unit (level 1)	**Vegetation unit (level 2)**	**Identification rate**
Highland Savanna	n.a.	81% – 97% – 98%
Cumulative family richness	**Dominant families (cover)**	**Dominant families (richness)**
49	Poaceae, Fabaceae, Bignoniaceae	Poaceae, Fabaceae, Asteraceae
Cumulative species richness (1 km²)	**Species richness (1000 m²)**	**Species richness (100 m²)**
284 – 195	57.9 (21–103)	27.6 (7–65)
z-value	**Species richness change per year (1000 m²)**	**Evenness (1000 m²)**
0.322 (0.133–0.826)	1.92	0.572 (0.255–0.737)
Evenness (100 m²)	**Simpson (1000 m²)**	**Simpson (100 m²)**
0.506 (0.105–0.754)	0.767 (0.282–0.909)	0.636 (0.075–0.873)

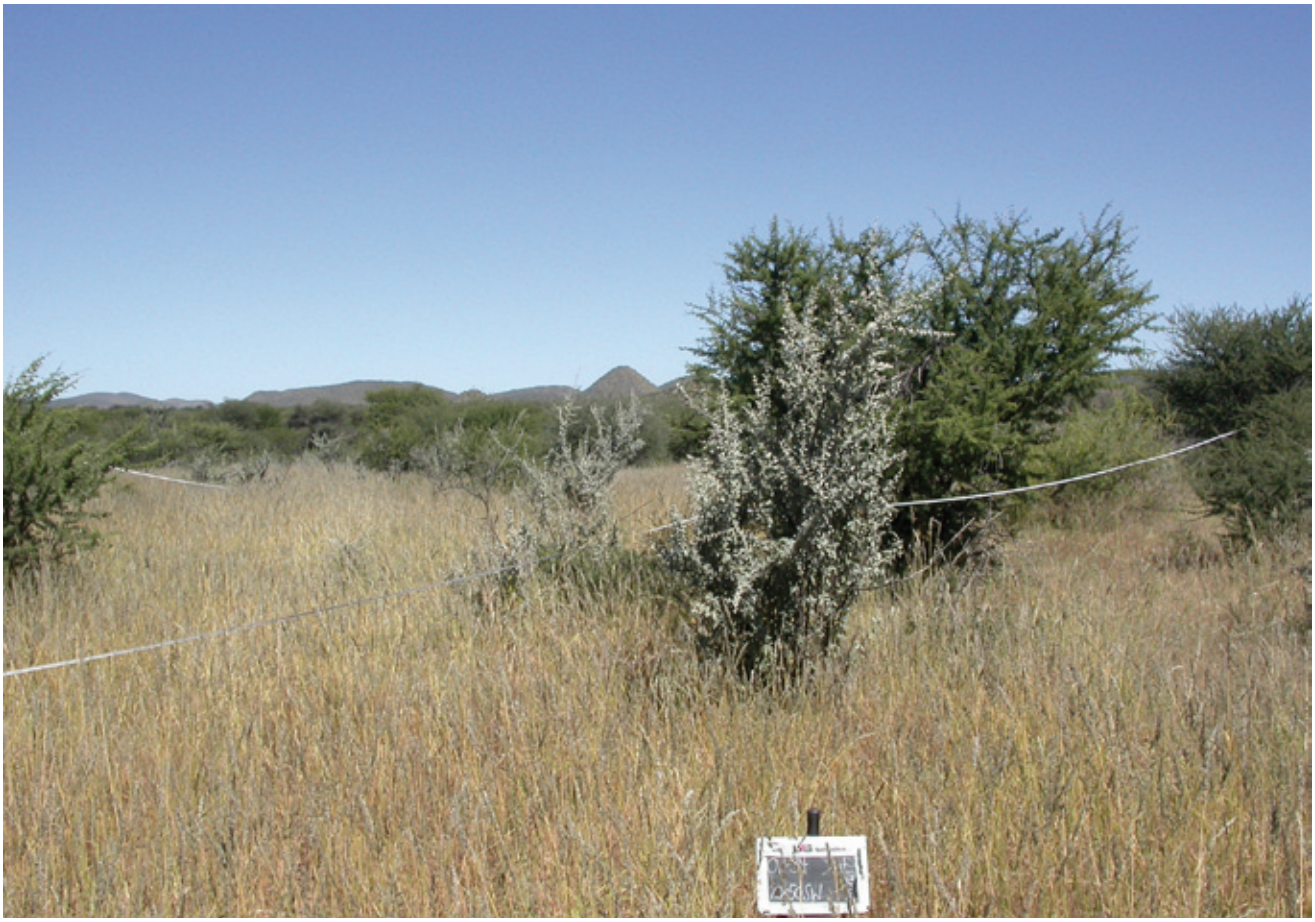
The vegetation represents a transition between the Thornbush savanna and the Namibian Highland savanna. Characteristic species of both savanna types can be found here. The Observatory is situated on a gently undulating plain at the foot slopes of mountains that rise from the plain to a height of 200–300 m. Several ephemeral rivers dissect the plain and increase the topographic and soil related heterogeneity. The vegetation is characterised by thorny shrubs, trees, and a grassy matrix mainly consisting of the annual grass species *Schmidtia kalahariensis*. The lack of perennial grass species

Life forms



Species richness

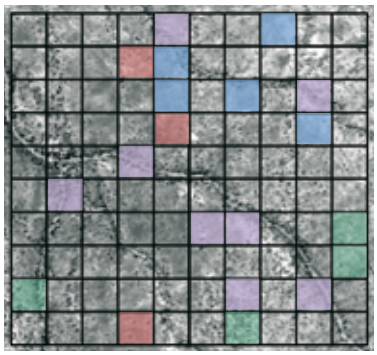




Unit 1, H34, 2008. Photo: D. Wesuls.

Unit 2, H38, 2009. Photo: J. Peters.

Map of vegetation units



is a clear sign of degradation due to overgrazing. The dominance of *Schmidtia kalahariensis* on many plots leads to low evenness values at small scales (100 m²). Nevertheless, the Thornbush savanna is relatively diverse in structure, which leads to a comparably high species richness. Woody vegetation becomes dominant along the riverbeds, while the plains and the foothills of the mountains tend to be more open. However, over the last few years there has been a strong tendency of bush thickening mainly caused by *Acacia reficiens* and some patches have become inaccessible. Seven different habitat types were described for this Observatory and four vegetation units can be recognised.

The *Catophractes alexandri-Helichrysum candolleanum* community (unit 1) represents the most open vegetation type of the whole Observatory. The grass layer can reach cover values of more than 80% and a height of 1 m in very good rainy seasons. The main species is *Schmidtia kalahariensis* (Kalaharisuurgras), which produces an acidic secretion, which can cause irritations on the skin of animals. The grey leaved shrub *Catophractes alexandri* is very prominent in this vegetation unit although it can also be found in other parts of the Observatory. Other typical species of this community are annual herbs such as *Helichrysum candolleanum* from the daisy family, the disturbance indicator *Tribulus terrestris* with its spiny fruits, and *Crotalaria podocarpa*, a legume with edible fruits.

Classification table (2009)

Column		Cover	All	1	2	3	4
Number of relevés			**20**	**3**	**5**	**4**	**8**
Mean cover [%]			44.5	42.0	37.3	45.3	49.6
Mean species richness (1000 m²)			77.2	64.7	76.2	72.8	84.8
Mean inclination [°]			1.0	0.2	0.7	1.6	1.3
Mean soil pH			6.21	5.33	6.38	5.48	6.80
Mean electrical conductivity [µS·cm^{-1}]			51	27	55	40	64
Organic carbon [%]			0.36	0.26	0.35	0.43	0.36
Nitrogen [%]			0.05	0.04	0.05	0.05	0.05
Fine material [%]			79.3	94.3	86.8	73.8	71.8
Gravel [%]			11.0	3.0	7.0	12.0	16.0
Stones 2-6 cm [%]			5.1	1.3	2.4	6.3	7.6
Stones 6-20 cm [%]			1.3	0.3	0.8	2.3	1.5
Stones 20-60 cm [%]			1.0	0.3	0.8	2.0	0.9
Blocks [%]			0.3	0	0.6	0.5	0.1
Rock outcrops [%]			0.5	0	0.6	1.5	0.1
Unit 1: Helichrysum candolleanum-Catophractes alexandri community							
Hper	Helichrysum candolleanum	0.10	20	100	20	.	.
T	Tribulus terrestris	0.10	25	100	20	.	13
T/Hper	Vahlia capensis	0.10	30	100	60	.	.
Hper	Kyllinga alba	0.17	30	100	60	.	.
T	Limeum myosotis	0.10	40	100	60	.	25
T	Crotalaria podocarpa	0.10	15	67	.	13	.
Unit 2: Pogonarthria fleckii-Suessenguthiella scleranthoides community							
T	Pogonarthria fleckii	0.19	45	.	100	38	13
T	Suessenguthiella scleranthoides	0.18	55	.	100	25	50
Unit 3: Acacia erubescens-Triraphis ramosissima community							
Pmic	Acacia erubescens	0.50	15	.	.	38	.
H	Triraphis ramosissima	0.10	15	.	.	38	.
Cmes	Tapinanthus oleifolius	0.18	25	.	.	38	25
T	Eragrostis nindensis	0.10	10	.	.	25	.
Cmes	Otoptera burchellii	0.10	50	.	20	50	63
H	Oropetium capense	0.79	50	.	40	50	50
Hper	Dicoma capensis	0.10	50	.	60	50	38
Unit 4: Ehretia rigida-Heteropogon contortus community							
H	Eragrostis echinochloidea	0.15	40	.	20	.	88
Pnan	Lantana angolensis	0.10	50	.	40	.	100
Pnan	Ehretia rigida	0.26	50	.	20	.	100
T	Setaria verticillata	0.10	25	.	.	.	63
Cmes	Hibiscus calyphyllus	0.44	35	.	20	13	75
Pnan	Grewia flava	0.23	45	.	20	.	88
H	Heteropogon contortus	0.20	20	.	.	.	50
T	Corchorus tridens	0.10	20	.	.	13	50
T	Enneapogon desvauxii	0.84	50	.	40	.	88
T	Tagetes minuta	0.20	45	67	.	13	88
T/Cmic	Sida ovata	0.17	30	.	.	.	63
T	Acalypha indica	0.10	15	.	.	50	38
Most frequent companions							
Pmes	Acacia reficiens	11.90	100	100	100	50	100
Pnan	Catophractes alexandri	4.53	100	100	100	50	100
Pmic	Acacia mellifera ssp. detinens	4.53	100	100	100	50	100
Hper	Achyranthes aspera var. sicula	1.27	100	100	100	50	100
Cmes	Acrotome fleckii	0.24	100	100	100	50	100
Cmes	Ptycholobium biflorum	0.12	100	100	100	50	100
T	Schmidtia kalahariensis	7.14	95	100	100	38	88
Pmic	Dichrostachys cinerea	0.62	95	100	100	50	88
H	Eragrostis jeffreysii	0.43	95	100	100	50	100

continued on next page

Unit 3, H79, 2007. Photo: D. Wesuls.

Unit 4, 2008. Photo: D. Wesuls.

The *Pogonarthria fleckii-Suessenguthiella scleranthoides* community (unit 2) is very similar to unit 1 but has a slightly higher shrub cover, with *Acacia reficiens* and *Acacia mellifera* as the dominant species, and consequently a lower grass cover. *Pogonarthria fleckii*, the so called Fishbone-grass, is an annual grass and a characteristic species in this community. The other eponymous species of this community is the annual *Suessenguthiella scleranthoides,* which mainly grows in the understorey in shady and damp conditions.

The *Acacia erubescens-Triraphis ramosissima* community (unit 3) occurs on the foot slopes of the surrounding mountains. The habitat is characterised by shallow soils and schist outcrops. This vegetation unit is most closely affiliated with the Highland savanna. A typical species is *Acacia erubescens* (blue thorn) with its characteristic yellowish bark that peels off in papery layers. *Triraphis ramosissima* is a perennial grass typically found on rocky soils and in rock fissures. Other perennial species, which are characteristic of this community are the palatable subclimax grass *Eragrostis nindensis* and the grey leaved, dioecious shrub *Tarchonanthus camphoratus*.

The *Ehretia rigida-Heteropogon contortus* community (unit 4) occurs in and around the ephemeral riverbeds. The cover of woody species is highest in this community, especially of the potential encroacher species *Acacia mellifera* and *Acacia reficiens*, which can form dense thickets. The edges of the rivers and the neighbouring plains that slope down towards these rivers are especially prone to bush encroachment by these species. The riverine vegetation is the most species rich community on the Observatory. Different woody species such as *Ehretia rigida* or *Ziziphus mucronata* as well as a wide range of ephemeral understorey plants such as *Acalypha indica* and *Tagetes minuta* occur here. The riverbed itself is sometimes populated by *Heteropogon contortus*, a hardy perennial tufted grass.

Classification table (continued)

Column		Cover	All	1	2	3	4
Number of relevés			**20**	**3**	**5**	**4**	**8**
T	Commelina benghalensis	0.27	95	67	100	50	100
Cmes	Peliostomum leucorrhizum	0.23	95	100	80	50	100
T	Nelsia quadrangula	0.21	95	100	100	50	88
Cmes	Solanum capense	0.16	95	100	80	50	100
T/Cmic	Talinum arnotii	0.12	95	100	100	50	88
T	Mollugo cerviana	0.10	95	100	80	50	100
Cmes	Albizia anthelmintica	0.91	90	67	100	50	88
T	Eragrostis porosa	0.63	90	67	80	38	100
Pnan	Phaeoptilum spinosum	0.61	90	100	100	50	75
T	Enneapogon cenchroides	0.59	90	67	80	50	100
Cmic	Pentarrhinum insipidum	0.17	90	100	100	25	88
T	Tragus berteronianus	0.12	90	100	100	50	100
Hper	Pollichia campestris	0.12	90	67	80	50	100
Hper	Ocimum americanum var. americanum	0.10	90	67	100	13	88
T	Melinis repens	0.48	85	67	100	38	88
Cmes	Aptosimum tragacanthoides	0.24	85	100	100	25	100
T	Bidens pilosa	0.18	85	67	80	50	88
T	Chenopodium pumilio	0.17	85	67	100	50	100
Pnan	Hibiscus micranthus	0.15	85	67	80	38	88
H	Stipagrostis uniplumis	0.12	85	67	100	25	88
T	Euphorbia inaequilatera	0.10	85	67	100	50	100
T	Geigeria acaulis	0.10	80	33	100	50	75
T/Hper	Phyllanthus pentandrus	0.10	80	33	100	50	75
T	Sericorema sericea	0.10	80	33	100	50	75
T	Bulbostylis hispidula	0.33	75	100	100	25	38
Cmes	Aptosimum arenarium	0.27	75	.	80	50	88
Cmes	Felicia clavipilosa	0.23	75	67	80	50	88
T/Hper	Kohautia cynanchica	0.13	75	67	100	25	63
Cmes	Tribulus zeyheri	0.10	75	100	100	38	63
T	Indigastrum parviflorum	0.10	75	.	60	38	100
H	Cenchrus ciliaris	0.36	70	33	40	50	100
T	Cucumis anguria var. longaculeatus	0.16	70	100	60	25	63
Cmes	Lycium eenii	0.16	70	67	40	25	75
T	Digitaria velutina	0.10	70	100	40	50	88
T	Gisekia africana	0.10	70	100	60	38	50
T	Monandrus squarrosus	0.70	65	33	60	50	75
Hper	Indigofera vicioides	0.13	65	33	100	50	38
Cmic	Leucosphaera bainesii	0.13	65	.	60	13	88
Hper	Monsonia senegalensis	0.10	65	67	60	.	75
T	Erucastrum arabicum	0.10	65	67	60	38	100
T/Hper	Phyllanthus maderaspatensis	0.10	65	33	80	38	63
H	Euphorbia glanduligera	0.10	65	33	60	38	63
Pmic	Ziziphus mucronata	0.35	60	100	20	38	88
Pnan	Lycium oxycarpum	0.33	60	67	20	38	75
Cmes	Monechma spartioides	0.30	60	.	20	13	88
T	Nidorella resedifolia	0.20	60	100	80	25	50
T	Boerhavia sp. 19573	0.13	60	100	40	13	63
Pmic	Boscia albitrunca	0.13	60	.	60	50	75
Cmic	Dicoma tomentosa	0.10	60	67	100	38	25
T	Limeum sulcatum	0.10	60	33	80	38	50
Pnan	Grewia flavescens	0.10	60	33	60	38	63
T	Ipomoea sinensis	0.10	60	33	60	50	63
T	Aristida adscensionis	0.10	60	.	60	38	63
H	Aristida effusa	0.17	55	33	80	25	63
n.a.	Selago kriechend	0.23	50	67	60	38	50
T/Hper	Portulaca kermesina	0.10	50	33	60	25	50
T	Portulaca oleracea	0.10	50	33	40	13	63
Pnan	Commiphora pyracanthoides	0.10	50	.	40	13	63
Pnan	Montinia caryophyllacea	0.23	45	.	40	25	50
T	Felicia smaragdina	0.10	45	67	80	38	25

Impression of the Ovitoto area, 2009. Photo: D. Wesuls.

Free ranging cattle are characteristic for the Ovitoto area, 2006. Photo: D. Wesuls.

Responsible authors: D. Wesuls & J. Luther-Mosebach

The people

Study period	Size of study area	Population in study area
2001–2003	57–58 km²	158 people
Number of households	**Mean household size**	**Mean age of inhabitants**
29 (26 users of communal rangeland)	6.2 people	33.7 years
Education of inhabitants	**Ethnicity of farm owners**	**Ethnicity of farm workers**
3.9 years of school	Ovaherero	Ovaherero, some Nama
Age structure	**Cohort fertility**	**Mortality rate**
31% children < 16 years	4.3 children per woman (2000)*	45.8 UFMR (2000)*
Life expectancy	**Main sources of income**	**Markets**
Male = 57.8 years; female: 62.0 years (1996)*	Livestock, old age pensions, permanent work, private transfer payments	Livestock market (permit auction) in Okanjira in the Ovitoto area, closest abattoir in Okahandja
Non-permanent household heads	**Female headed households**	
23.1%	30.8%	

**Source: Ministry of Health and Social Services, Republic of Namibia, 2002*

The community near the Observatory Okamboro (S06) is made up of the Ovaherero people and is located in the Ovitoto Native Reserve, which is a communal area of about 61,200 ha situated about 30 km east-southeast of Okahandja.

The Ovitoto Reserve was proclaimed in 1923 (Wagner 1957) and there are currently 10 communities living on this communal land which is surrounded mainly by commercial farm. Okamboro is located in the north of the Ovitoto area, and the Observatory lies a few kilometres south-east of the Okamboro village. The rangelands of Okamboro lie adjacent to the Osona military base in the west, and a military area called "Swakophoehe", which was formerly a commercial farm, in the east. A nature reserve called the Van Bach Recreation area straddles the northern parts of the Okamboro area. Houses in the Okamboro community are concentrated in two clusters, north and south of a large dry riverbed. Partly steep slopes were found beside the riverbed, which topographically divide the landscape of the village. The community makes use of 14 fenced camps for keeping their livestock. The area of the fenced camps constitutes about 10% of the total communal rangelands of Okamboro, which cover about 5.8 km² (see Fig. 6.1).

Demography

In 1954, the settlement of Okamboro had a population of 73 people (20 men, 31 women, 8 boys, 14 girls) and was one of the larger villages in the Ovitoto Native Reserve in those days (mean size 61 inhabitants, median 37 inhabitants; Wagner 1957). By 2001, there were 158 inhabitants from 26 households (+ 3 households lacking data) in the community. The mean household size was 6.1 and about 30% of the people were children under the age of 16.

Other forms of income besides livestock keeping have become important to the community due to the close proximity of Okamboro to the urban centres of Okahandja and Windhoek, with 23% of the households being absentee households. People from these households spend most of their time outside of the community in an urban centre, and workers take care of their houses and their livestock. Absentees invest a part of their wages in livestock, which they then graze on the communal rangelands. Many children from the Ovitoto communities attend the boarding school in Okanjira and therefore only stay within the community during school holidays.

Results from semi-structured interviews conducted for 29 households in 2001 show that 35% of the households settled in the area before the 1970s. Members of one household have been in the community for 83 years, and two others households have been there for 66 and 69 years respectively. Thirty-five percent of the existing households settled or were established between 1981 and 1990, and 25% of the households settled or were established between 1990 and 2000. In 2001, the mean age of households in the village was 28.7 years (SE of mean: 5.6 years, median: 16 years). Members of households which moved in and out of the village during this period were not available to be interviewed.

Socio-economic context of Okamboro

The infrastructure on the Ovitoto-Reserve is reasonable with most communities within the Ovitoto Reserve being connected by gravel roads with the closest town, Okahandja. Shops, a boarding school, a petrol station, the livestock market, and most of the Ovitoto administrational offices are located in Okanjira, which is approximately 15 km away from Okamboro. However, if people do not have a means of transport, such as cars or horses, the distances are long and it is time-consuming to walk. In Okamboro itself, a few households run a small shop, and a mobile trader regularly comes to the community, often just after the old age pensions are paid out. In one house-

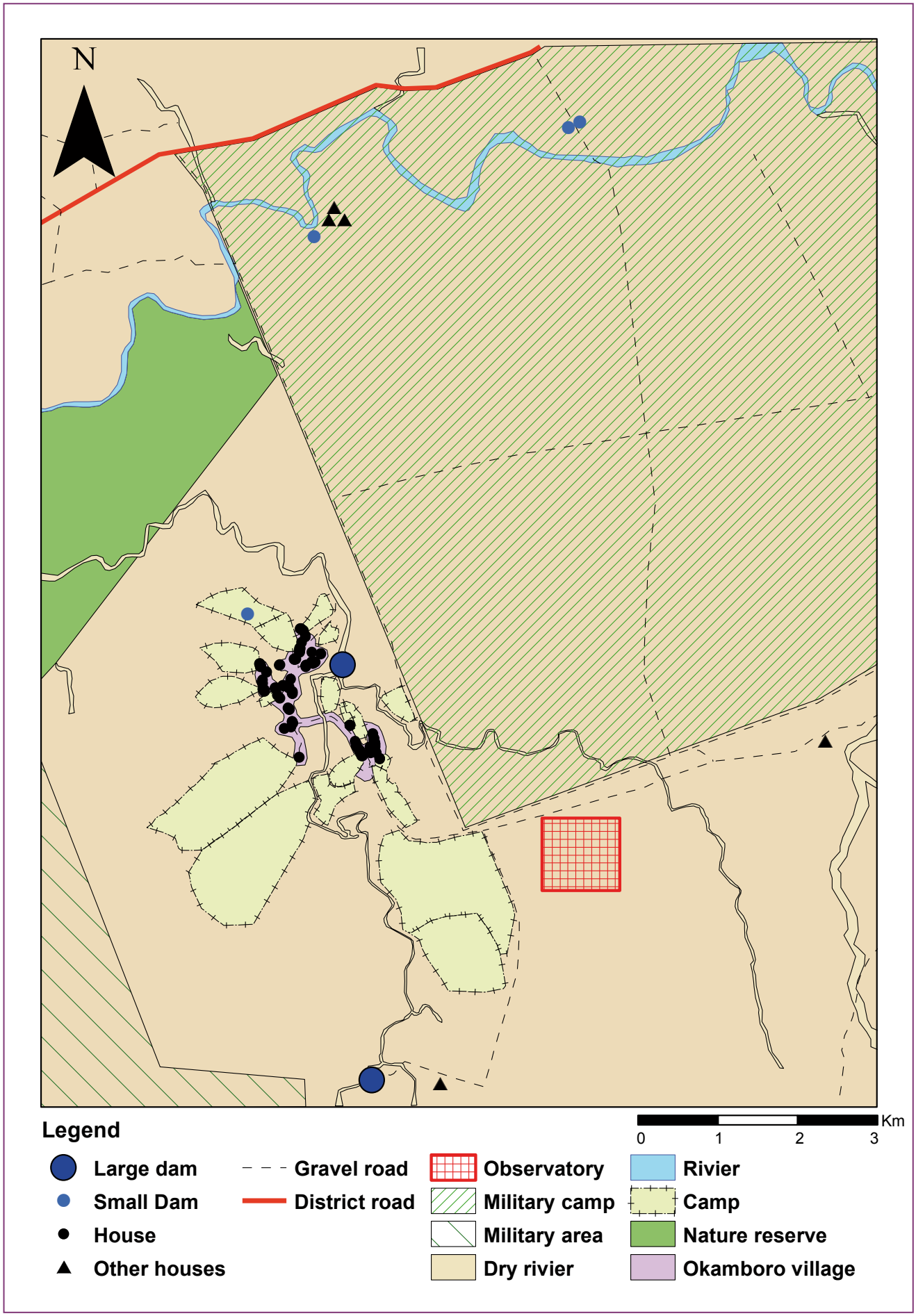


Fig. 6.1: Study area of Okamboro.

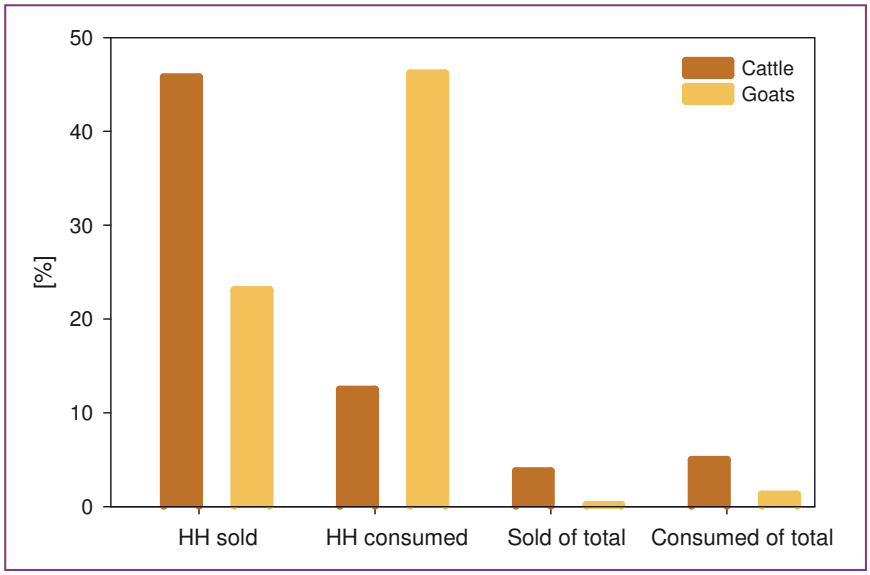


Fig. 6.2: Frequencies of households, which sold or consumed cattle and goats, and share of sold and consumed livestock species of total livestock per household.

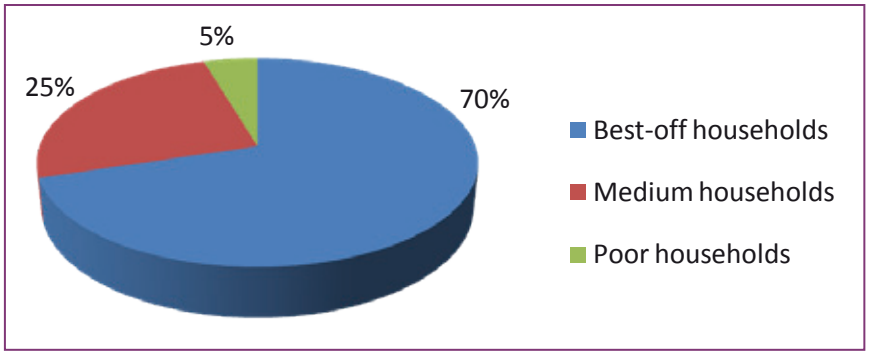


Figure 6.3: Ownership of livestock by different wealth groups (in percent).

hold, a young woman has started a small business selling cool drinks and beer.

Since May 2002, Okamboro has been connected to the electrical power supply grid. Most of the households only use electricity for lighting in the evening, because they cannot afford to pay for more electricity, or cannot afford to buy electronic equipment.

The main economic activity is livestock keeping, and only a few households grow vegetables or maize on garden plots. Although livestock is still the most important source of income, the number of livestock, which are sold and slaughtered are relatively low. In 2002, 36 head of cattle were sold (3.8% of the total number of cattle) and 5 were slaughtered (0.5% of the total number of cattle, see Fig 6.1). During the same year, nine goats were sold or slaughtered (1.5% of the total number of goats made up of 63% male and 7% female goats) and no sheep off-take was reported. Almost half of the households (46.2%) did not sell or slaughter livestock at all. Cattle in Okamboro are mainly slaughtered at special events such as ceremonies or visits. Sick or old livestock are usually slaughtered for home consumption. These low sale figures indicate that Okamboro has been little affected by the commercialisation trend reported for other communal areas, which are dominated by Ovahereros. However, this is not true for all households in the community as there are two different types of farmers in Okamboro: the farmer with farming-independent income; and the pensioner or permanent residents. While livestock is more of a business for the former, the latter use livestock to satisfy basic survival needs. During our survey in 2002, it was noticeable that well-off farmers with larger herds, savings, and access to motor vehicles were the ones who sold or slaughtered livestock from their herds, while the poorer households stated that they were unable to sell their livestock. Permanent residents tended to favour the keeping of livestock more than absentees. In addition, the higher their level of education, the lower the preference for keeping livestock and we noted during our survey in 2002 that this group also slaughtered less livestock. It was also clear that wealthier, better educated residents who were receiving secure non-farming income and who possessed larger herds had a more commercial approach to their livestock farming.

Livestock owners prefer to sell and slaughter male animals. While most of the female calves were kept within the herds, 22% of the male calves were sold and 10% were slaughtered. Females are kept within the herds because they ensure herd growth. Additionally, they provide milk during lactation, which is an important source of protein and calcium to the people in the community

A social stratification was observed at Okamboro, with the wealthier groups owning the highest percentage of the livestock. Ninety-six percent of all households kept livestock in Okamboro. Livestock ownership was analysed within three wealth groups, which were defined according to the assets of the household and their economic activities. The best-off households, defined as the upper third of the calculated wealth points, owned 70% of all livestock (compare Fig. 6.3). The poorest households, defined as the lowest third, owned less than 5% of the total livestock in the community, while the households with moderate wealth accounted for the remaining 25% of the total livestock.

Market access is difficult for rural farmers who often have limited means of transport and live in areas with poor road infrastructure. This means that transaction costs are high for marketing livestock. Livestock marketing is organised within the Ovitoto Reserve, where a farmers association organises a regular permit market (many sellers – one buyer) in Okanjira, where livestock are categorised according to age and condition, and official prices are paid per kg live body-

weight. Farmers in Okamboro mentioned that people who are interested in buying animals sometimes come to visit the village. This appears to be the easiest way for the community to market their livestock. However, information on current livestock prices and the estimation of the exact bodyweights of their livestock often makes this type of marketing insecure, and requires a trustful relationship between buyers and sellers.

Responsible author: U. Schneiderat

Landuse

Observatory farm

Study period	Size of study area	Recommended stocking rate
2001–2003	57–58 km²	30–40 kg·ha-1
Actual stocking rate	**Households owning livestock**	**Number of animals**
41.9 kg·ha–1	96% (2001)	Total: 1,740 (243,370 kg: 76% grazers, 24% browsers) cattle: 941; goats: 623; sheep: 157; donkeys: 19 (2001)
Number of boreholes on Observatory farm	**Farming activities**	**Agricultural products**
One sand dam with a pump, a hand pump, and since 2002 a new water pump with a tank	Pastoralism with cattle, goats, and few sheep	Milk and meat, livestock as a 'bank account', and as insurance against crisis ('capital on the hoof')

Pastoralism and livestock production

Livestock production is the main form of agriculture in Ovitoto. Cattle, goats and fewer sheep, donkeys and horses use the 58 km² of communal rangeland. The main types of cattle are the Afrikaner breed, or crossbreeds between Brahman and Afrikaner cattle. Additionally, Boergoats and a few Damara sheep are kept. An extensive small-scale pastoral system with a focus on large stock dominates in the Ovaherero community, which consists of traditional cattle farmers. Cow's milk is used daily, and sometimes a goat is slaughtered. Ovaherero people traditionally make sour milk from cows' milk and store this in calabashes. This sour milk is eaten with maize and is the main staple food.

Small-scale gardening is very limited, due to the low and variable precipitation in the area. In good rainfall years, some maize and vegetables can be harvested and used to supplement the food supply of the community. However, people usually have to buy maize or wheat flour, and other items for daily consumption, from shops or from hawkers who visit the villages.

The erratic and low rainfall in arid and semi-arid regions limits livestock production to a large degree due to the often low and seasonal forage productivity on rangelands. Large areas are necessary to run an economically viable livestock farm. Additionally, the high risk of droughts requires strategies to cope with these unpredictable events. Intensive farming during the 1970s in the central districts of Namibia caused massive bush encroachment in the commercial farming sector, which is another factor that can limit forage production.

Stocking rates and carrying capacity

The historical fluctuations of livestock numbers in Ovitoto from 1943 to 2000 is shown in Fig. 6.4. The area has had a history of high grazing pressure since at least the second half of the 20th century. In 1943, the estimated stocking density in the Ovitoto area was around 33 kg·ha^{-1} (Wagner 1957), assuming a similar herd composition as in 2001. Grazing pressure increased significantly until 1954, when stocking densities were around 62 kg·ha^{-1} (Wagner 1957).

Stocking rates dropped to 45 kg·ha^{-1} in 1989, and there was a notable declined to a minimum of 29 kg·ha^{-1} in 1997, after the drought years of 1995/1996. The number of small stock decreased dramatically in comparison to large stock during and just after this drought period. After 1997, cattle numbers recovered slowly, and the stocking rate reached 41.9 kg·ha^{-1} in Okamboro in 2001, which was just above the recommended stocking rate of between 30 to 40 kg·ha^{-1}. The numbers of small stock declined from the peak of over 15,000 animals in 1995 to less than 100 animals in 1997. Since then, the number of small stock has recovered fast to 7080 animals in 2000, but did not reach the high levels of 1943. The number of large stock, which was mainly composed of cattle, increased from 7060 animals in 1997 up to the level of 10,800 animals in 2000. The recent increases in livestock numbers is expected within the communal areas of Ovitoto due to higher numbers of community members earning wages in the nearby urban centres, which enables them to invest more money in livestock in these areas.

The human population of the Ovitoto Reserve was 1,419 people in 1951 and

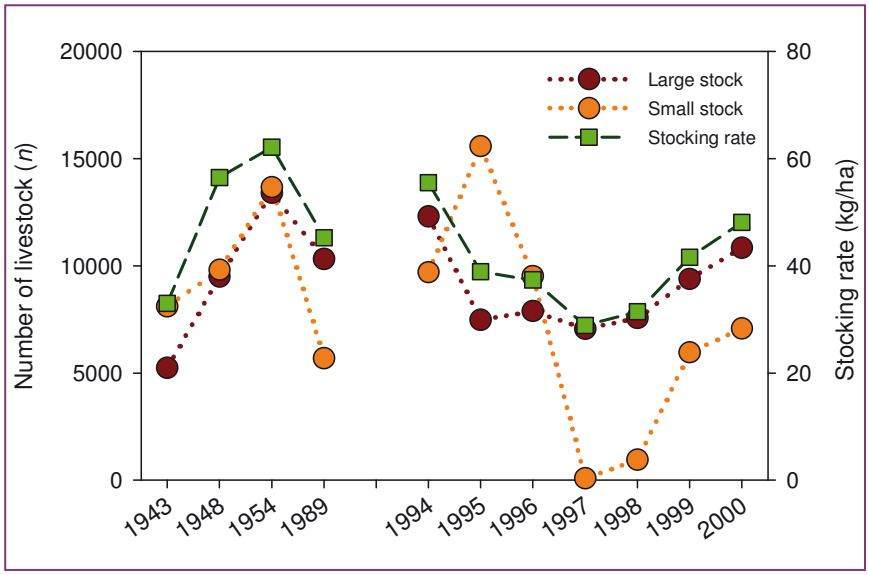


Fig. 6.4: Fluctuations in livestock numbers and stocking rates at Ovitoto between 1943–2000. Sources: 1943–1954: Wagner (1957); 1989: Adams et al. (1990); 1994–2000: Veterinarian Office Okahandja.

1,542 people in 1954, with the population being spread between 25 villages (Wagner 1957). This meant, that one household (assumed to consist of 6 persons) could use a grazing area of 238 ha in 1951. By 1954 this grazing area had declined to 188 ha per household due to the population increase. At Okamboro in 2001, 28 livestock-keeping households used an estimated grazing area of approximately 58 km² (5,800 ha). Each household could therefore theoretically use an area of 207 ha, which lies between the available areas for 1951 and 1954. In 1954, the livestock density was four hectares per Large Stock Unit (LSU, approximately 112 kg·ha^{-1}, depending on the bodyweight of animals and herd composition) even though the estimated carrying capacity was 8 ha LSU^{-1} (approximately 56 kg·ha^{-1}) (Adams et al. 1990). Mendelsohn et al. (2002) recommended a carrying capacity between 30–40 kg·ha^{-1}. The stocking density in 2001 was 41.9 kg·ha^{-1}, composed of 31.9 kg·ha^{-1} grazers and only 10.0 kg·ha^{-1} browsers. In 2001, livestock with a total bodyweight of 243,370 kg (horses and donkeys included) used the available grazing area of approximately 58 km² at Okamboro.

In 2002, livestock farmers mentioned the low rainfall and poor grazing resources as their main problems. The mean grass biomass during the 2002 dry season (September–November 2002) was only 8.6 g m^{-2}, and the mean basal cover was 7.5%. The ground was nearly without vegetation within Okamboro, but there were some grazing and browsing resources available in the peripheral areas. This meant that livestock had to walk longer distances to find fodder and they therefore lost bodyweight and condition. However, during normal rainfall years, livestock recover quickly after the commencement of the rainy season.

Biomass productivity responses to a gap in rainfall distribution during the 2003 rainy season

Rainfall started early in September 2001, with low rainfall amounts in Okamboro, and increased by between 70 and 100 mm each month until February 2002. February and March 2002 were the only two humid months during the rainy season of 2001/2002. Two rainfall peaks were experienced during the October 2002 to April 2003 rainy season, with a break in rainfall during March 2003. The peak of rainfall was during April, instead of February and March, and this was the only humid month during the 2002/2003 rainy season.

Analysis of the daily rainfall amounts revealed a period of 38 days with very low rainfall which totalled 8.6 mm between 3 March 2003 and 9 April 2003. The rainfall during April 2003 (98 mm) fell over a period of six days in the middle of the month (10th to the 16th), and no more rain fell thereafter. This rainfall pattern resulted in a mean grass biomass of only 1.3 g·m^{-2}, and a mean basal cover of only 25% for the 2002/2003 rainy season. Young grasses hardly grew and produced very little dry matter during March 2003, although they were able to produce inflorescences and therefore to reproduce. Annual grasses and some herb species were most common and all produced little biomass during this rainy season. There was therefore not enough dry matter available to meet the requirements of livestock in the area. Cattle prolonged their grazing time and were observed feeding throughout the night. Especially cattle and their calves were found to be in bad condition during May/June 2003. The mean body condition scores of the investigated cows in Okamboro (about 12% of the total cows) was 2.5 on a scale of 1 to 5, indicating that they were thin to normal. However, 51% of these cows had a condition score of two indicating that they were thin.

Promotion of goats

During the drought of 2002/2003, there was a vast deficit of grazing fodder for cattle, which constituted 87.5% of the total livestock bodyweight. Despite the drought, browsers only used up 5.1% of the available browsing resources during the eight month post-wet season period. Despite the drought situation in May 2003, goats, which are mainly browsers, were in good condition due to their ability to utilise other fodder resources such as litter and Acacia pods. According to calculations based on grass and browse biomass as well as their nutrient values, which need to meet the protein and energy demands of all livestock in the village, only 49.3% of the initial body weight of 243,370 kg could be stocked in the area. Additionally, 94.9% of the remaining animals should have belonged to the browser category, such as goats. Goats should therefore be encouraged. Goats are more flexible than cattle in their fod-

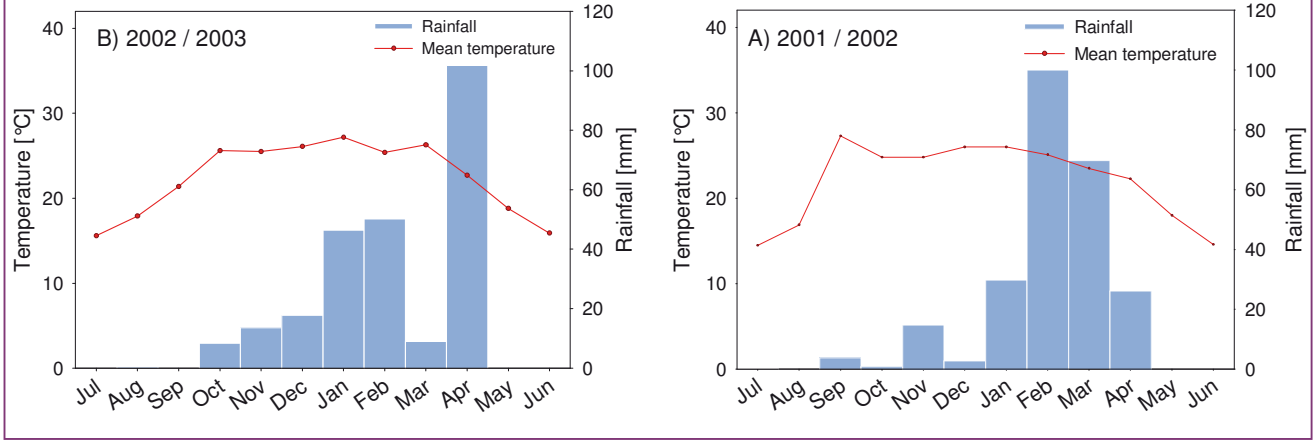


Fig 6.5: Rainfall and temperature in Okamboro. A) season 2001/2002, B) season 2002/2003.

der requirements and their main fodder resource (i.e. browse material) is less affected by droughts. Browse also has the advantage of a high protein level and some of the early sprouting trees even provide forage at the end of the dry season. In addition, goats are easier to sell and exchange because they are smaller and cheaper than cattle. They also have a higher reproduction rate and are more successful than cattle at coping with the variable environment and droughts. Browsers can also prevent encroachment of thorny bush species, which is a major problem especially on commercially managed farms in Namibia. However, bush encroachment is not a major issue in the communal areas of Namibia due to the presence of mixed herds of large and small livestock and a combination of grazers and browsers in these areas.

If the total available grass and browse resources are pooled, and the feeding behaviour of the different livestock species is ignored, then the maximum calculated stocking density during the dry-season months would be 77.1 kg·ha^{-1} and 74.8 kg·ha^{-1} during the post wet-season period. The deficit for the grazers during both seasons was not considered in the calculation of the values for the pooled resources, leading to a much higher recommended stocking rate. This does not reflect the real situation, but is a common method for calculating the carrying capacity of rangelands. Lower stocking rate values would result if browsing resources were not integrated in these calculations. Usually, the maximum standing herbaceous biomass, and partly also their quality, is used in models to calculate the carrying capacity of the land. This can lead to unrealistic estimates when applied to communal farming systems when the feeding behaviour of the often mixed herds is ignored. Therefore, the methods and formulae need to be adapted and to differentiate between grazing and browsing capacity (GBC), instead of concentrating solely on grazing capacity.

Gardening

Two households have a crop garden near a riverbed, where the soil fertility and soil moisture is sufficient. One woman does gardening on a slightly larger scale near her house away from the river, in order to generate some income. These farmers have to irrigate the maize, tomatoes, and other vegetables to ensure the harvest. They do not start seeding and planting unless there has been an appropriate amount of rainfall. For example, during the 2002/2003 season, nobody planted anything due to the poor and unequally distributed rainfall.

Responsible author: U. Schneiderat

Site-specific studies

The institutional framework guiding natural resource management of Okamboro communal farmers (S06.01)

[T. Falk]

Sustainable biodiversity management requires effective institutional incentives. Document analyses, expert interviews, and empirical surveys were applied to describe the multiple rules and norms guiding the management of communal farmers around the Observatory S06 (Okamboro).

Key results show that multifaceted supportive but also conflicting interactions between the statutory and customary legal system exist. Access to communal pastures is efficiently regulated. The rangeland management within the settlement is, however, weak. Stocking rate controls and grazing rotation are not coordinated. The currently implemented Rural Water Supply Reform increases incentives for sustainable ground water management. A crucial problem around this Observatory is the privatisation of land by powerful community members. This is prohibited by statutory law and decreases the land available to poorer farmers. Pressure on the resources is supposed to be reduced by resettling owners of larger herds within the framework of the land reform.

Diverse rules and norms regarding resource use exist in the research area. In order to increase their efficiency in the interest of biodiversity maintenance and economic development a stronger integration of sectoral policies and a more polycentric governance approach is recommended.

Falk, T. (2008): Communal farmers' natural resource use and biodiversity preservation. A new institutional economic analysis from case studies in Namibia and South Africa. – Göttingen: Cuvillier.

Falk, T., Bock, B., Kirk, M. (2009): Polycentrism and poverty: experiences of rural water supply reform in Namibia. – Water Alternatives **2**: 115–137.

Spectral variation versus species beta diversity at different spatial scales: a test in African highland savannas (S06.02)

[J. Oldeland & D. Wesuls]

Few studies exist that explicitly analyse the grain effect on species turnover (beta-diversity) among sites. While beta diversity is often a result of environmental heterogeneity, remotely sensed spectral distances among sampling units may be used as a proxy of environmental gradients, which shape the patterns of species turnover spatially. In this paper, we aimed at (i) testing the potential relation between spectral variation and species beta-diversity in savanna environments and (ii) investigating the effect of grain on the achieved patterns. We used field data sampled from the Observatory Okamboro (S06) to model the relation between spectral variation and species turnover at different spatial grains (10 m × 10 m and 20 m × 50 m).

Our results indicate that the overall fit improved with increasing grain, confirming the theoretical assumption that using a smaller grain size would generally lead to a higher noise in the calculation of species turnover. This paper represents one of the first attempts of relating beta diversity to spectral variation, while incorporating the effects of grain. The results of this study could have significant implications for biodiversity research and conservation planning at the regional or even a larger scale.

Rocchini, D., He, K., Oldeland, J., Wesuls, D., Neteler, M. (2010): Spectral variation versus species beta-diversity at different spatial scales: a test in african highland savannas. – Journal of Environmental Monitoring **12**: 825–831.

Does using species abundance data improve estimates of species diversity from remotely sensed spectral heterogeneity?

► *See* **S04.05**

Further Studies

Schneiderat, U., Siegmund-Schultze, M., Steinbach, J. (2005): Do communal rangelands meet the requirements of communal livestock? – Congress abstract. Tropentag 2005, 13.–15.10.2005, University Stuttgart-Hohenheim, Germany. http://www.tropentag.de/2005/abstracts/full/333.pdf.

General data

Number	Name	Alternative name(s)
S37	Rooisand	Rooisand Desert Ranch
Implementation	Country	Province/ region
2004	Namibia	Khomas
District/ constituency	Locality	Farm name
Windhoek	Rooisand Desert Ranch	Chausib 27
Latitude	Longitude	Altitude
23.294542 S	16.104978 E	1160 m a.s.l.
Rainfall season	Biome	WWF Ecoregion
Summer	Thornbush Savanna	AT1316 Namibian savanna woodlands
Agro-Ecological Zone	Relative intensity of land use	Tenure
ESC5	Medium	Private
Type and history of landuse	Land owner	
Cattle farming and tourism	Private	

Rooisand (S37)

Sparse thornshrub savanna of the western Khomas Hochland at the Rooisand Observatory. Photo: J. Deckert.

The BIOTA Observatory Rooisand (S37) is situated ca 150 km south-west of Windhoek in the Khomas region of Namibia, below the Khomas Hochland escarpment at the Gamsberg. This area of the western Khomas Hochland forms part of the Chausib Turbidite basin along the southern margin of the Damara orogenic belt (Porada & Wittig 1976). This relatively low-lying Observatory is surrounded by higher mountains of the Hakos and Chaibis ranges. The vegetation of the area is dominated by *Acacia* and *Catophractes* shrubs, dwarf shrubs, and desert-adapted grasses. The Observatory is a typical example of the Semi-desert and savanna transition of the escarpment zone sensu Giess (1998). The altitude is on average about 1160 m a.s.l., and ranges from 1134 to 1187 m. The area has a typical summer rainfall climate, with an average of 200 mm of precipitation per annum.

The Observatory is on the Rooisand Desert Ranch on the farm Chausib. The farm is managed as a commercial cattle farm, and has diversified into tourism.

This BIOTA Observatory was established as part of an east-west gradient of observatories, reflecting both changes in altitude and rainfall. The closest neighbouring Observatories for direct comparisons are, Ganab (S36) on the fringe of the Namib Desert to the west and Claratal (S38) further east.

Responsible authors:
B.J. Strohbach & D.H. Haarmeyer

Remote sensing and landscape

Geomorphology	Geological units	Lithological units
Slope, rivier	Hakos Group in Damara Supergroup and Gariep Complex	Sandstones
Mean EVI	**EVI absolute range**	**Mean leaf area index**
0.109 (0.079–0.193)	0.067 (2003)–0.321 (2006)	0.40

Grid map of Observatory

	0	1	2	3	4	5	6	7	8	9
0	98	62	82	40	22	78	13	65	25	14
1	67	42	31	74	5	48	24	86	47	29
2	70	63	51	44	68	93	87	21	55	64
3	53	76	81	96	18	75	54	43	2	69
4	97	7	16	80	12	92	83	38	50	10
5	85	35	90	60	77	1	99	88	52	39
6	6	30	59	37	79	91	32	33	36	66
7	49	28	57	84	20	94	26	89	58	17
8	72	4	27	95	73	100	71	45	23	61
9	9	19	56	15	41	34	8	11	3	46

1 Upper slope rock type
2 Reddish lower slope rock type
3 Lower slope rock type
4 Embedded river

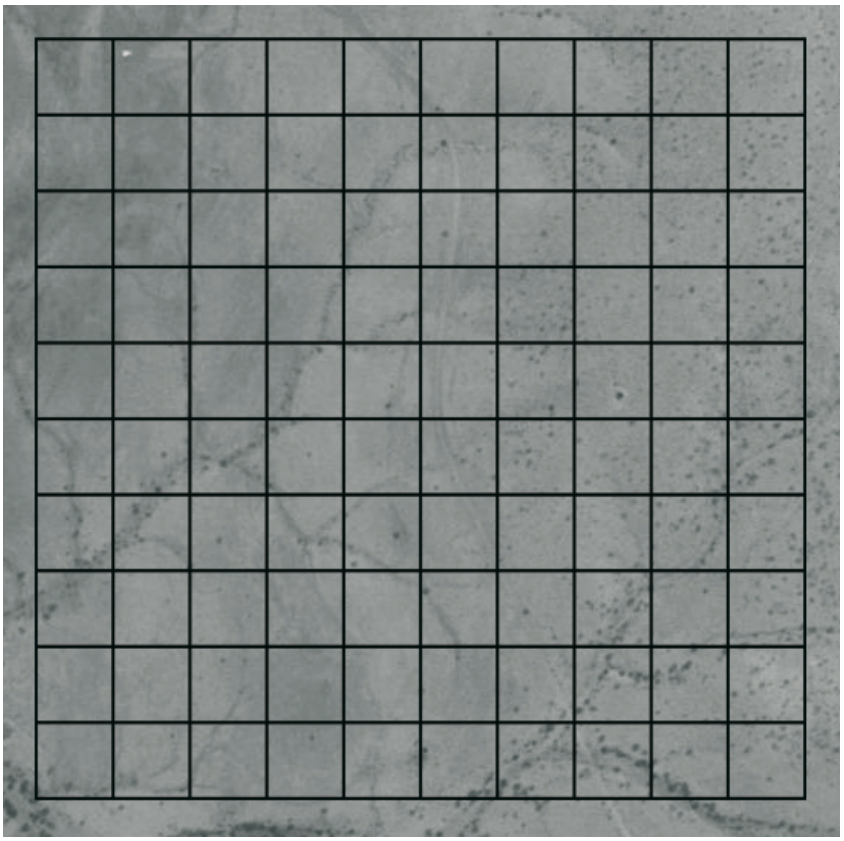
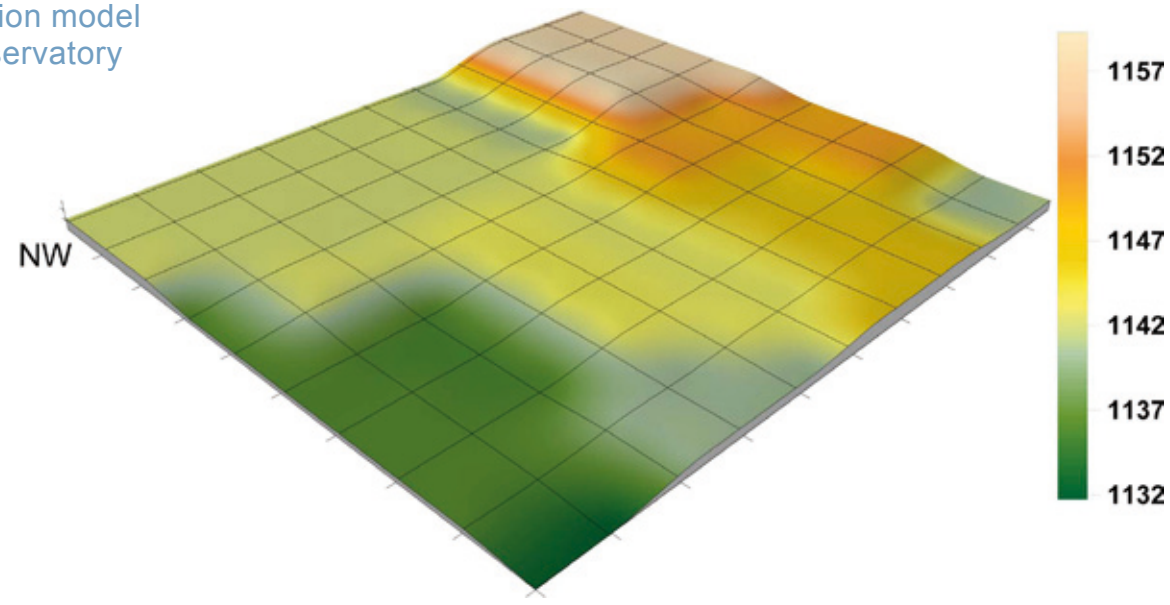


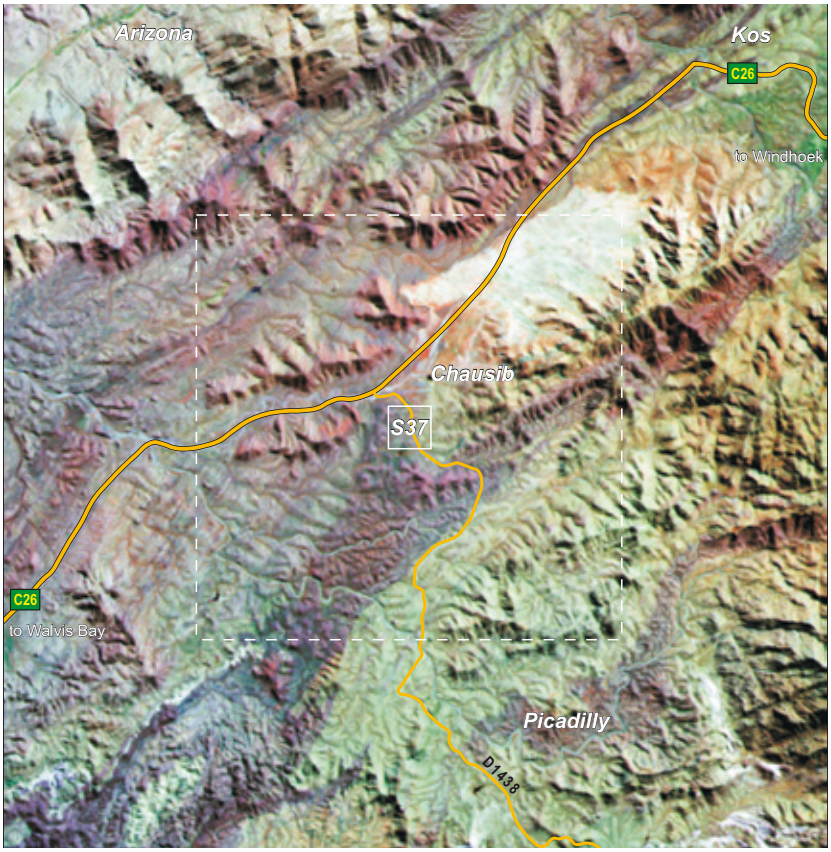
Image: aerial photograph

Elevation model of Observatory



Landsat image

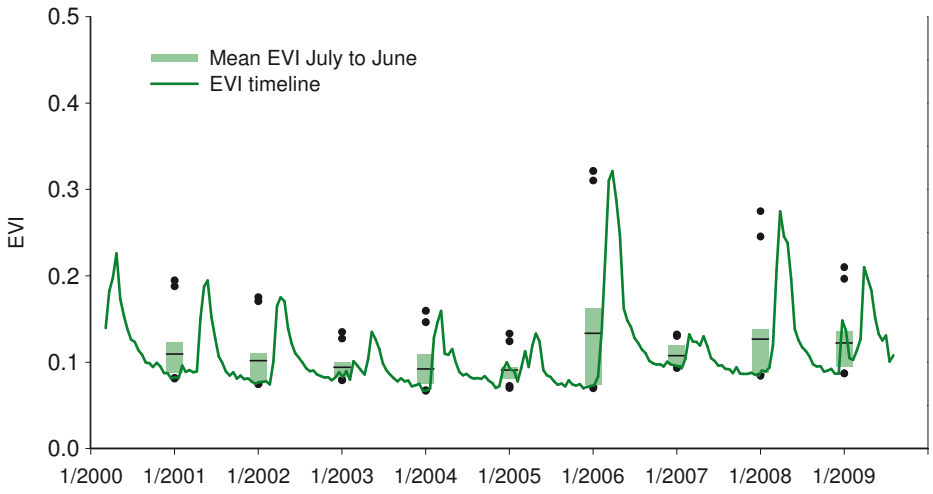
Several drainage lines are winding towards the west through the mountainous terrain of the Khomas Hochland. The vegetation (bright green) in this region of the Namibian "Randstufe" (escarpment) is very sparse. It consists of annual grasses and dwarf shrubs (bright green tones where it is more dense and grey tones where it is sparser). The satellite image mainly provides spectral information about different geological structures.



Scene: 178/76, acquisition date: 24 April 2006

MODIS time series

Temporal patterns of vegetation cover, and phenology



Responsible authors: M. Keil & T. Labitzky

Climate

Data from BIOTA weather station

Location	Recorded period	Mean temperature
Rooisand (S37)	2006–2009	24.2 (4.9–40.3) °C
Mean solar radiation	**Mean wind speed**	**Mean annual precipitation**
613 (432–836) MJ·m^{-2}·month^{-1}	2.2 (12.6) m·s^{-1}	165 (80–258) mm
Mean annual potential evapotranspiration	**Interannual precipitation variability**	**Mean relative humidity**
1973 mm	189%	32% (18–64%)
Aridity index (UNEP)		
0.08 (arid)		

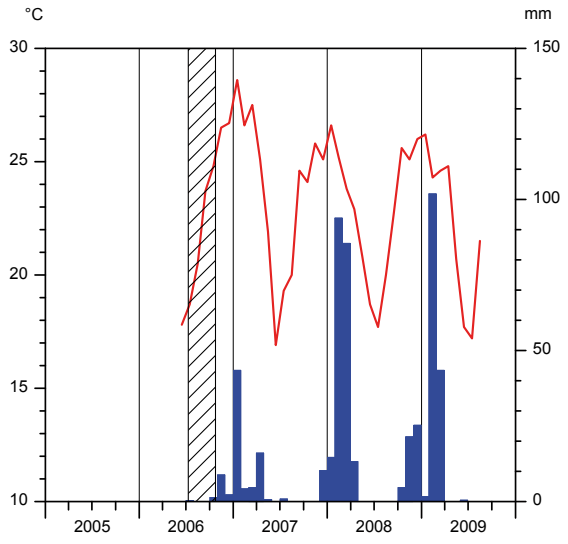
Modelled data

Mean temperature	Mean annual temperature range	Mean diurnal temperature range
19.5 (5.6–31.6) °C	8.5 °C	16.9 °C
Mean annual precipitation	**Precipitation seasonality**	**Percentage winter precipitation**
200 mm	125%	12% (strong summer)
Climate type	**Length of dry season**	**Aridity index (De Martonne)**
BWh	9 months	6.8 (dry)

The climate at the Observatory is characterised by semi-arid to arid conditions. Rainfall shows a pronounced seasonality with the major portion of rain falling during the summer season, peaking in February. The mean annual rainfall over the observation period was 165 mm, which is drier than the average rainfall recorded over the entire transect, and makes it the driest Observatory within the Thornbush Savanna. However, substantial interannual variability is evident. The observed near-surface air temperatures show a moderate seasonal cycle. The mean annual temperature is 24.2°C, which is the warmest mean temperature observed for all Observatories and is slightly warmer than the average for this biome. Compared to the interpolated long-term data taken from the WorldClim dataset, a markedly warmer mean annual temperature is evident at the BIOTA weather station. Furthermore, the station records of temperature extremes deviate substantially from the interpolated data, showing substantially warmer maximum and minimum temperatures. For precipitation, mean annual rainfall observed at the station is markedly lower than that of the WorldClim dataset. Additionally, the timing of the rainfall peak is about two months earlier in the station data.

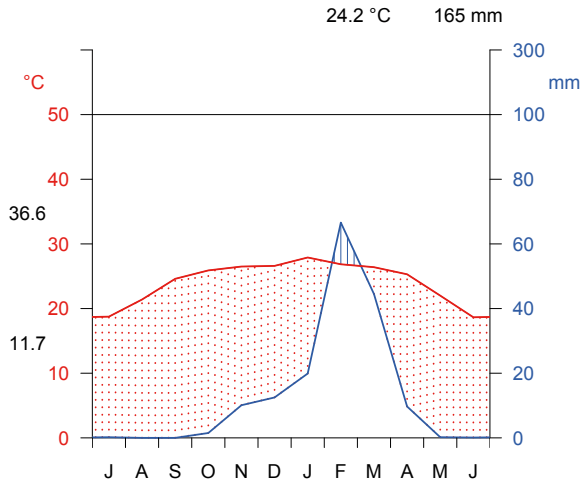
The observed near-surface winds at the Observatory are mainly constituted of northerly flows during spring and summer. During the autumn and winter seasons, the circulation changes to flows from a south-southeasterly direction. Mean wind speed shows a substantial annual cycle in the mornings and evenings, having reverse amplitudes. Mean wind speed recorded in the evenings shows a pronounced annual cycle, peaking during mid-summer. Winds observed during the mornings and early afternoons remain fairly constant throughout the year, with higher wind speeds in the early afternoon, reaching about 10 to 12 km/h.

Time series: rainfall and temperature

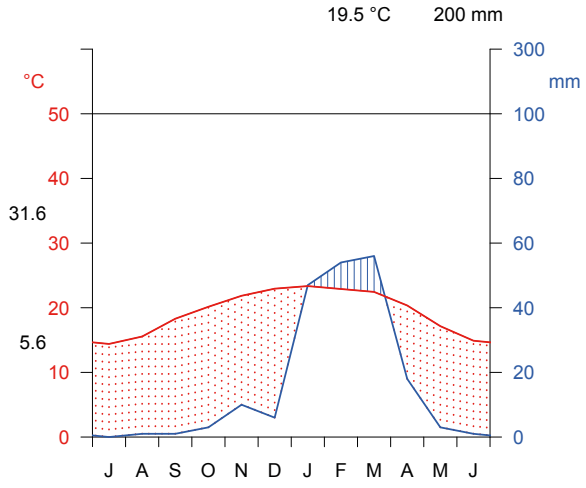


Climate diagrams

Recorded data (BIOTA)

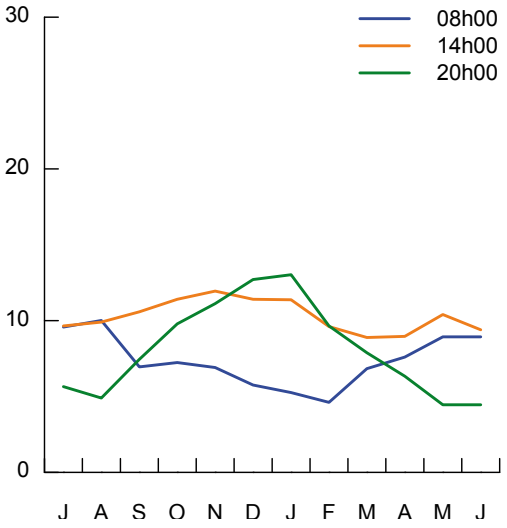


Modelled data (WorldClim)

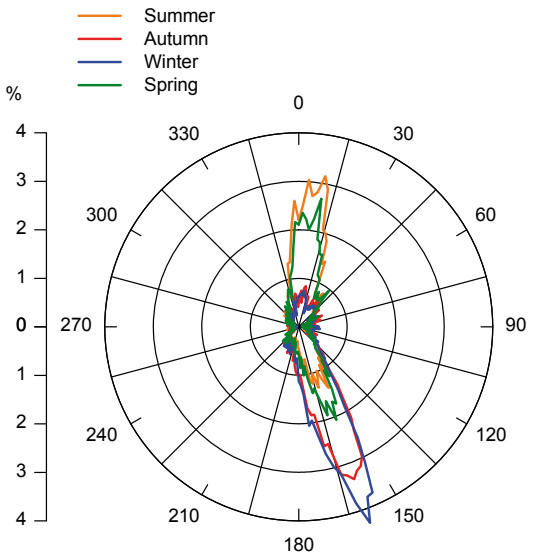


Wind diagrams

Speed



Directions



Responsible authors: K. Berger, A. Haensler & J. Luther-Mosebach

Lichens

Sampling period(s)	Hectare plots sampled	Cover
2005	5 (R1–R5)	0%
Total species richness	Species richness on soil [1 km²]	Species richness on rock [1 km²]
20	4 (20%)	16 (80%)
Species richness on plants [1 km²]	Species richness on soil [1000 cm²]	
n.a.	0	

This Observatory is relatively rich in saxicolous lichens, while only a few terricolous species occur. Epiphytic lichens are also infrequent, probably due to low air humidity and precipitation. Lichens are particularly abundant on exposed schistose boulders, on which inconspicuous cyanophilous taxa are especially common. It was discovered that one of these cyanolichens is a new species of the genus *Phloeopeccania* (M. Schulz, unpublished data). Only cyanolichens, with a dominating peltate growth habit, occur on the soil surface. No lichens were recorded on soils of the examined hectare plots at this Observatory. The absence of lichen soil crusts can be attributed to unsuitable soil conditions (i.e. high cover of pebbles).

List of Taxa

Terricolous (on soil):

Collema coccophorum
Heppia despreauxii
Lichinella stipatula
Peltula patellata

Saxicolous (on rock):

Acarospora sp.
Caloplaca sp.
Gloeoheppia turgida
Lichenothelia sp. 01 (M-0125442)
Lichenothelia sp. 02 (M-0125435)
Lichinella cf. granulosa
Peccania arizonica
Peltula obscurans var. obscurans
Peltula obscurans var. hassei
Peltula cf. omphaliza
Phloeopeccania sp. 01 (M-0125428)
Porocyphus coccodes
Psorotichia sp.
Psorotichia hassei
Thelochroa cf. montinii
Thyrea plicatissima

Epiphytic (on plants):

No records

Gloeoheppia turgida. Photo: M. Schultz, L. Zedda & G. Rambold.

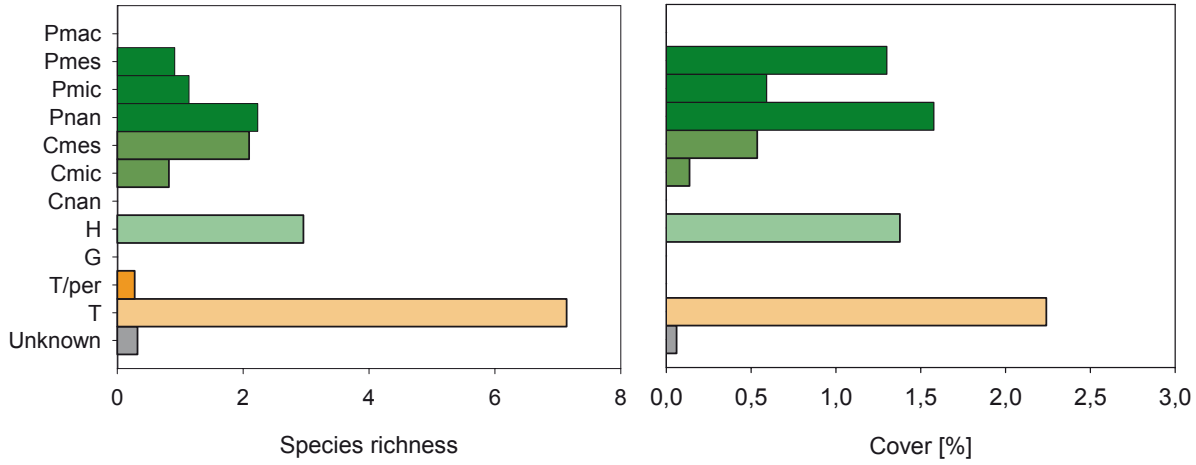
Peccania arizonica. Photo: M. Schultz, L. Zedda & G. Rambold.

Responsible authors: L. Zedda & G. Rambold

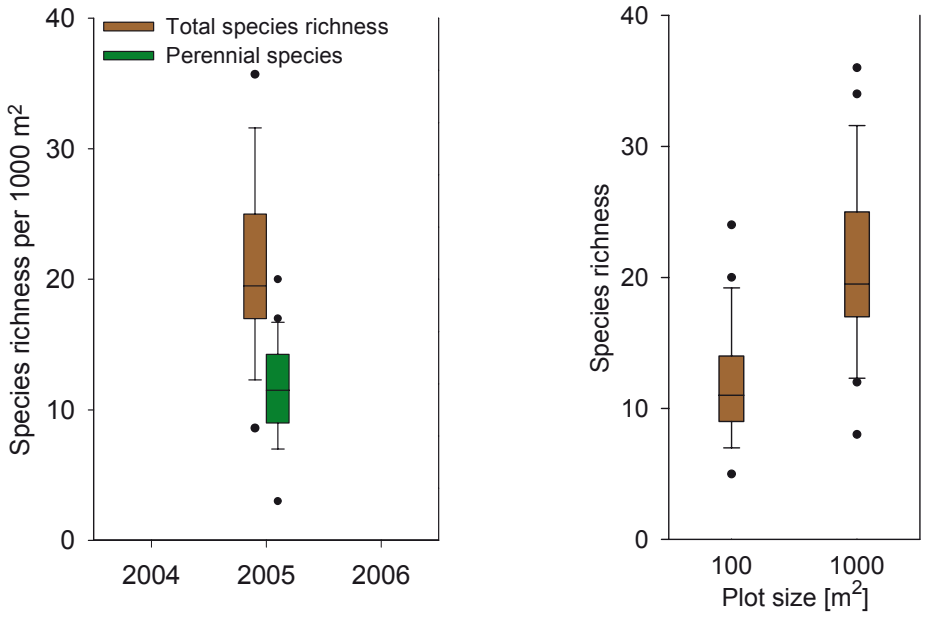
Vascular plants

Sampling period(s)	Hectare plots sampled	Biome
2005	20 (R1–R20)	Thornbush Savanna
Vegetation unit (level 1)	**Vegetation unit (level 2)**	**Identification rate**
Semi-desert and Savanna Transition (Escarpment Zone)	n.a.	100% – 100% – 100%
Cumulative family richness	**Dominant families (cover)**	**Dominant families (richness)**
31	Poaceae, Fabaceae, Bignoniaceae	Fabaceae, Poaceae, Asteraceae
Cumulative species richness (1 km²)	**Species richness (1000 m²)**	**Species richness (100 m²)**
95 – 95	20.5 (8–36)	11.8 (5–24)
***z*-value**	**Species richness change per year (1000 m²)**	**Evenness (1000 m²)**
0.240 (0.151–0.556)	n.a.	0.605 (0.287–0.761)
Evenness (100 m²)	**Simpson (1000 m²)**	**Simpson (100 m²)**
0.666 (0.442–0.884)	0.770 (0.388–0.877)	0.675 (0.323–0.849)

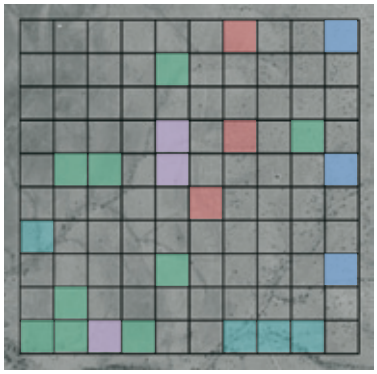
Life forms



Species richness



Map of vegetation units



The Rooisand Observatory (S37) is situated in the western Khomas Hochland, below the escarpment formed by the Gamsberg and Hakos mountains. The topography is undulating to moderately steep, but is not as deeply incised as the typical Khomas Hochland (e.g. at the Observatory Claratal S38). Being below the escarpment, towards the Namib Desert, the vegetation is a mix between desert elements and Highland Savanna elements. The presence of a large number of stem succulent *Commiphora* species makes this a part of the semi-desert and savanna transition sensu Giess (1998). In this environment, soil moisture relations (as a result of the topographic position in the landscape) are of major importance to the composition of the vegetation.

The *Acacia reficiens-Catophractes alexandri* association is represented in unit 1, and is widespread in the lower Khomas Hochland on sloping hills and mountainsides, and is also the largest community at the Rooisand Observatory. Although *Acacia reficiens* (Rooihaak) and *Catophractes alexandri* (Trumpet Thron) do not occur at all sites, they still dominate the vegetation with on average of 9% and 5% cover, respectively (Strohbach, in prep.). The other common woody species is *Boscia foetida* (Noeniebos), in association with the dwarf shrub *Leucosphaera bainesii* (Wolbos). The grass sward is dominated by *Eragrostis nindensis* (Agdaepluimgras), *Stipagrostis uniplumis* var. *uniplumis* (Bushmangrass), *S. ciliata* (Langbeenboesmangras), *Anthephora schinzii* (Annual Wool-

Classification table (2005)

Column		Cover	All	1.1	1.2	1.3	2	3
Number of relevés			**22**	**3**	**3**	**9**	**3**	**4**
Mean cover [%]			7.6	18.7	5.9	3.3	6.2	15.1
Mean species richness (1000 m²)			18.8	24.7	25.0	16.8	15.3	26.0
Gravel [%]			2.9	3.0	2.7	3.3	3.3	1.5
Stones 2-6 cm [%]			4.5	5.0	4.3	5.0	5.0	3.0
Stones 6-20 cm [%]			2.9	3.0	3.3	2.8	2.3	3.3
Stones 20-60 cm [%]			2.1	2.0	2.0	2.0	1.3	3.0
Blocks [%]			1.4	1.3	1.7	1.2	0.7	2.0
Unit 1: Acacia reficiens-Catophractes alexandri community								
Pnan	Catophractes alexandri	1.17	82	100	100	100	.	75
Unit 1.1: Commiphora glandulosa-Adenolobus gariepensis community								
Pnan	Commiphora glandulosa	0.25	18	100	33	.	.	.
Pnan	Adenolobus garipensis	0.50	23	100	.	11	.	25
Pnan	Monechma genistifolium ssp. australe	0.50	9.1	67	.	.	.	.
T	Indigastrum parviflorum	0.31	32	100	67	11	.	25
Unit 1.2: Acacia erubescens community								
Pmic	Acacia erubescens	1.00	14	.	100	.	.	.
T	Heliotropium ciliatum	0.05	9.1	.	67	.	.	.
Cmic	Dicoma tomentosa	0.13	27	.	100	11	33	25
G	Cucumis sagittatus	0.10	14	.	67	.	33	.
Unit 1.3: Acacia reficiens-Catophractes alexandri community								
T	Aristida adscensionis	0.02	27	.	33	56	.	.
Unit 2: Acacia reficiens-Catophractes alexandri community (degraded)								
T	Eragrostis annulata	0.07	14	.	.	11	67	.
Hper	Cleome angustifolia ssp. diandra	0.11	32	33	.	22	100	25
Pnan	Orthanthera albida	0.20	14	33	.	.	67	.
Unit 3: Acacia reficiens-Stipagrostis hochstetteriana community								
H	Tephrosia burchellii	0.02	23	33	.	.	.	100
Cmes	Lycium oxycarpum	0.30	9.1	.	.	.	.	50
Cmes	Hermbstaedtia argenteiformis	0.05	9.1	.	.	.	.	50
H	Triraphis ramosissima	0.05	9.1	.	.	.	.	50
H	Fingerhuthia africana	0.25	9.1	.	.	.	.	50
T	Forsskaolea viridis	0.05	9.1	.	.	.	.	50
Pmes	Acacia reficiens	2.18	41	33	33	33	.	100
Pmes	Acacia senegal	0.92	27	33	.	22	.	75
H	Stipagrostis hochstetteriana	0.69	50	.	33	44	67	100
Most frequent companions								
T	Chamaesyce glanduligera	0.14	95	100	100	89	100	100
T	Entoplocamia aristulata	0.05	95	100	100	100	67	100
H	Stipagrostis uniplumis var. uniplum	0.35	91	100	100	100	67	75
T	Eragrostis nindensis	1.37	86	100	100	100	67	50
T	Tribulus zeyheri	0.12	77	100	100	78	33	75
H	Stipagrostis hirtigluma ssp. hirtigluma	0.60	68	67	33	78	100	50
Cmes	Geigeria pectidea	0.37	59	33	33	78	100	25
T	Gisekia africana	0.46	50	33	67	56	33	50
T	Enneapogon desvauxii	0.24	50	67	.	56	100	25
H	Stipagrostis ciliata	0.55	45	100	.	56	33	25
Pmic	Boscia foetida	0.43	45	33	100	44	.	50
T	Crotalaria podocarpa	0.17	45	100	67	22	.	75
H	Anthephora schinzii	0.17	45	100	.	67	.	25
H	Monsonia senegalensis	0.02	45	33	67	33	33	75

continued on next page

Unit 1.1, 2005. Photo: B.J. Strohbach.

Unit 1.2, 2005. Photo: B.J. Strohbach.

Unit 1.3, 2005. Photo: B.J. Strohbach.

Unit 2, 2005. Photo: B.J. Strohbach.

Unit 3, 2005. Photo: B.J. Strohbach.

Grass), and *Entoploclamia aristula* (Velskoengras). A very common annual species is *Euphorbia glanduligera* (synonym = *Chamaesyce glanduligera*), which is indicative of the very arid nature of the environment. Three subunits can be distinguished in this community:

The *Commiphora glandulosa-Adenolobus gariepensis* subunit (subunit 1.1) occurs on the steeper west-facing slopes of the Observatory. It is characterised by the fairly dense occurrence of low *Commiphora glandulosa* (Tall Common Corkwood) trees, as well as large *Adenolobus gariepensis* shrubs (Bloubeesklou), in association with the dwarfshrub *Monechma genistifolium* subsp. *australe*.

The *Acacia erubescens* subunit (subunit 1.2) occurs on the top-slopes along the eastern parts of the Observatory. Part of this subunit also occurs on the cooler, but steeper east-facing slopes of the Observatory. It is characterised by small trees of the Yellow-Bark Acacia (*A. erubescens*), in association with *Dicoma tomentosa* and *Cucumis sagittatus*. The latter is an indication of the steep rocky habitat, on which this sub-community occurs.

The *Acacia reficiens-Catophractes alexandri* community (typical subunit 1.3) is characterised by the wide-spread occurrence of *Aristida adscensionis* (Annual Bristle-Grass). *Calicorema capitata,* a common shrub in the desert environment, occurs in this subunit as well. This subunit covers the largest area of the Observatory, on the rolling to moderately steep footslopes along the western part of the Observatory.

Classification table (continued)

Column		Cover	All	1.1	1.2	1.3	2	3
Number of relevés			**22**	**3**	**3**	**9**	**3**	**4**
Pnan	Calicorema capitata	0.44	41	.	.	67	.	75
Cmic	Leucosphaera bainesii	0.22	41	.	.	67	.	75
T	Hermannia modesta	0.16	41	33	100	33	.	50
T	Cleome suffruticosa	0.22	27	33	33	22	67	.
T	Hirpicium gazanioides	0.12	27	67	67	22	.	.
T	Sericorema sericea	0.03	27	67	.	.	33	75
Pmes	Acacia erioloba	0.63	18	.	33	11	.	50
T	Eragrostis porosa	0.40	18	33	33	.	67	.
Cmes	Otoptera burchellii	0.28	18	67	.	.	.	50
H	Stipagrostis obtusa	0.15	18	33	33	22	.	.
n.a.	Aptosimum glandulosum	0.08	18	67	.	11	33	.
T	Pegolettia senegalensis	0.05	18	33	33	.	.	50
Pmic	Parkinsonia africana	1.00	14	.	.	11	33	25
Cmes	Cryptolepis decidua	0.70	14	33	33	11	.	.
T	Anticharis senegalensis	0.33	14	33	.	11	.	25
Hper	Aizoon asbestinum	0.23	14	.	.	22	.	25
T	Monsonia angustifolia	0.17	14	33	33	.	33	.
Hper	Emilia marlothiana	0.10	14	33	33	11	.	.
Cnan	Aptosimum spinescens	0.07	14	.	33	22	.	.
Pmes	Dichrostachys cinerea	0.03	14	.	33	.	.	50

A degraded form of the *Acacia reficiens-Catophractes alexandri* community is represented by unit 2, characterised by the presence of *Cleome angustifolia* subsp. *diandra* and *Eragrostis annulata*. The community is extremely species poor, with an average of only 8 species per 1000 m^2. The average vegetative cover also barely reaches 5% in this community. Degradation is caused either by overgrazing (hectare H92 seems to be at an old kraal) or road building (hectare H44).

The rivers within this observatory are characterised by the *Acacia reficiens-Stipagrostis hochstetteriana* community (unit 3). Much like most rivers and washes in arid environments, this community consists of various species from adjacent communities, which, through wind-blown or washed seeds, are able to establish in the favourable moist conditions. *Acacia reficiens* trees therefore dominate this community, with *A. senegal* (Three-Hook Acacia), *Catophractes alexandri,* and *Calicorema capitata* also occurring here. The occurrence of *Stipagrostis hochstetteriana* (Gemsbokstert) in this community is typical of many drainage lines in arid areas.

Responsible authors: B. J. Strohbach & J. Luther-Mosebach

Termites

Taxon richness	Abundance index	Dominant (sub-) family
4	31	Rhinotermitidae

The termite species encountered most frequently at this Observatory was *Psammotermes allocerus* (see Observatory S11/Nabaos for more details on this species). Termites of this species rapidly attacked most of the toilet paper baits at this Observatory.

List of taxa

Taxon	(Sub-)family	Frequency Index	Feeding substrate
Psammotermes allocerus	Rhinotermitidae	0.33	w, d
Hodotermes mossambicus	Hodotermitidae	0.22	g
Trinervitermes	Termitidae (Nasutitermitinae)	0.11	s, w, g, l, m
Lepidotermes	Termitidae (Termitinae)	0.11	s, w, g

Responsible authors: C. Grohmann & K.E. Linsenmair

True bugs

Sampling period(s)	Methods	Family richness
2007/I; 2008/IV	Trapping (light); net sweeping; beating of plants	10
Species richness	**Individuals sampled**	**Fisher's alpha diversity**
26	237	7.44

At Rooisand Observatory (S37), Heteroptera were only collected over two nights at light traps. The trap attracted altogether 23 Heteroptera species. In between were several Miridae, *Dicranocephalus schmitzi* (Stenocephalidae), and *Piezodorus purus* (Pentatomidae) with notable species abundances. On specimen of *Lohoraglius notabilis* was collected at light. This species is widely distributed in Africa and especially common along the Escarpment in Namibia. This species was also found at Koeroegap Vlakte (S18), Karios (S12), Ganab (S36), and Otjiamongombe (S05).

Species richness in families

Family	*S*
Miridae	10
Rhyparochromidae	4
Alydidae	2
Lygaeidae	2
Pentatomidae	2
Stenocephalidae	2
Berytidae	1
Cydnidae	1
Geocoridae	1
Tingidae	1
Total	**26**

Species abundances

Light traps

Species	Family	*N*	%
Miridae spec. 1	Miridae	93	50
Miridae spec. 2	Miridae	36	19
Dicranocephalus schmitzi	Stenocephalidae	17	9
Miridae spec. 3	Miridae	7	4
Piezodorus purus	Pentatomidae	6	3
Galeatus scrophicus	Tingidae	4	2
Others (16)		23	12
Total		**186**	**100**

Responsible author: J. Deckert

Butterflies and moths

Sampling period(s)	Number of samples (moths)	Species richness (total)
2007/I; 2008/IV	2	131
Species richness (butterflies)	**Species richness (all moths)**	**Species richness (Microlepidoptera)**
10	121	49
Species richness (Pyraloidea)	**Species richness (Macrolepidoptera)**	**Species richness (Noctuidae)**
35	7	30
Individuals sampled (moths)	**Fisher's alpha diversity (moths)**	
1714	29.7	

Butterflies

The species collected at Rooisand have wide ranges in southern Africa and are common residents in Namibia. There is without a doubt a richer resident butterfly fauna than recorded so far. The flowers in the garden on the nearby farmhouse were observed to be an attractive nectar source for many species, including some that were not observed on the Observatory, e.g. *Papilio demodocus*. This species probably developed on *Citrus* trees planted on the farm.

Taxonomic spectrum of moths

Collection period: I/2007

Family	S	N
Opostegidae	1	1
Nepticulidae	2	60
Tineidae	3	4
Psychidae	1	1
Pseudurgis group	1	1
Bucculatricidae	2	4
Gracillariidae		
Lyonetiidae		
Coleophoridae	1	13
Ethmiidae		
Scythrididae	4	32
Elachistidae		
Oecophoridae	1	2
Chrysopeleidae	6	78
Cosmopterigidae		
Gelechiidae	26	185
Gelechiidae, indet.		
Tortricidae	1	1
Epermeniidae		
Microlepidoptera	49	382
Pyralidae: Phycitinae	21	179
Pyralidae: Galleriinae	1	1
Pyralidae: Pyralinae	1	2
Crambidae	12	61
Pyraloidea	35	243
Lasiocampidae	1	1
Sphingidae		
Geometridae	5	8
Lymantriidae	1	1
Noctuidae	30	1079
Macrolepidoptera	37	1089
Total	**121**	**1714**

Butterfly species and main food plants

Nymphalidae	
Danaus chrysippus aegyptius	Asclepias, Stapelia, Cynanchum (Asclepiadaceae)
Hypolimnas misippus	Portulaca, Talinum (Portulacaceae)
Junonia hierta cebrene	Asystasia, Adhatoda, Barleria, Ruellia (Acanthaceae)
Lycaenidae	
Leptotes pirithous pirithous	Plumbago (Plumbaginaceae), Indigofera (Fabaceae), Burkea (Caesalpiniaceae)
Azanus ubaldus	Acacia (Fabaceae)
Lampides boeticus	Medicago, Crotolaria, Polygala (Fabaceae)
Iolaus mimosae mimosae	Moquinella, Tapinanthus (Loranthaceae)
Zizyla hylax	Phaulopsis, Ruellia (Acanthaceae)
Chilades trochylus	Indigofera (Fabaceaea), Heliotropium (Boraginaceae)
Pieridae	
Belenois aurota aurota	Boscia, Capparis, Maerua (Capparaceae)

Male of *Coenobasis argentilinea*. Photo: W. Mey.

Moths

In January 2007, the moth fauna was dominated by small microlepidopterans. Abundant species of these tiny moths were *Ectoedemia vannifera* (Nepticulidae), *Bucculatrix wittnebeni* (Bucculatricidae), *Parapsectris* sp. (Gelechiidae), and two unknown species of Cosmopterigidae. The dominant species among the *Pyraloidea* was *Epicrosis nigrinella* (Pyralidae: Phycitinae). Together with *Pseudozarba schencki* and *Spodoptera exigua* (Noctuidae) the three species made up 60% (more than 1000 specimens) of the total sample. This combination of species is typical for samples taken in the Nama-Karoo Biome from January to March. Among the rarely collected macro-moth species were *Galtara nepheloptera* (Arctiidae) (see Photo) and *Coenobasis argentilinea* (Limacodidae) (see Photo).

Male of *Galtara nepheloptera*. Photo: J. Deckert.

Responsible author: W. Mey

Vertebrates

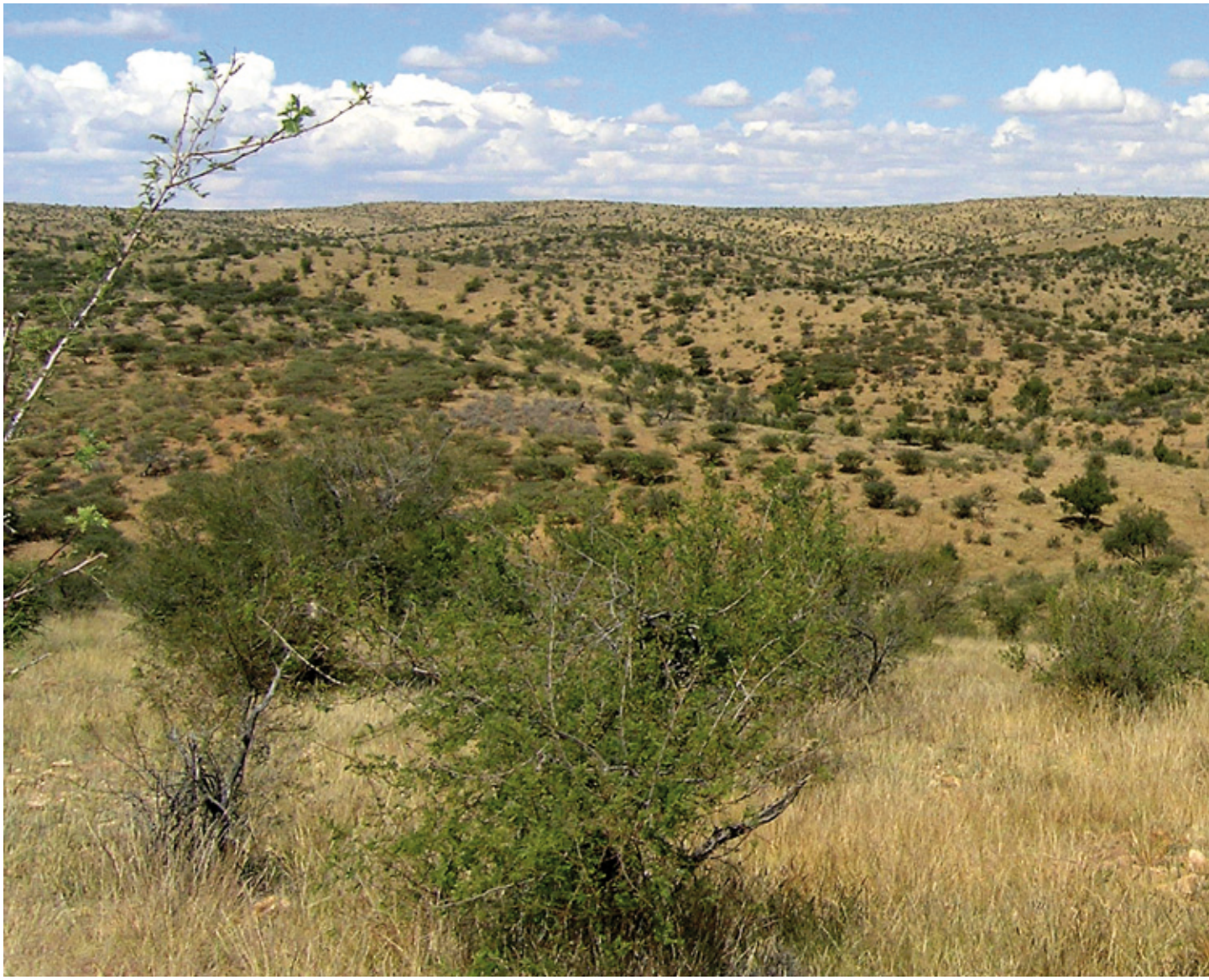
Total species richness	Reptile species richness	Bird species richness
6	n.a.	6
Large mammal species richness	Small mammal species richness	
n.a.	n.a.	

Birds

Passeriformes	**Perching birds**
Mirafra sabota	Sabota Lark
Lanioturdus torquatus	White-tailed Shrike
Dicrurus adsimilis	Fork-tailed Drongo
Serinus albogularis	White-throaded Canary
Cinnyris fuscus	Dusky Sunbird
Piciformes	**Woodpeckers and relatives**
Tricholaema leucomelas	Acacia Pied Barbet

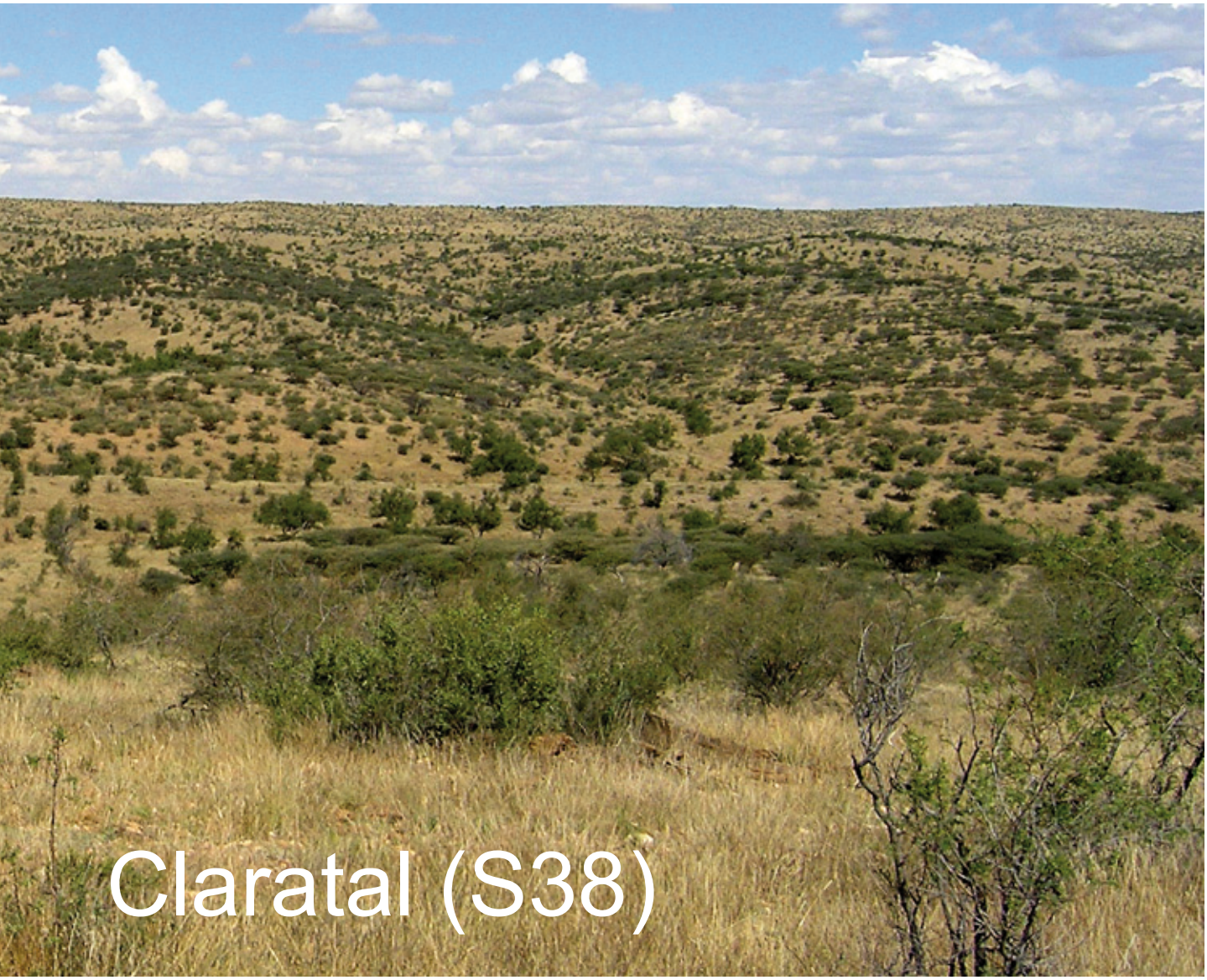
White-throaded Canary (*Serinus albogularis*). Photo: J. Deckert.

Responsible authors: J. Deckert, A. Hoffmann & A. Mills



General data

Number	Name	Alternative name(s)
S38	Claratal	n.a.
Implementation	Country	Province/ region
2004	Namibia	Khomas
District/ constituency	Locality	Farm name
Windhoek	Windhoek	Claratal 18
Latitude	Longitude	Altitude
22.779382 S	16.774852 E	1865 m a.s.l.
Rainfall season	Biome	WWF Ecoregion
Summer	Thornbush Savanna	AT1309 Kalahari xeric savanna
Agro-Ecological Zone	Relative intensity of land use	Tenure
ESC2	Medium	Private
Type and history of landuse	Land owner	
Farming with cattle and game	Private	



Claratal (S38)

The mountainous landscape of the Khomas Hochland at the Claratal Observatory. Photo: C. Grohmann.

The BIOTA Observatory Claratal (S38) is situated ca 40 km south-west of Windhoek in the Khomas region of Namibia, forming part of the upper Kuiseb catchment. This forms part of the mountainous highlands west of Windhoek commonly known as the "Khomas Hochland". The Khomas Hochland was formed by erosion of the mica schists of the Kuiseb formation of the Damara sequence. This very steep landscape has generally shallow soils, which are dominated by an open bushland of Acacia and Combretum trees. The vegetation on the Observatory is a typical example of Highland Savanna sensu Giess (1998). The altitude averages about 1865 m a.s.l., and ranges from 1803 to 1912 m. The area has a typical summer rainfall climate, with an average of 335 mm of precipitation per annum.

Claratal was purchased from Chief Samuel Maherero in 1882 by the trader A. Schmerenbeck. Since 1923 the farm has been managed as a horse stud and for Karakul pelt breeding, and lately as a cattle and game farm combined with horse breeding. The present owner has managed the farm since 1975 (Kellner 1986).

This BIOTA Observatory was established as part of a monitoring programme for the Auas-Oanob Conservancy, into which the farm Claratal falls. Furthermore, it forms an important part of the Kuiseb catchment area, and erosion studies are possible due to the extreme slopes.

Responsible authors:
B. J. Strohbach & D.H. Haarmeyer

Remote sensing and landscape

Geomorphology	Geological units	Lithological units
Slopes, ridge, rivier, drainage line	Khomas Group in Damara Supergroup and Gariep Complex	Schists
Mean EVI	**EVI absolute range**	**Mean leaf area index**
0.164 (0.114–0.271)	0.103 (2007)–0.323 (2006)	0.60

Grid map of Observatory

	0	1	2	3	4	5	6	7	8	9
0	54	20	58	85	13	50	94	43	86	40
1	11	35	31	51	99	98	37	28	88	84
2	45	77	65	8	16	55	89	63	69	19
3	71	59	64	56	22	30	17	70	32	42
4	83	33	24	62	6	60	49	53	47	36
5	91	7	5	90	66	9	96	12	41	87
6	21	72	15	92	68	81	82	75	76	67
7	100	23	39	73	25	18	1	78	29	52
8	80	57	97	48	14	44	38	3	10	46
9	93	2	74	61	4	26	34	95	79	27

1	Drainage line
2	Rivier
3	Ridge
4	North-facing slope
5	South-facing slope
6	East- or west-facing slope

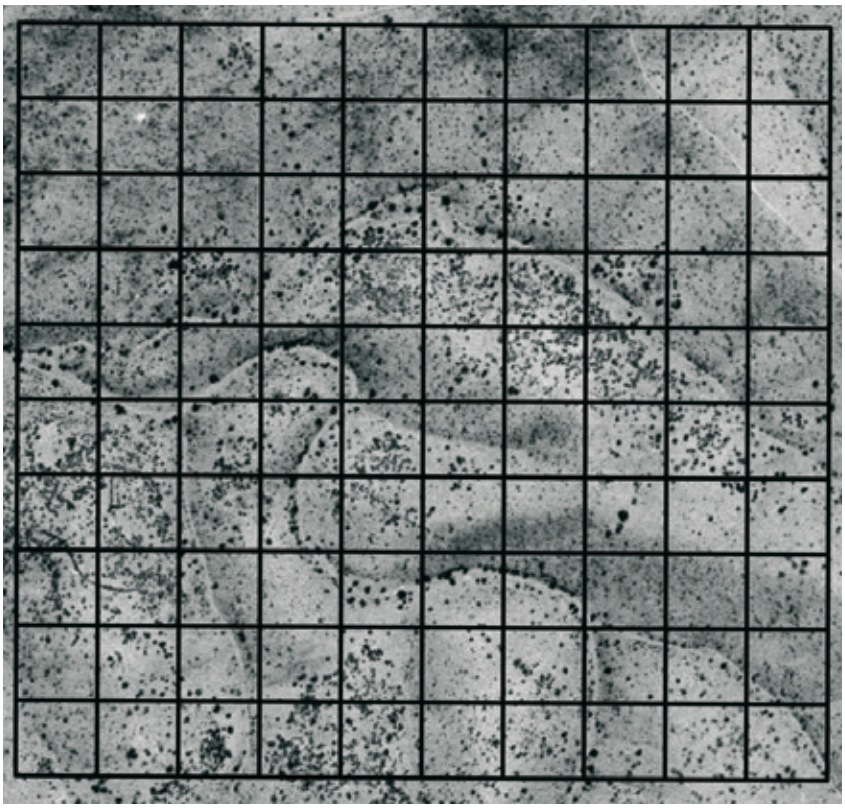
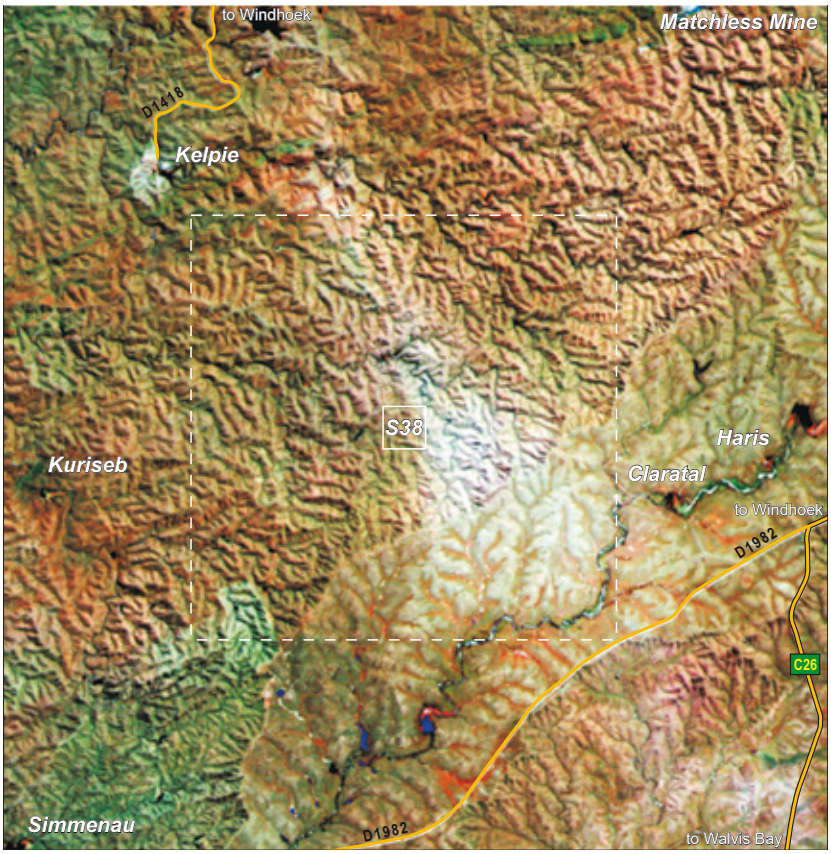


Image: aerial photograph

Landsat image

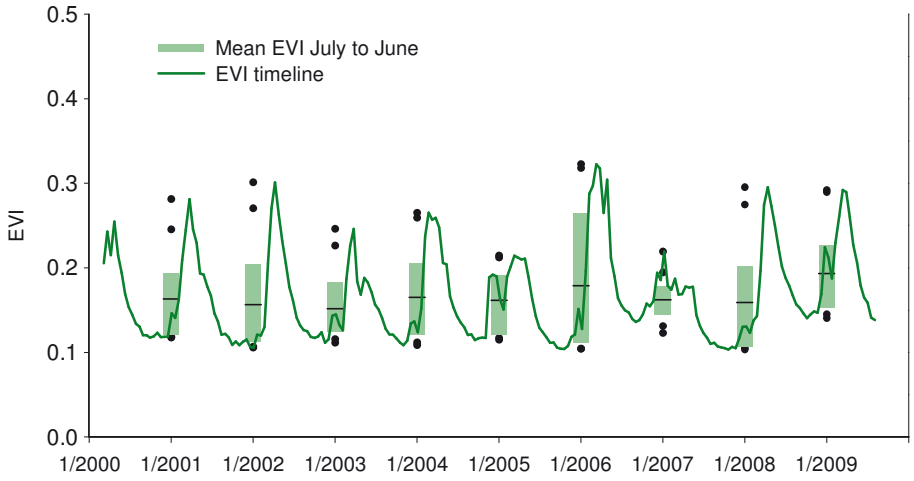
The dissected landscape around the Observatory and in the north-western and central parts of the image is drained westwards to the Kuiseb River. In the south-eastern part of the image, the relief structure indicates another lithologic formation, crossed by a tributary of the Oanob River, draining south-west and south to the Oanob as a part of the Fish River catchment. The vegetation on the Observatory is a typical example of Highland Savanna with a mix of grassy and woody vegetation. Reddish/brown colours indicate higher shrub densities while greenish colours indicate higher grass coverage. The very bright to white colours in the central parts of the image indicate very low vegetation cover in April 2006, during the time of Landsat data acquisition. The black spots in some valleys are lakes and artificial dams.



Scene: 178/76, acquisition date: 24 April 2006

MODIS time series

Temporal patterns of vegetation cover, and phenology



Responsible authors: M. Keil & T. Labitzky

Climate

Data from BIOTA weather station

Location	Recorded period	Mean temperature
Claratal (S38)	2006–2009	18.6 (5.0–40.9) °C
Mean solar radiation	**Mean wind speed**	**Mean annual precipitation**
564 (415–774) MJ·m^{-2}·month^{-1}	2.8 (9.3) m·s^{-1}	387 (151–644) mm
Mean annual potential evapotranspiration	**Interannual precipitation variability**	**Mean relative humidity**
1469 mm	155%	44% (17–85%)
Aridity index (UNEP)		
0.26 (semi-arid)		

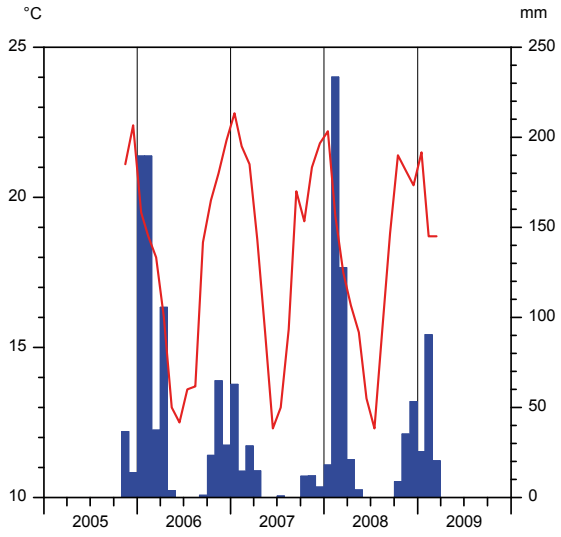
Modelled data

Mean temperature	Mean annual temperature range	Mean diurnal temperature range
17.9 (3.0–30.5) °C	10.1 °C	16.8 °C
Mean annual precipitation	**Precipitation seasonality**	**Percentage winter precipitation**
335 mm	110%	11% (strong summer)
Climate type	**Length of dry season**	**Aridity index (De Martonne)**
BWh	9 months	12.0 (semi-dry)

The climate at the Observatory is characterised by semi-arid conditions. Rainfall shows a strong seasonality with the major portion of rain falling during the summer season, peaking in February. The mean annual rainfall over the observation period was 387 mm, which is wetter than the average rainfall recorded over the entire transect, and makes it the wettest Observatory within the Thornbush Savanna. However, substantial interannual variability is evident. Observed near-surface air temperatures show a moderate seasonal cycle. The mean annual temperature is 18.6°C and is therefore slightly cooler than the mean for this biome. The observed mean minimum temperature is above the freezing point, but there is still a possibility of the occurrence of frost during the months of June to August. Compared to the interpolated long-term data taken from the WorldClim dataset, a slightly warmer mean annual temperature and a substantially warmer minimum temperature is evident at the BIOTA weather station. For precipitation, mean annual rainfall observed at the station is noticeably higher than that of the WorldClim dataset. Additionally, the station data shows a secondary rainfall maximum in early summer that is not evident in the WorldClim dataset.

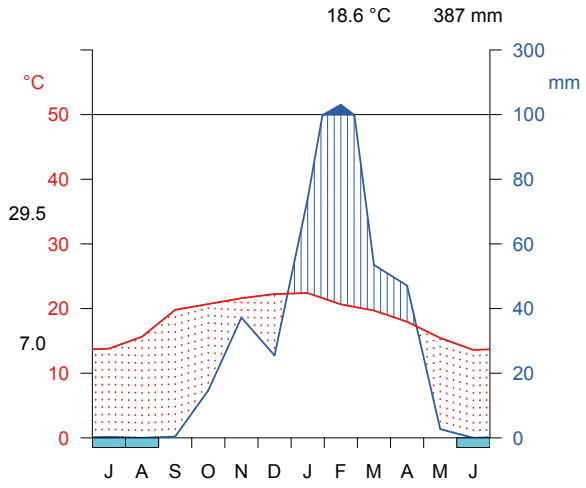
The observed near-surface winds at the Observatory are mainly constituted of north-easterly flows during spring, summer and autumn, and shifts towards an enhanced north-westerly component during the winter period. Mean wind speed is highest during the early afternoons, reaching about 15 km/h. Winds during that time of the day stay fairly constant throughout the year, whereas a weak annual cycle is visible for the mean wind speed recorded during the mornings and evenings.

Time series: rainfall and temperature

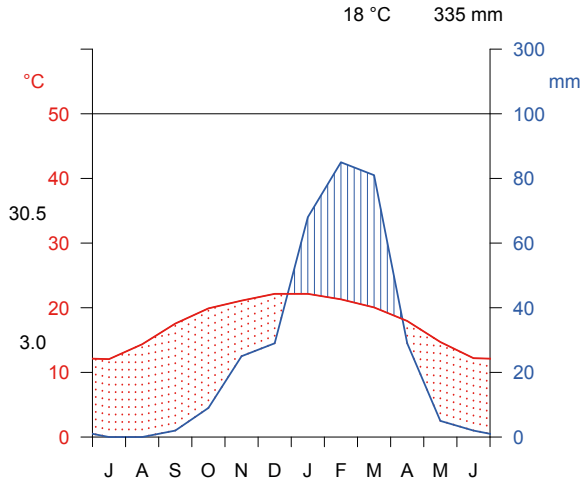


Climate diagrams

Recorded data (BIOTA)

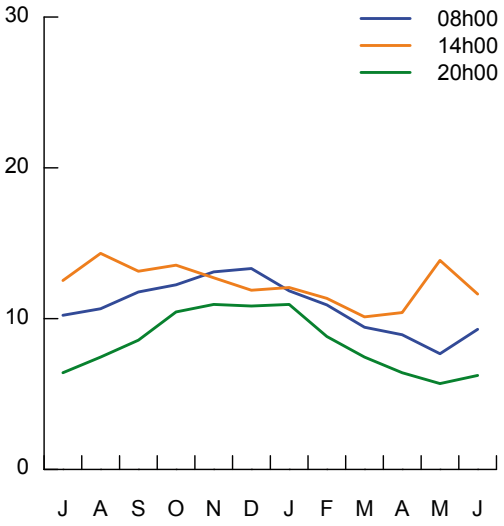


Modelled data (WorldClim)

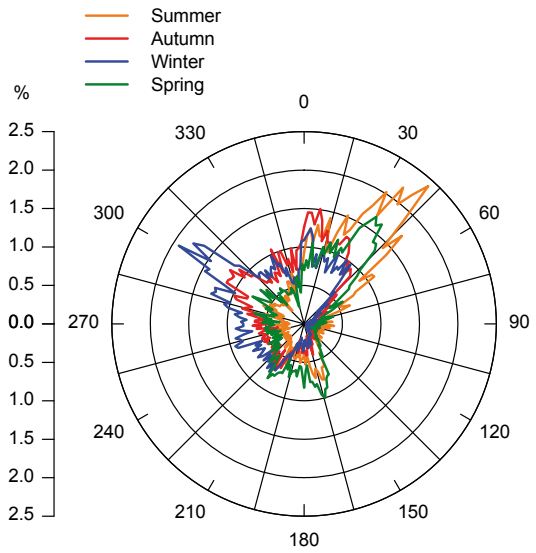


Wind diagrams

Speed



Directions



Responsible authors: K. Berger, A. Haensler & J. Luther-Mosebach

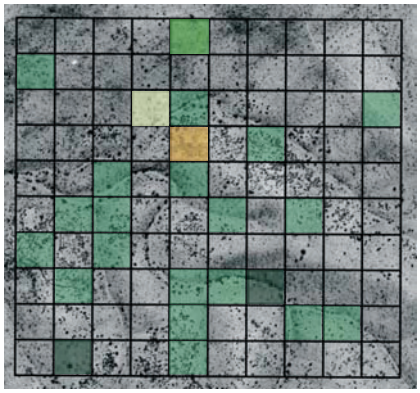
Soils

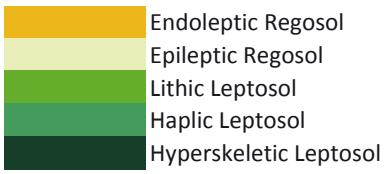
Year of sampling	Hectare plots sampled	SOTER unit
2009	25 (R1–25)	NA2
Soilscape	**Dominant soil group(s)**	**Reference group richness**
Leptosol	Leptosol	2
Soil unit richness	**Soil unit evenness**	**Soil ecotype richness**
9	0.432	n.a.
Parametric space	**pH**	**Electrical conductivity**
n.a.	6.0 (5.0–6.9)	23 (5–51) µS·cm^{-1}
Organic carbon		
1.09% (0.60–2.90%)		

Except for two Regosols, all profiles of this Observatory are Leptosols. Most dominant are the Haplic Leptosols (Eutric, Endoskeletic). These shallow soils reflect the rocky and steep sloping mountainous landscape of mica schist with quartz intrusions resulting in a quite homogenous texture of sandy loam of the weathered schist and a high content of quartz fragments. Due to material translocations and restricted depth, signs of eluviation are missing in all soils. Although rooting space is restricted within the soil by both, the shallow bedrock and the high proportion of rock fragments (median 64% of the volume), there is most likely additional rooting volume within the steeply inclined fissures of the schist.

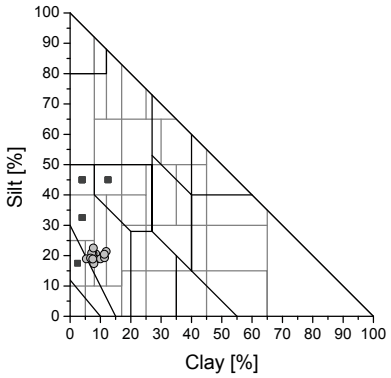
Predominantly, soils are moderately acid and low in electrical conductivity. The variability of both properties is low, due to the uniformity of the substrate and regular leaching. With a median of 1.1%, the contents of organic carbon are exceptionally high. However, if the contents are summarised for the whole soil volume, the total organic carbon enrichment lies within the normal range (see Article III.3.3). With a mean C/N ratio of 9, the composition of the soil organic matter can be characterised as fairly well decomposable. The texture analysis presented low variability with typically 8% clay, 19% silt and 83% sand, of which the dominant share is fine-sand (54% of sand), but also with some coarse sand (16% of sand) occurring.

Map of soil profiles

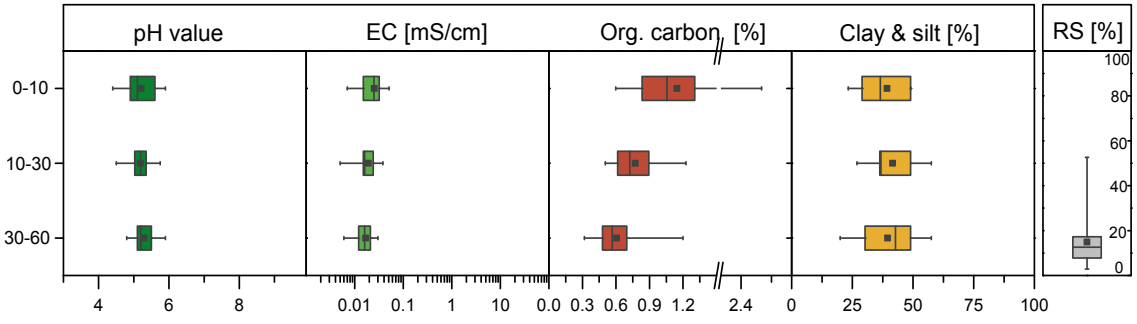




Soil texture triangle



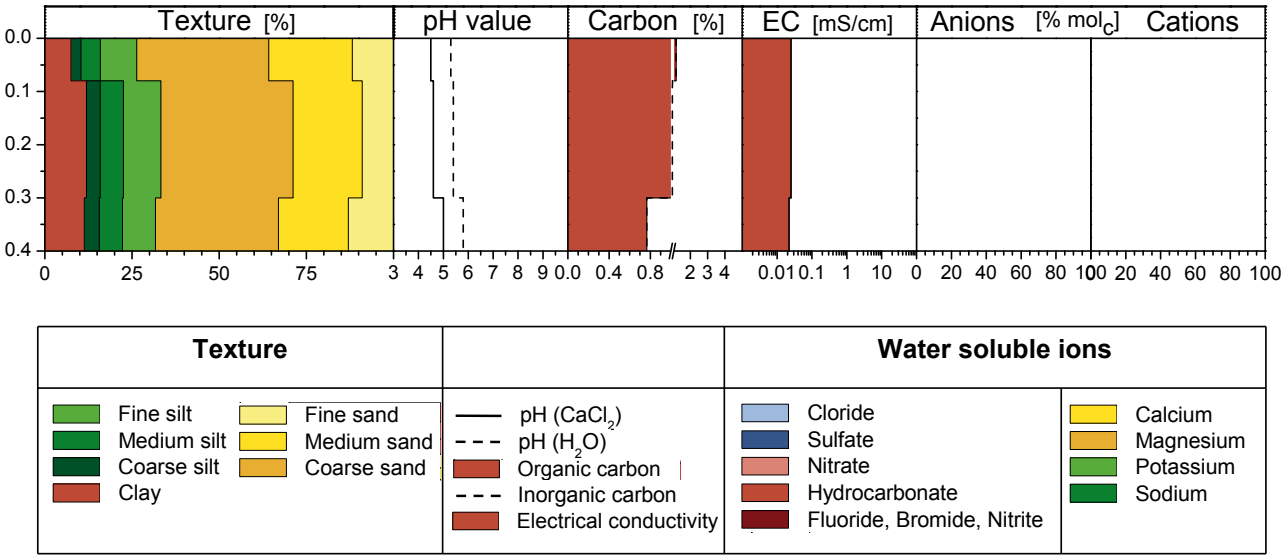
Soil characteristics



Reference profile (H87)

The **Haplic Leptosol (Eutric, Endosceletic)** is the most common soil type of the Observatory. In this profile the schist bedrock starts at 60 cm depth, whereas in many other profiles of the Observatory the mica schist is much shallower. The content of rock fragments in 30 to 60 cm depth is very high, with over 80% by weight. The soil is covered with 50% coarse gravel. It is positioned on a backslope with a relatively steep slope angle of 21%. The texture is dominated by sand, mainly fine sand, originated from the weathered schist.

Electrical conductivity is low (25 µS cm^{-1}) and the pH values are moderately low. The contents of organic carbon are high, ranging from 1.2 to 0.8% (see above). The content of rock fragments, mainly consisting of quartz, increases from 66% by weight in the topsoil to 81% in 60 cm depth, with moderate excavation difficulty. Rooting is moderate with 11–20 roots dm^{-2}.



Responsible authors: U. Wisch, A. Petersen, A. Gröngröft & D. Mager

Lichens

Sampling period(s)	Hectare plots sampled	Cover
2005	10 (R1−R10)	0%
Total species richness	**Species richness on soil [1 km²]**	**Species richness on rock [1 km²]**
14	0	14 (100%)
Species richness on plants [1 km²]	**Species richness on soil [1000 cm²]**	
n.a.	0	

In spite of the potentially favourable climatic conditions (high average rainfall), this high altitude Observatory is poor in terricolous and epiphytic species but does host several saxicolous species. Many of the lichens occurring on rock have cyanobacterial photobionts.

Terricolous lichens are absent in the surveyed hectare plots of this Observatory, probably due to relatively high soil acidity, and the high cover of pebbles and stones.

List of Taxa

Terricolous (on soil):

No records

Saxicolous (on rock):

Acarospora sp.
Caloplaca sp.
Lecanora sp.
Lecidea sp.
Lichenothelia sp.
Lichinella stipatula
Peccania sp.
Peltula cf. omphaliza
Peltula obscurans var. hassei
Peltula obscurans var. obscurans
Phloeopeccania sp.
Psorotichia hassei
Psorotichia sp.
Xanthoparmelia sp.

Epiphytic (on plants):

No records

Peltula omphaliza. Photo: M. Schultz, L. Zedda & G. Rambold.

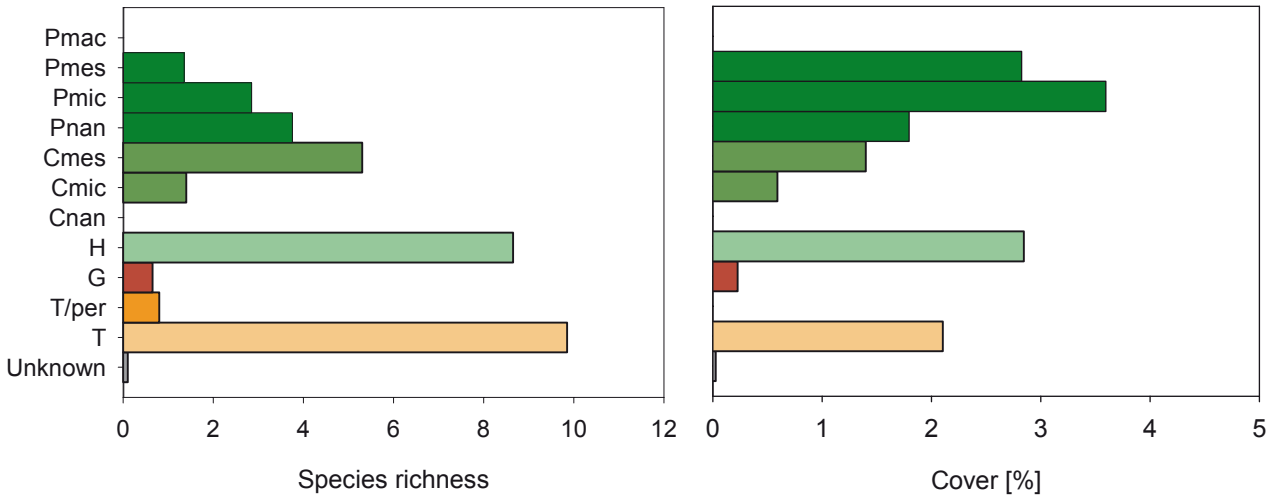
Caloplaca sp. Photo: M. Schultz, L. Zedda & G. Rambold.

Responsible authors: L. Zedda & G. Rambold

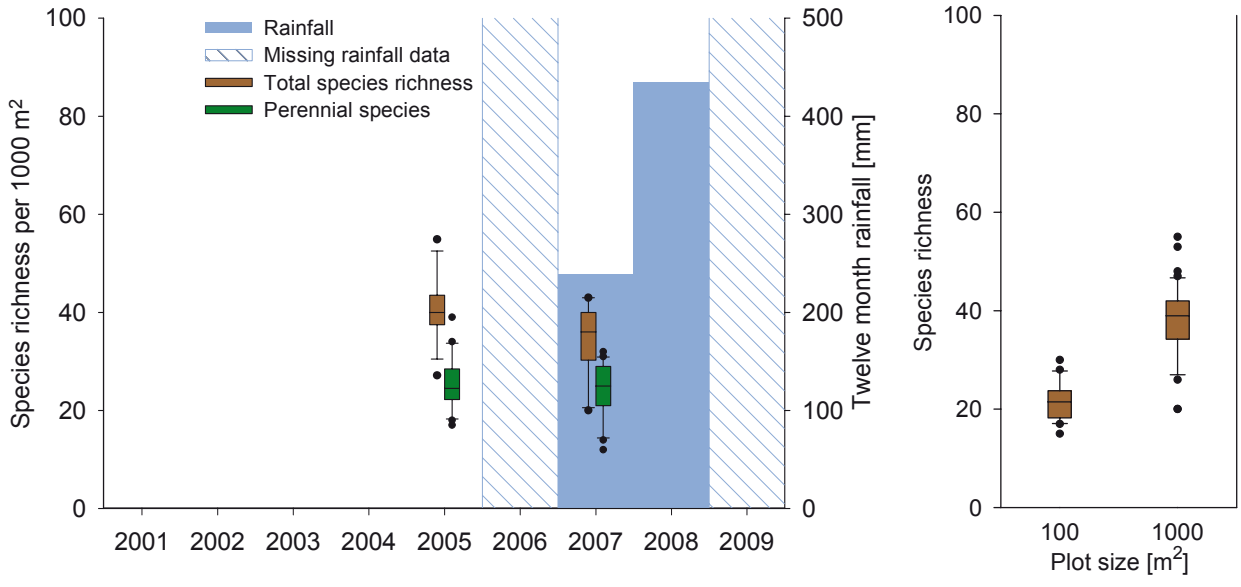
Vascular plants

Sampling period(s)	Hectare plots sampled	Biome
2005, 2007, 2009	20 (R1–R20)	Thornbush Savanna
Vegetation unit (level 1)	**Vegetation unit (level 2)**	**Identification rate**
Highland Savanna	n.a.	98% – 98% – 99%
Cumulative family richness	**Dominant families (cover)**	**Dominant families (richness)**
47	Poaceae, Fabaceae, Asteraceae	Poaceae, Fabaceae, Asteraceae
Cumulative species richness (1 km²)	**Species richness (1000 m²)**	**Species richness (100 m²)**
205 – 115	37.8 (20–55)	21.6 (15–30)
***z*-value**	**Species richness change per year (1000 m²)**	**Evenness (1000 m²)**
0.243 (0.115–0.382)	n.a.	0.778 (0.516–0.969)
Evenness (100 m²)	**Simpson (1000 m²)**	**Simpson (100 m²)**
0.722 (0.554–0.864)	0.899 (0.669–0.964)	0.811 (0.636–0.904)

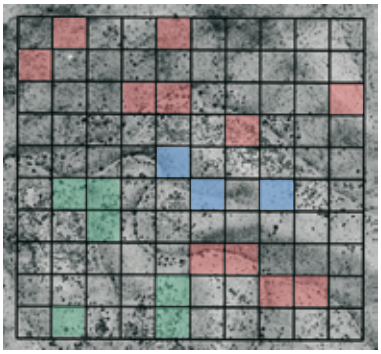
Life forms



Species richness



Map of vegetation units



The Claratal Observatory (S38) is situated in the steeply dissected mountainous highlands of the Khomas Hochland. Two main habitats occur here: the steep, shallow-soiled hill slopes, and the valley-bottoms with small rivers, which are fed by the run-off from the slopes. The relatively reliable ground water at the valley-bottoms makes it possible for larger trees and associated shade vegetation to grow along the river banks. This area falls within the Highland Savanna sensu Giess (1998). The mountain slopes are dominated by various *Acacia* species, which are adapted to these shallow soils and steep inclines, particularly *Acacia hereroensis* (Mountain Thorn). The vegetation on the slopes is fairly uniformly dense, as indicated by the relatively high Simpson's index and the high species eveness. An interesting feature here is that the aspect of the slopes has no influence on the species composition—rather the depth of the soil and the occurrence of rocky ledges and outcrops are of high importance in determining species composition (Kellner 1986).

The *Acacia hereroensis-Brachiaria nigropedata* community (unit 1) is widespread in the Khomas Hochland on sloping hills and mountainsides, and is also the most widespread community at the Claratal Observatory. The dominant shrub is the mountain thorn *Acacia hereroensis*, in association with *Rhus marlothii* (Bitter Karee), *Acacia mellifera* subsp. *detinens* (swarthaak) and *A. reficiens* (Rooihaak). Smaller shrubs typical of this community are *Lantana dinteri* and to a lesser extent *L. angolensis*. Shrubs and small

Classification table (2005)

Column		Cover	All	1	2	3
Number of relevés			**20**	**11**	**3**	**6**
Mean cover [%]			18.0	17.9	16.7	18.9
Mean species richness (1000 m²)			44.3	49.1	38.3	38.3
Unit 1: Acacia hereroensis-Brachiaria nigropedata community						
H	Brachiaria nigropedata	0.30	60	100	.	17
H	Aristida meridionalis	0.18	55	91	.	17
T	Cleome rubella	0.19	60	91	.	33
T	Nidorella resedifolia	0.05	30	55	.	.
H	Heteropogon contortus	0.18	30	55	.	.
Pmes	Acacia hereroensis	1.27	75	100	.	67
n.a.	Eragrostis scopelophila	0.46	60	91	33	17
Unit 2: Acacia mellifera-Eragrostis nindensis community						
T	Pupalia lappacea	0.30	25	9	100	17
H	Aristida effusa	0.17	30	9	100	33
H	Geigeria ornativa	0.16	40	45	100	.
H	Oropetium capense	n.a.	15	9	67	.
Cmes	Leucas pechuelii	0.17	15	.	67	17
Unit 3: Acacia karroo-Cynodon dactylon community						
Cmic	Limeum myosotis	0.08	40	27	.	83
Pmic	Acacia karroo	0.40	25	9	.	67
Most frequent companions						
T	Aristida adscensionis	n.a.	100	100	100	100
T	Pogonarthria fleckii	0.55	95	100	67	100
H	Aptosimum angustifolium	0.22	95	91	100	100
T	Melinis repens ssp. grandiflora	0.53	90	100	33	100
T	Eragrostis nindensis	0.28	90	91	67	100
T	Kyphocarpa angustifolia	0.17	90	91	67	100
Cmes	Otoptera burchellii	0.14	90	91	67	100
T	Enneapogon cenchroides	0.39	85	82	67	100
H	Anthephora pubescens	0.06	85	91	67	83
Pmes	Ziziphus mucronata	0.74	80	73	100	83
Pmes	Rhus marlothii	0.42	80	91	67	67
H	Stipagrostis uniplumis var. uniplumis	0.06	75	64	67	100
Pmic	Acacia mellifera ssp. detinens	2.00	70	45	100	100
Cmes	Solanum dinteri	0.30	70	82	33	67
H	Achyranthes aspera var. sicula	0.24	70	64	100	67
Pnan	Antizoma angustifolia	1.43	65	82	.	67
H	Eragrostis lehmanniana	0.75	65	64	100	50
G	Cenchrus ciliaris	0.64	65	55	67	83
G	Talinum arnotii	0.08	65	82	67	33
H	Monelytrum luederitzianum	0.51	60	73	33	50
H	Dicoma capensis	0.20	55	36	100	67
Pmes	Acacia reficiens	1.79	50	45	100	33
Cmes	Lycium bosciifolium	0.42	50	36	33	83
H	Pergularia daemia	0.31	50	64	33	33
Cmic	Dicoma schinzii	0.30	50	45	.	83
n.a.	Blepharis integrifolia var. integrifolia	0.26	50	64	67	17
T	Hermannia modesta	0.22	50	36	67	67
Cmes	Monechma divaricatum	0.34	40	36	33	50
H	Fingerhuthia africana	0.33	40	36	67	33
Cmes	Blepharis mitrata	0.20	40	36	33	50
H	Schmidtia pappophoroides	0.03	40	45	.	50
G	Raphionacme velutina	1.90	35	36	33	33
Pnan	Asparagus nelsii	0.51	35	36	67	17
n.a.	Aizoon virgatum	0.37	35	45	.	33
n.a.	Hirpicium gazanioides	0.20	35	27	33	50
T	Vernonia poskeana ssp. botswanica	0.02	35	45	.	33

continued on next page

Unit 1, 2005. Photo: B. Strohbach.

Unit 2, 2005. Photo: B. Strohbach.

Unit 3, 2005. Photo: B. Strohbach.

trees of *Combretum apiculatum* subsp. *apiculatum* (Kudubush) are often limited to rocky outcrops. The shrub cover is on average 12% (Strohbach, in prep.). The grass sward is well developed, contributing 22% to the overall cover. It is dominated by the perennial grasses *Stipagrostis uniplunis* var. *uniplumis* (Bushman Grass), *Eragrostis nindensis* (Agtdae Pluimgrass), *Monelytrum luederitzianum* (Lüderitz Grass), *Aristida meridionalis* (Giant Bristle-grass), *Anthephora pubescens* (Wool Grass), *Brachiaria nigropedata* (Swartvoetjie), and *Heteropogon contortus* (Spear Grass). The mountain love-grass *Eragrostis scopelophylla* is an indicator of the very rocky, shallow habitats occurring on the Observatory. Common annual grasses are *Enneapogon cenchroides* (Common Nine-awned Grass), *Aristida adscensionis* (Annual Bristle-grass), and *Melinis repens* subsp. *grandiflora* (Red Top). An interesting feature of this community is the relatively common occurrence of ferns, particularly *Pellaea calomelanos, Cheilanthes marlothii*, and to a lesser extent *C. dinteri*. These generally grow below rocky ledges in semi-shade conditions, with run-off from the rocks creating a relatively moist micro-habitat.

The *Acacia mellifera-Eragrostis nindensis* community (unit 2) is a degraded, heavily bush encroached derivative of the *Acacia hereroensis-Brachiaria nigropedata* association. It is often associated with the lower slopes in the Khomas Hochland, possibly because a fair amount of soil deposition and/or erosion has taken place in these areas over centuries. The possible influence of selective grazing in these areas should also not be disregarded. Being a degraded area, most perennial grasses have vanished, and have been replaced with a mix of annual grasses and herbs, which are often ephemeral species. The shrub layer is dominated by the Common Blackthorn *Acacia mellifera* subsp. *detinens*, with a multitude of other woody species also encroaching, e.g. *Acacia reficiens, A. erubescens* (Yellow-bark Acacia), *A. hebeclada* subsp. *hebeclada* (Candlepod Acacia) and *Ziziphus mucronata* (Buffalo Thorn). The degraded state is further emphasised by the dominance of the annuals *Aristida adscensions, A. effusa* (Loose Bristle-grass), *Pupalia lappaceae* and *Geigeria ornativa* (Vermeerbos). *Pupalia lappaceae* is a weedy exotic, spreading via a burr-coated seed, whilst *Geigeria ornativa* is a poisonous species. The common occurrence of *Cyperus fulgens* (Uintjie), which possesses a corm that is sought after by guinea fowl, is notable. Large patches of soil are often scratched up by these birds in the quest for these succulent corms.

The *Acacia karroo-Cynodon dactylon* community (unit 3) forms the riverine thickets along the banks of ephemeral rivers and larger washes on the Observatory. The relatively high moisture content of the soils here enable the establishment of large *Acacia karroo* (Sweet Thorn) trees, and a host of other woody species, e.g. *Acacia mellifera* subsp. *detinens*, *Ziziphus mucronata, Lycium bosciifolium* (Wolfdoring) and *Rhus marlothii*. Scattered large *Acacia reficiens, A. erioloba* and *Rhus lancea* (Karee) trees also occur within this community. The grass sward consists of a mixture of species from all other nearby communities, as seeds are blown or washed into this habitat and established in the favourable moist conditions. *Cynodon dactylon* is typically found along larger ephemeral rivers in the area (Kellner 1986, Strohbach, in prep.), but has not been observed at the Observatory.

Classification table (continued)

Column		Cover	All	1	2	3
Number of relevés			**20**	**11**	**3**	**6**
G	Ipomoea bolusiana	0.70	30	18	67	33
H	Microchloa caffra	0.55	30	27	33	33
Cmes	Ehretia rigida	0.50	30	18	67	33
H	Phyllanthus maderaspatensis	0.32	30	45	.	17
n.a.	Lantana dinteri	0.30	30	45	33	.
n.a.	Indigastrum parviflorum	0.29	30	36	.	33
T	Tephrosia dregeana	0.24	30	36	67	.
Cmes	Pollichia campestris	0.16	30	27	33	33
n.a.	Trichoneura grandiglumis	0.12	30	45	.	17
Cnan	Aptosimum spinescens	0.73	25	27	33	17
Pmic	Grewia flava	0.29	25	27	33	17
T	Gisekia africana	0.13	25	18	33	33
T	Pegolettia senegalensis	0.12	25	.	67	50
T	Tribulus zeyheri	0.12	25	27	67	.
Cmic	Leucosphaera bainesii	0.66	20	.	67	33
H	Eragrostis echinochloidea	0.53	20	27	33	.
n.a.	Emilia marlothiana	0.52	20	9	.	50
Pnan	Albizia anthelmintica	0.37	20	.	33	50
H	Tephrosia burchellii	0.33	20	36	.	.
G	Cyperus fulgens	0.29	20	9	67	17
Pnan	Solanum lichtensteinii	0.25	20	27	33	.
H	Bidens biternata	0.03	20	27	.	17
T	Tragus berteronianus	0.03	20	9	67	17
Cmes	Pentzia calva	0.03	20	27	.	17
G	Cucumis sagittatus	1.00	15	18	33	.
H	Chascanum pinnatifidum	0.63	15	18	.	17
n.a.	Cucumis sp. 22314	0.50	15	9	.	33
H	Kyllinga alba	0.37	15	27	.	.
Cmes	Pavonia burchellii	0.34	15	9	.	33
H	Ocimum americanum var. americanum	0.20	15	18	.	17
H	Xerophyta humilis	0.17	15	18	33	.
H	Kohautia cynanchica	0.13	15	18	.	17
Cmes	Acrotome inflata	0.10	15	18	.	17
n.a.	Nolletia tenuifolia	0.05	15	18	.	17
n.a.	Eragrostis superba	0.05	15	18	.	17
n.a.	Cheilanthes marlothii	n.a.	15	27	.	.

Responsible authors: B.J. Strohbach & J. Luther-Mosebach

Termites

Taxon richness	Abundance index	Dominant (sub-)family
0	1	n.a. (not identified worker)

Termites were encountered on only one occasion during hand collection in 2005. Unfortunately, no soldiers were collected, which means that the specimens could not be identified. Presumably, termites are rare at this Observatory as the soil over large areas is too rocky to enable termite colonies to build nests.

Responsible authors: C. Grohmann & K.E. Linsenmair

True bugs

Sampling period(s)	Methods	Family richness
2007/I; 2008/IV	Trapping (light), net sweeping, beating of plants, hand collecting	14
Species richness	**Individuals sampled**	**Fisher's alpha diversity**
37	204	13.21

Most of the 37 species collected at Claratal Observatory (S38) belong to Miridae (38%), Pentatomidae (14%), and Lygaeidae (11%). *Paromius gracilis* (Rhyparochromidae) and *Camptocoris rostratus* (Lygaeidae) were the only species that were collected not only at light traps, but also using net sweeping or hand collecting. *Paromius gracilis* feeds on grasses in the tropical and subtropical parts of the Old World. *Camptocoris rostratus* is endemic to southern Africa and is widely distributed in Namibia.

Other species recorded either at light traps or by hand collecting were *Dicranocephalus pseudotestaceus* (Stenocephalidae) (27%), *Oncylocotis nasutus* (Enicocephalidae) (22%) and *Paromius gracilis* (Rhyparochromidae) (7%).

Species abundances

Light traps

Species	Family	*N*	%
Dicranocephalus pseudotestaceus	Stenocephalidae	11	27
Oncylocotis nasutus	Enicocephalidae	9	22
Paromius gracilis	Rhyparochromidae	3	7
Others (12)		18	44
Total		**41**	**100**

Species richness in families

Family	*S*
Miridae	14
Pentatomidae	5
Lygaeidae	4
Coreidae	3
Rhyparochromidae	2
Alydidae	1
Berytidae	1
Enicocephalidae	1
Geocoridae	1
Micronectidae	1
Nabidae	1
Reduviidae	1
Rhopalidae	1
Stenocephalidae	1
Total	**37**

Responsible author: J. Deckert

Butterflies and moths

Sampling period(s)	Number of samples (moths)	Species richness (total)
2007/I; 2008/IV	2	227
Species richness (butterflies)	**Species richness (all moths)**	**Species richness (Microlepidoptera)**
10	217	79
Species richness (Pyraloidea)	**Species richness (Macrolepidoptera)**	**Species richness (Noctuidae)**
44	31	63
Individuals sampled (moths)	**Fisher's alpha diversity (moths)**	
1334	73.5	

Butterflies

A low number of butterflies were observed at this Observatory as the sampling visits unfortunately occurred during unfavourable weather conditions. The list of recorded species is therefore only a fragment of the resident fauna, which should have a similar diversity to Observatories S04 and S05, as they are all situated in the same Biome. All observed species are common and widespread elements in Namibia, with the exception of *Pontia helice helice* (see photo), which is at the edge of its northernmost distribution (Henning et al. 1997). A transect analysis was performed only once.

Transect analysis of butterflies

Sampling period: 23 April 2008.
Description of transect: The 1000 m transect starts at the north-east corner of the Observatory and crosses the Observatory along a small pathway. The starting point of the transect is at 22.4644 S, 16.4651 E and the endpoint is at 22.4708 S, 16.4715 E.
Species richness: 10; **number of individuals:** 33

Abundance

Species	*N*	Proportion
Danaus chrysippus	16	48.5%
Coeliades forestan	5	15.2%
Colotis regina	4	12.1%
Pinacopteryx eriphia eriphia	3	9.1%

Moths

The diversity of moths is comparable to the results from the other Observatories in the Thornbush Savanna (S04, S05). Samples obtained in January and April differ considerably in species diversity and abundance. This was due to the arrival of a cold front in April. Temperatures dropped below 10°C during the night and the flight activity of moths stopped. The low numbers of Microlepidoptera was a clear indication of the unfavourable conditions in April 2008.

The sample from January 2007 contained an abundance of a *Ceratophaga* species (Tineidae). The caterpillars of *Ceratophaga* spp. feed on the horns and claws of dead mammals, especially antelope. The farm Claratal has large numbers of Kudu, Gemsbok, Zebra, and other antelope species, which may provide this special kind of food in large quantities. The family Gelechiidae is well represented and contains at least three common species of *Athrips*, which have long flight periods. Among the Noctuidae, the assemblage is characterised by the occurrence of several species of *Ozarba* spp. and *Eublemma* spp., with *E. anachoresis* being dominant. Among macro-moths, the day-flying *Utetheisa pulchella* (Arctiidae) (see photo) also appeared in the light-traps.

Butterfly species and main food plants

Hesperiidae
Coeliades forestan — Parinari (Chrysobalanaceae), Combretum (Combretaceae), Solanum (Solanaceae)

Lycaenidae
Leptotes pirithous pirithous — Plumbago (Plumbaginaceae), Indigofera (Fabaceae), Burkea (Caesalpiniaceae)

Nymphalidae
Danaus chrysippus aegyptius — Asclepias, Stapelia, Cynanchum (Asclepiadaceae)
Junonia hierta cebrene — Asystasia, Adhatoda, Barleria, Ruellia (Acanthaceae)

Papilionidae
Papilio demodocus demodocus — Citrus, Clausena (Rutaceae)

Pieridae
Catopsilia florella — Senna (Caesalpiniaceae)
Pinacopteryx eriphia eriphia — Boscia, Maerua (Capparaceae)
Colotis regina — Boscia, Capparis (Capparaceae)
Pontia helice helice — Heliophila, Lobularia (Cruciferae), Rheseda (Rhesedaceae)
Belenois aurota aurota — Boscia, Capparis, Maerua (Capparaceae)

Taxonomic spectrum of moths

Collection period: I/2007

Family	S	N
Adelidae	1	1
Opostegidae	1	1
Nepticulidae	1	2
Tischeriidae	2	10
Tineidae	11	120
Eriocottidae	3	13
Psychidae	2	6
Bucculatricidae	3	16
Gracillariidae	2	2
Yponomeutidae	1	1
Scythrididae	11	28
Elachistidae	1	2
Oecophoridae	1	35
Chrysopeleidae	6	40
Cosmopterigidae	1	2
Gelechiidae	29	114
Gelechiidae, indet.		19
Tortricidae	1	1
Pterophoridae	1	1
Alucitidae	1	15
Microlepidoptera	**79**	**429**
Pyralidae: Phycitinae	29	95
Pyralidae: Epipaschiina(	1	2
Pyralidae: Galleriinae	1	6
Pyralidae: Pyralinae	2	14
Pyralidae, indet.		4
Crambidae	11	60
Pyraloidea	**44**	**181**
Cossidae	2	3
Limacodidae	3	12
Lasiocampidae	2	19
Sphingidae	1	2
Geometridae	16	49
Arctiidae	3	3
Notodontidae	1	6
Lymantriidae	3	3
Noctuidae	63	611
Noctuidae, indet.		16
Macrolepidoptera	**94**	**724**
Total	**217**	**1334**

Male of *Pontia helice helice*. Photo: W. Mey.

Female of *Utetheisa pulchella*. Photo: J. Deckert.

Responsible author: W. Mey

Vertebrates

Total species richness	Reptile species richness	Bird species richness
12	n.a.	12
Large mammal species richness	Small mammal species richness	
n.a.	n.a.	

Birds

Passeriformes	**Perching birds**
Achaetops pycnopygius	Rockrunner/Damara Rockjumper
Anthoscopus minutus	Cape Penduline-Tit
Lamprotornis nitens	Cape Glossy Starling
Laniarius atrococcineus	Crimson-breasted Gonolek
Lanioturdus torquatus	White-tailed Shrike
Mirafra sabota	Sabota Lark (incl. Bradfield's)
Parisoma subcaeruleum	Chestnut-vented Tit-Babbler
Sporopipes squamifrons	Scaly-fronted Weaver
Columbiformes	**Doves and pigeons**
Columba guinea	Speckled Pigeon
Streptopelia capicola	Ring-necked Dove
Oena capensis	Namaqua Dove
Coraciiformes	**Kingfishers and relatives**
Tockus monteiri	Monteiro's Hornbill
Piciformes	**Woodpeckers and relatives**
Tricholaema leucomelas	Acacia Pied Barbet
Gruiformes	**Cranes, rails, coots, and allies**
Eupodotis ruficrista	Red Crested Korhaan

Responsible authors: J. Deckert, A. Hoffmann & A. Mills

General data

Number	Name	Alternative name(s)
S41	Sandveld	n.a.
Implementation	**Country**	**Province/ region**
2004	Namibia	Omaheke
District/ constituency	**Locality**	**Farm name**
Gobabis	near Drimiopsis	Dipcadi 389
Latitude	**Longitude**	**Altitude**
22.043351 S	19.133903 E	1523 m a.s.l.
Rainfall season	**Biome**	**WWF Ecoregion**
Summer	Thornbush Savanna	AT1309 Kalahari xeric savanna
Agro-Ecological Zone	**Relative intensity of land use**	**Tenure**
KAL3-4	Medium	State
Type and history of landuse	**Land owner**	
Experimental farming with cattle	MAWF	

Sandveld (S41)

Camelthorn trees dominate the landscape at Sandveld Observatory. Photo: J. Deckert.

The BIOTA Observatory Sandveld (S41) is situated ca. 60 km north-east of Gobabis in the Omaheke region of Namibia. It falls within the extensive sand plateau of the Central Kalahari. Similar to other sites in the Kalahari, the deep sandy soils are occasionally replaced by more fertile, loamy soils. The deep sands support open to moderately closed bushlands, whilst the heavier soils often support a dense thornbush thicket. Some shallow soils on calcrete are also present. The vegetation on the Sandveld Observatory is a typical example of the Camelthorn savanna of the Central Kalahari sensu Giess (1998). The average altitude is about 1523 m a.s.l. There is a typical summer rainfall climate, with an average annual rainfall of 397 mm. The Sandveld Research Station belongs to the Ministry of Agriculture, Water and Forestry, and has been used for livestock research since 1968. A long-term grazing intensity trial has been running on the farm since 1984. The veld is grazed by various herds of small-, medium-, and large-framed cattle.

This Observatory was established to monitor potential variation of climate-change impacts within the Camelthorn savanna, especially regarding the predicted mobilisation of Kalahari dune systems due to global climate change (Thomas et al. 2005). This has been done in comparison with the observatories Mile 46 (S01), Mutompo (S02), Sonop (S03) and Alpha (S17).

Responsible authors:
B.J. Strohbach & D.H. Haarmeyer

Remote sensing and landscape

Geomorphology	Geological units	Lithological units
Sandy plain	Kalahari and Namib Sands of Kalahari Group	Sands and calcrete
Mean EVI	**EVI absolute range**	**Mean leaf area index**
0.166 (0.116–0.257)	0.106 (2002)–0.340 (2008)	0.65

Grid map of Observatory

	0	1	2	3	4	5	6	7	8	9
0	97	38	81	19	88	64	22	16	55	58
1	74	8	4	93	35	56	65	66	57	99
2	24	21	29	1	77	76	68	37	53	43
3	41	95	31	48	50	54	7	3	47	91
4	85	18	15	69	44	83	10	61	17	79
5	87	89	73	23	14	12	52	26	33	28
6	63	71	67	60	34	80	45	100	62	32
7	72	2	92	49	51	11	94	98	96	39
8	70	42	82	9	25	5	78	86	84	6
9	75	90	36	30	46	20	59	40	27	13

1 *Terminalia sericea*-dominated bushland
2 *Acacia erioloba*-dominated bushland
3 *Acacia erioloba* and *A. mellifera*-dominated bushland
4 *Grewia flava* and *Tarchonathus camphorathus*-dominated bushland
5 *Acaia mellifera*-dominated shrubland

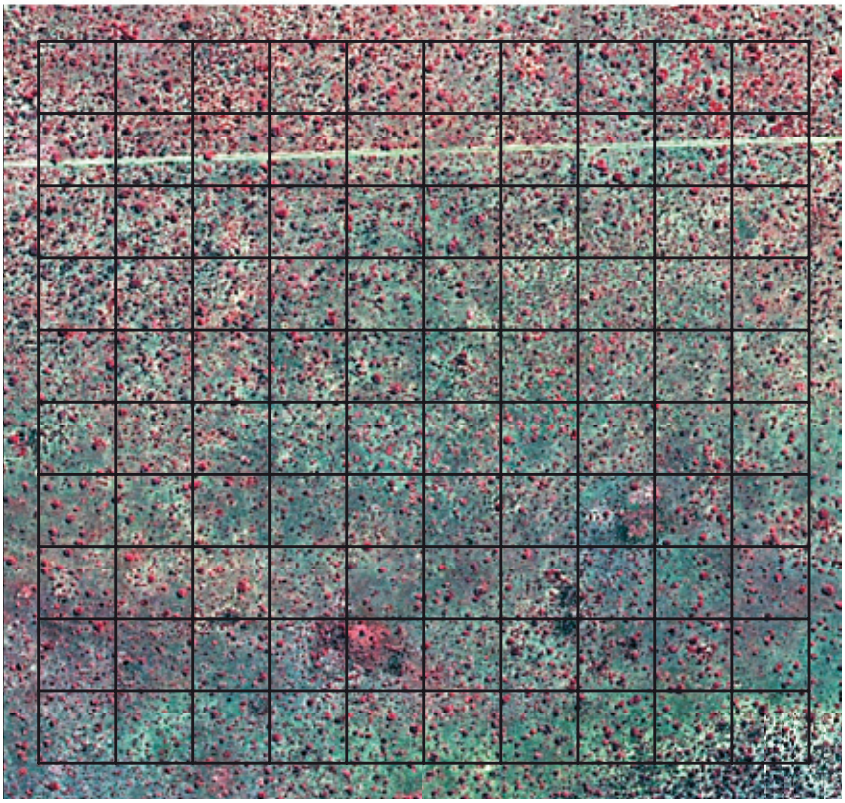
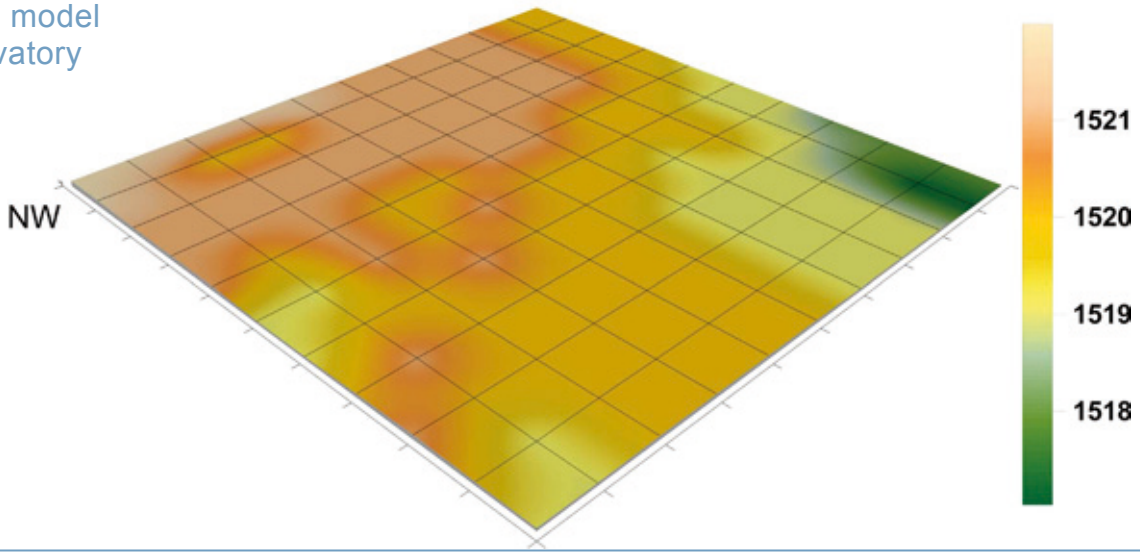


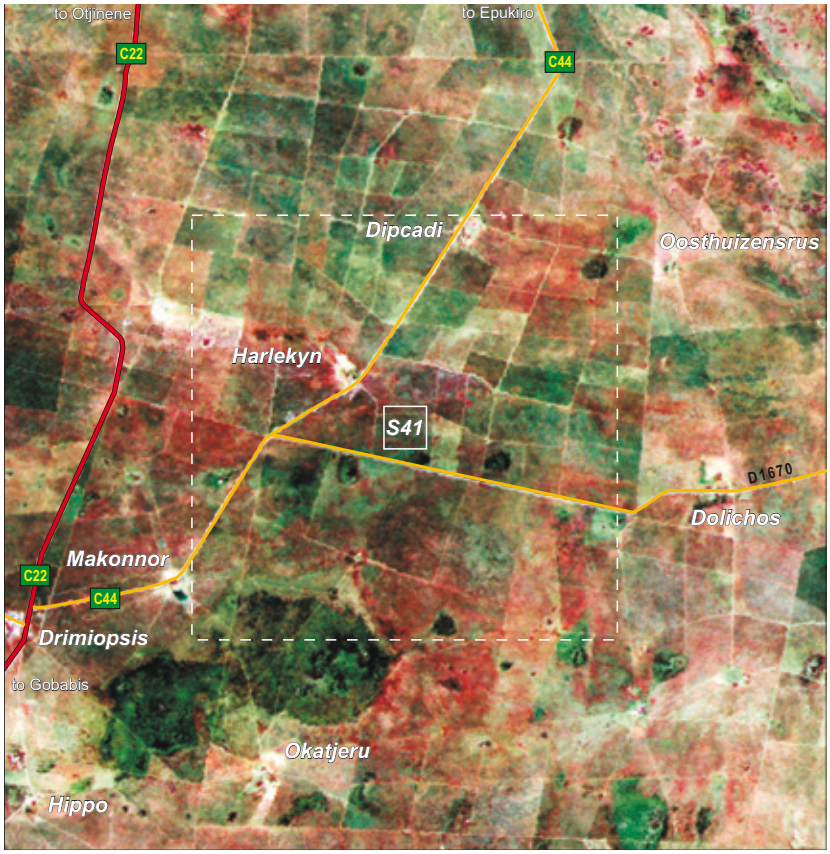
Image: IKONOS, 29 March 2008

Elevation model of Observatory



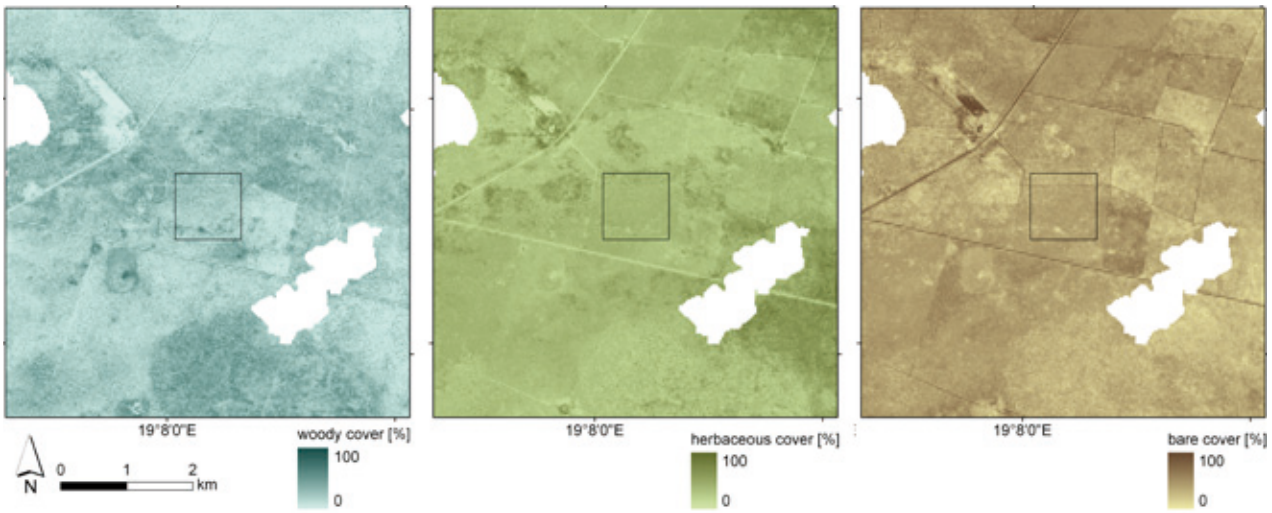
Landsat image

The landscape of the Observatory is a mosaic of open woodland patches (grey-green) and patches with higher proportions of trees and shrubs (red). The area is used for cattle farming. The different colours in the squares between the tracks are caused by different levels of grazing intensity. Recent grazing impacts and camps cleared of bush possess low vegetation cover and are visible as bright rectangular patches. The dark-green circles and ovals south of the Observatory indicate pans, which were probably partly filled with water during the time of image acquisition.



Scene: 177/75, acquisition date: 22 April 2008

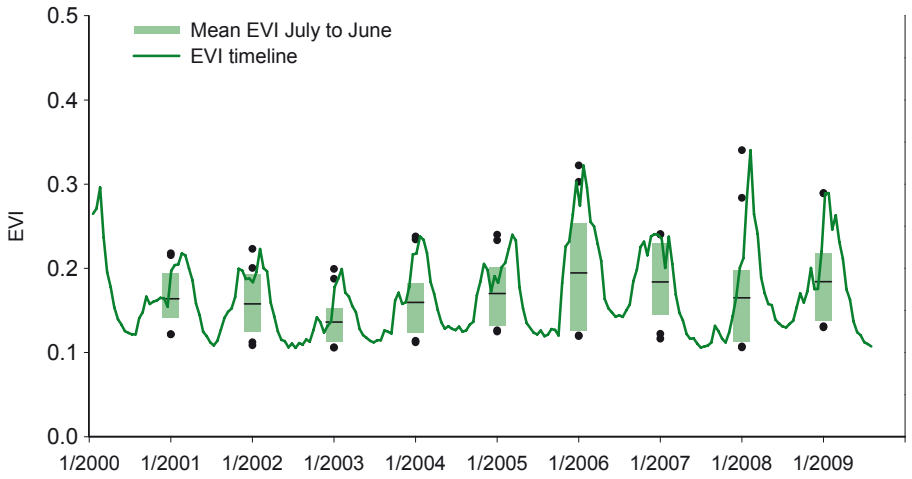
Fractional cover image



White spots: shadow of clouds

MODIS time series

Temporal patterns of vegetation cover, and phenology



Responsible authors: M. Keil & T. Labitzky

Climate

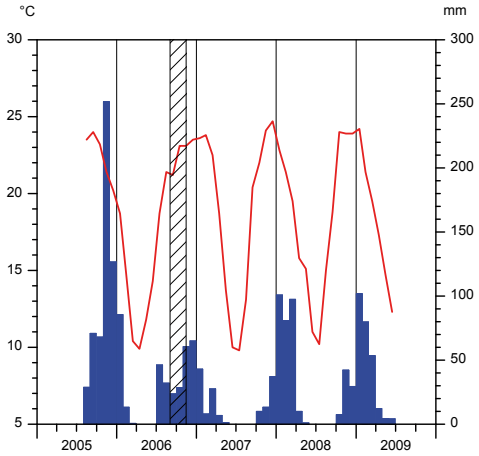
Data from BIOTA weather station

Location	Recorded period	Mean temperature
Sandveld (S41)	2005–2009	19.4 (-6.5–40.2) °C
Mean solar radiation	**Mean wind speed**	**Mean annual precipitation**
508 (282–729) MJ·m^{-2}·month^{-1}	1.2 (4.3) m·s^{-1}	404 (250–545) mm
Mean annual potential evapotranspiration	**Interannual precipitation variability**	**Mean relative humidity**
1369 mm	136%	47% (19–74%)
Aridity index (UNEP)		
0.30 (semi-arid)		

Modelled data

Mean temperature	Mean annual temperature range	Mean diurnal temperature range
19.0 (2.2–31.9) °C	12.2 °C	16.9 °C
Mean annual precipitation	**Precipitation seasonality**	**Percentage winter precipitation**
397 mm	90%	15% (strong summer)
Climate type	**Length of dry season**	**Aridity index (De Martonne)**
BSh	7 months	13.7 (semi-dry)

Time series: rainfall and temperature



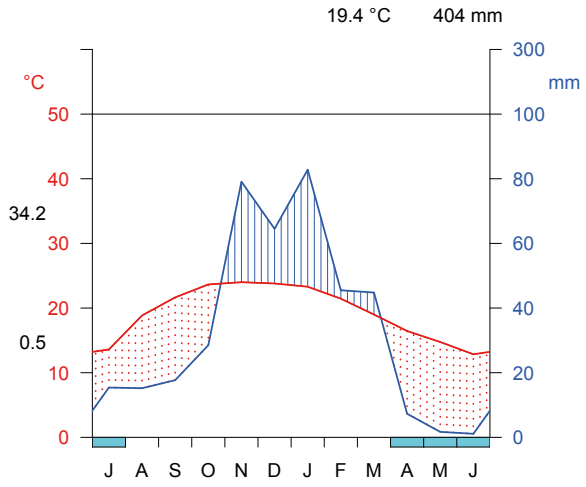
The climate at the Observatory is characterised by semi-arid conditions. Rainfall shows a strong seasonality with the major portion of rain falling during the summer season, peaking in February. The mean annual rainfall over the observation period was 404 mm, which is fairly wet in comparison to the average rainfall for all the Observatories, and makes this the wettest Observatory within the Thornbush Savanna. However, substantial interannual variability is evident. The observed near-surface air temperatures show a moderate seasonal cycle. The mean annual temperature is 19.4°C,

which is slightly cooler than the mean temperature of the Observatories within this biome. The observed mean minimum temperature at the Observatory is 0.5°C, which is the coldest of all Observatories. However, even though the observed mean minimum temperature is above the freezing point, there is still a possibility of the occurrence of frost during the months of April to July. Compared to the interpolated long-term data taken from the WorldClim dataset, slightly warmer mean annual temperatures, and especially substantially warmer maximum temperatures, are evident at the BIOTA weather station. For precipitation, the station data shows a secondary rainfall maximum during early summer that is not evident in the WorldClim data.

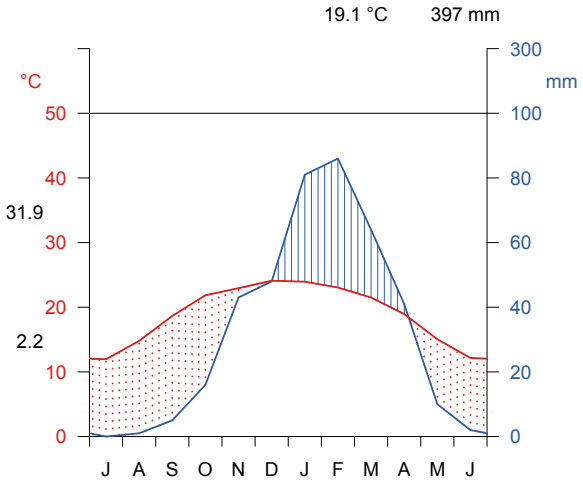
The observed near-surface winds at the Observatory are variable with no clear pattern in wind direction. Mean wind speed is highest during the early afternoon, reaching about 10 km/h. Winds during that time of the day stay fairly constant throughout the year, whereas a weak annual cycle is evident for mean wind speeds recorded during the mornings and evenings.

Climate diagrams

Recorded data (BIOTA)

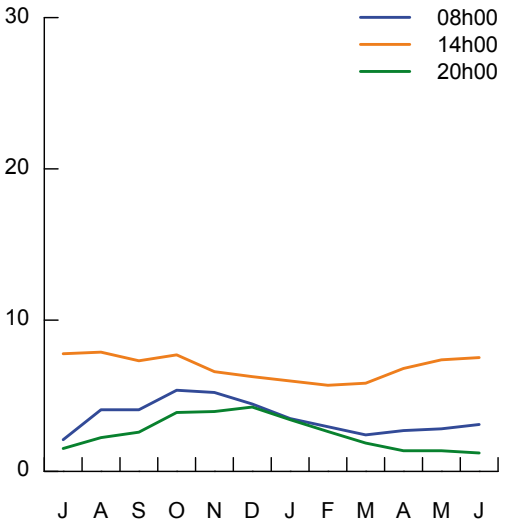


Modelled data (WorldClim)

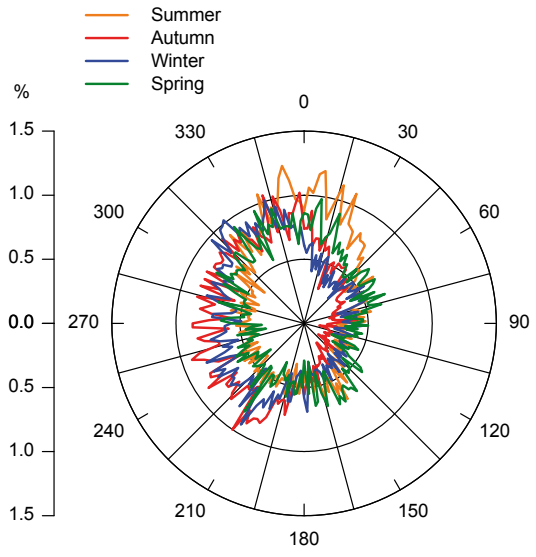


Wind diagrams

Speed



Directions



Responsible authors: K. Berger, A. Haensler & J. Luther-Mosebach

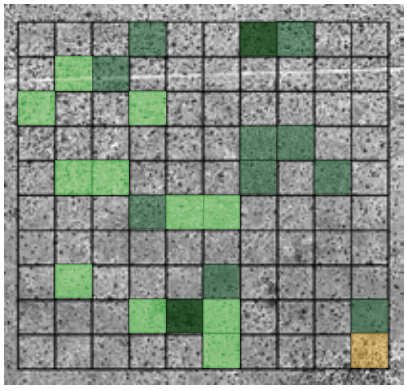
Soils

Year of sampling	Hectare plots sampled	SOTER unit
2008	25 (R1–25)	NA17
Soilscape	**Dominant soil group(s)**	**Reference group richness**
n.a.	Arenosol	2
Soil unit richness	**Soil unit evenness**	**Soil ecotype richness**
7	0.470	n.a.
Parametric space	**pH**	**Electrical conductivity**
n.a.	6.0 (5.2–6.9)	10 (5–32) µS·cm^{-1}
Organic carbon		
0.26% (0.20–0.40%)		

The by far most dominant soil type on this Observatory is Rubic Arenosols. Depending on their base saturation, these soils can be classified as 'Eutric', 'Dystric' and 'Hypereutric', all occurring equally frequent. In a pan, a Petric Calcisol occurred. Calcretes, though sometimes only weak, are regularly found below 1 m depth, but they are not critically limiting of the rooting space.

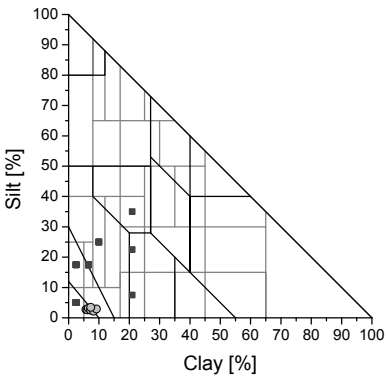
As supposed from the soil parent material, which is aeolian sand from the Kalahari basin, the texture is sand with very small proportions of silt (median 2.5%) and 5.8 to 9.2% of clay. Within the sand fraction, medium sands slightly dominate fine sand, but also 16% of the sand fraction is larger than 0.63 mm (coarse sand). The comparatively high pH values are presumably related to the calcareous subsoil, regularly brought into the otherwise acid topsoil by bioturbation, for example by ants. The amount of soluble ions is low, indicating episodic leaching processes. For most soil properties, the variance with depth is low. Only the organic carbon content decreases substantially with depth. The median C/N ratio of the topsoil is 9.2, indicating soil organic matter of fairly well composition.

Map of soil profiles

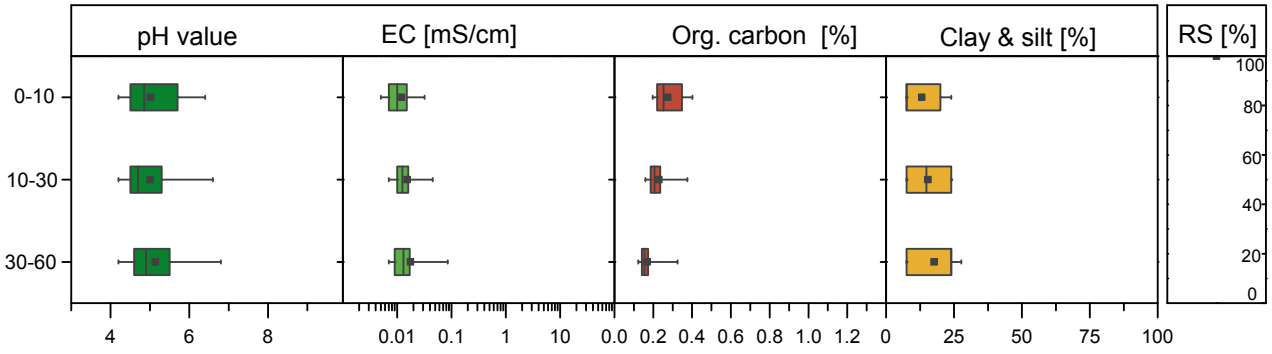


Haplic Arenosol
Brunic Arenosol
Rubic Arenosol
Petric Calcisol

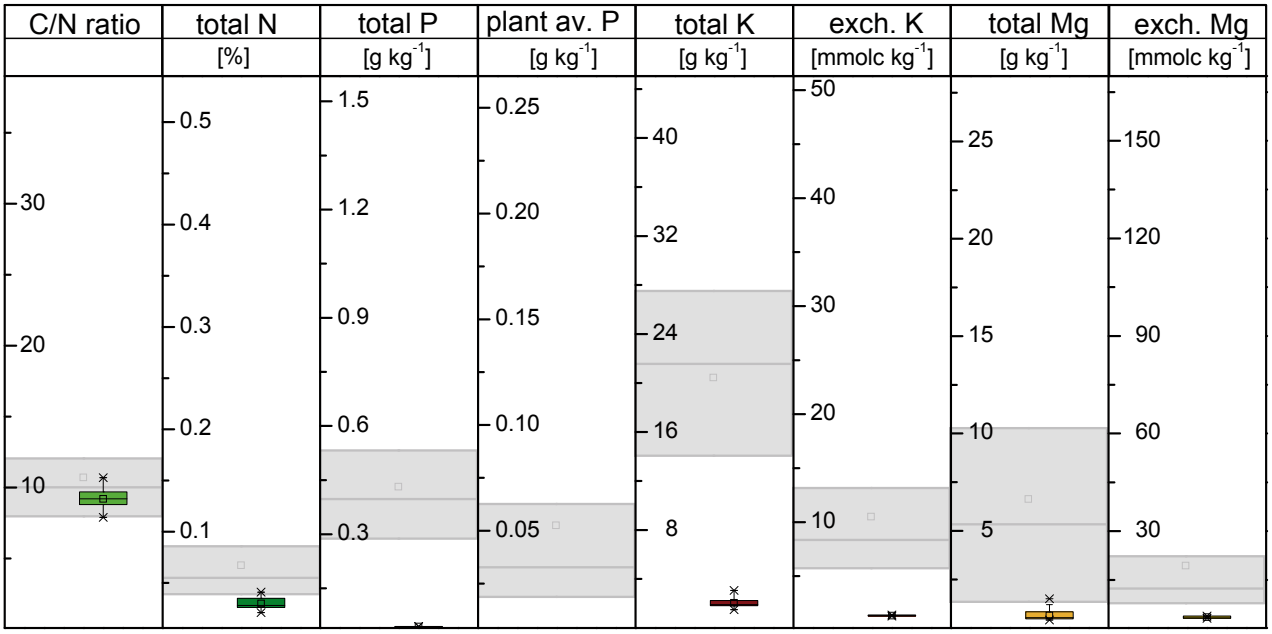
Soil texture triangle



Soil characteristics



Soil nutrients



Reference profile (H11)

The **Brunic Rubic Arenosol (Eutric)** is one of the typical sandy soils of the region. Clay content and pH values show a slight increase with depth but stay overall low. The texture is dominated by fine and medium sand, and no rock fragments can be found. Excavation difficulty is low, with a single-grain structure or very weakly subangular-blocky. No calcium carbonate was found down to a depth of 2 m. Rooting is intense in the topsoil (>20 roots dm^{-2}), decreasing to 1–5 roots dm^{-2} at a depth of 90 cm.

Ion content is extremely low, content of water soluble ions ranged from 0.7–1.9 $mmol_c\ kg^{-1}$, and those of exchangeable cations do not exceed 25 $mmol_c\ kg^{-1}$.

Responsible authors: U. Wisch, A. Petersen, A. Gröngröft & D. Mager

Lichens

Sampling period(s)	Hectare plots sampled	Cover
2006	n.a.	n.a.
Total species richness	Species richness on soil [1 km²]	Species richness on rock [1 km²]
11	0	0
Species richness on plants [1 km²]	Species richness on soil [1000 cm²]	
11 (100%)	n.a.	

A general survey of lichens was carried out throughout the Observatory, but no vegetation sampling of lichen soil-surface crusts was conducted at the hectare plot level. The Observatory is very rich in epiphytic lichens, while no terricolous or saxicolous species occur. The relatively high diversity of corticolous lichens appears to be due to the favourable macroclimatic conditions (relatively high rainfall) and to the presence of suitable phorophytes. Rocks are rare at this Observatory, and soils are either too sandy or unstable for lichen growth or competitive grasses form a dense matrix which limits the formation of soil crust communities.

List of Taxa

Terricolous (on soil):

No records

Saxicolous (on rock):

No records

Epiphytic (on plants):

Caloplaca sp.
Candelaria concolor
Flavopunctelia flaventior
Flavopunctelia soredica
Hyperphyscia adglutinata
Hyperphyscia granulata
Parmotrema austrosinense
Peltula corticola
Pyxine cocoës
Pyxine nubila
Pyxine petricola

Peltula corticola. Photo: M. Schultz, L. Zedda & G. Rambold.

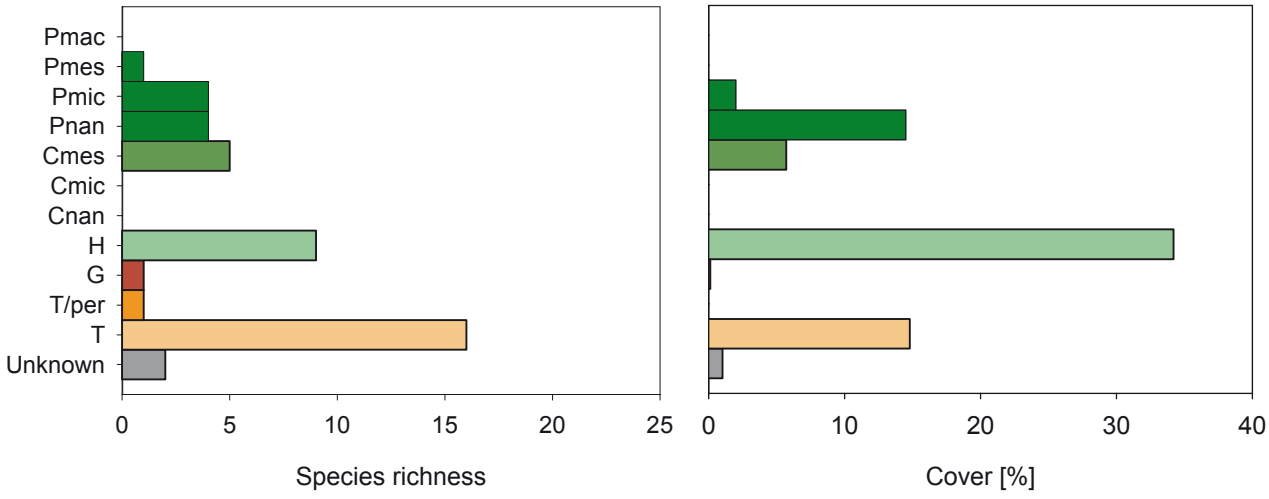
Candelaria concolor. Photo: M. Schultz, L. Zedda & G. Rambold.

Responsible authors: L. Zedda & G. Rambold

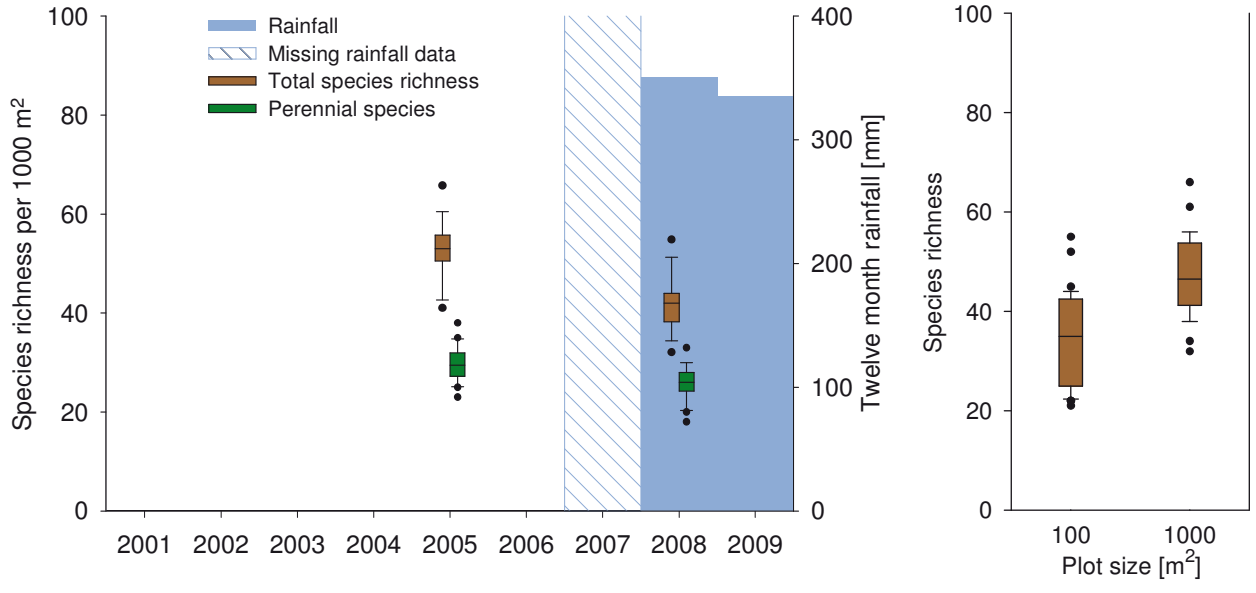
Vascular plants

Sampling period(s)	Hectare plots sampled	Biome
2005, 2008, 2009	20 (R1–R20)	Thornbush Savanna
Vegetation unit (level 1)	**Vegetation unit (level 2)**	**Identification rate**
Camelthorn Savanna (Central Kalahari)	n.a.	96% – 99% – 99%
Cumulative family richness	**Dominant families (cover)**	**Dominant families (richness)**
44	Poaceae, Fabaceae, Tiliaceae	Poaceae, Fabaceae, Asteraceae
Cumulative species richness (1 km²)	**Species richness (1000 m²)**	**Species richness (100 m²)**
203 – 121	47.4 (32–66)	34.4 (21–55)
***z*-value**	**Species richness change per year (1000 m²)**	**Evenness (1000 m²)**
0.140 (0.000–0.402)	n.a.	0.686 (0.575–0.758)
Evenness (100 m²)	**Simpson (1000 m²)**	**Simpson (100 m²)**
0.814 (0.620–0.945)	0.872 (0.719–0.925)	0.903 (0.732–0.956)

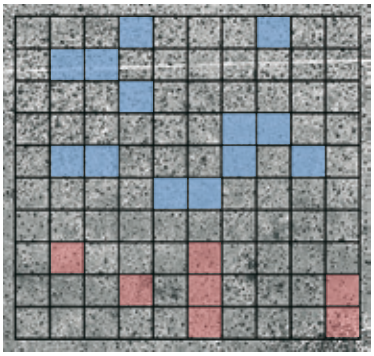
Life forms



Species richness



Map of vegetation units



The Sandveld Observatory (S41) possesses very similar soils to the other Observatories within the Kalahari basin (Mile 46, Mutompo, Sonop, and Alpha), including the deep sandy soils of the Kalahari basin (from which the station's name is derived), and loamy soils. However, in contrast to the other Kalahari basin Observatories, the soils at this Observatory are not arranged in a linear pattern, but rather in a coarse patchy pattern. These soil patterns define the vegetation types: the sandy soils support an open, mixed broad-leaved *Acacia* savanna typical of the Central Kalahari, whilst the loamy soils are dominated by very dense *Acacia* thicket. A relatively high diversity of species occurs within relatively small areas, with more than 34 species per 100 m², which indicates the importance of grasses and herbs in contributing to the diversity of plant species at this Observatory.

The two vegetation types occurring here are the *Acacia mellifera-Eragrostis trichophora* community (unit 1) and the *Terminalia sericea-Acacia erioloba* community (unit 2).

The *Acacia mellifera-Eragrostis trichophora* community (unit 1) occurs on the heavier, loamier soils in the southern half of the Observatory. This community is patchy, occasionally forming tall, dense shrublands (with more than 70% canopy cover), but mostly being a moderately-closed, tall shrubland (up to 50% canopy cover) dominated by *Acacia mellifera* subsp. *detinens*. Other woody species within the canopy are *Grewia flava*

Classification table (2005)

Column		Cover	All	1	2
Number of relevés			**20**	**7**	**13**
Mean cover [%]			84.2	82.2	85.2
Mean species richness (1000 m²)			53.0	56.1	51.3
Mean soil pH			5.13	6.05	4.71
Mean electrical conductivity [µS·cm^{-1}]			13	21	10
Organic carbon [%]			0.29	0.35	0.26
Nitrogen [%]			0.03	0.04	0.03
Unit 1: Acacia mellifera-Eragrostis trichophora community					
H	Indigofera alternans	1.50	30	86	.
Cmes	Otoptera burchellii	0.39	35	86	8
H	Phyllanthus pentandrus	0.14	25	71	.
H	Phyllanthus maderaspatensis	0.18	25	71	.
Cmes	Geigeria pectidea	n.a.	20	57	.
T	Tragus racemosus	0.78	20	57	.
Cmes	Aptosimum decumbens	0.55	20	57	.
H	Eragrostis trichophora	0.63	20	57	.
n.a.	Indigastrum parviflorum	0.46	25	57	8
H	Limeum fenestratum	0.33	70	100	54
Unit 2: Terminalia sericea -Acacia erioloba community					
T	Aristida stipitata	4.35	65	.	100
Pmes	Terminalia sericea	7.00	60	.	92
H	Indigofera filipes	0.23	75	29	100
H	Triraphis schinzii	0.96	70	29	92
G	Acanthosicyos naudinianus	0.69	70	29	92
H	Eragrostis pallens	1.07	35	.	54
H	Brachiaria nigropedata	0.03	30	.	46
T	Oxygonum alatum var. alatum	0.41	85	57	100
Most frequent companions					
H	Stipagrostis uniplumis var. uniplumis	17.10	100	100	100
H	Schmidtia pappophoroides	8.50	100	100	100
Pmic	Grewia flava	7.00	100	100	100
H	Eragrostis rigidior	4.18	100	100	100
H	Urochloa brachyura	2.43	100	100	100
T	Melinis repens ssp. repens	1.88	100	100	100
Pmes	Acacia erioloba	1.95	95	86	100
T	Melinis repens ssp. grandiflora	1.08	95	100	92
Pmic	Acacia mellifera ssp. detinens	6.53	90	100	85
T	Limeum sulcatum var. sulcatum	0.74	90	100	85
H	Tephrosia burchellii	0.73	90	100	85
T	Pogonarthria fleckii	0.33	90	100	85
T	Gisekia africana	0.33	90	100	85
Pmes	Dichrostachys cinerea	4.50	85	71	92
H	Aristida congesta ssp. congesta	0.95	85	100	77
n.a.	Barleria macrostegia	0.65	85	71	92
G	Talinum arnotii	0.61	85	86	85
Cmic	Dicoma schinzii	0.34	85	71	92
T	Vernonia poskeana ssp. botswanica	0.32	85	71	92
H	Eragrostis lehmanniana	0.79	80	100	69
Cmes	Portulaca kermesina	0.28	80	100	69
Pmic	Acacia hebeclada ssp. hebeclada	2.83	75	86	69
Pmic	Ozoroa paniculosa	1.33	75	57	85
T	Sida ovata	0.35	75	57	85
Pmes	Tarchonanthus camphoratus	5.00	70	57	77
G	Raphionacme velutina	0.44	70	43	85
Cmes	Lantana angolensis	0.33	70	86	62
n.a.	Euphorbia inaequilatera var. inaequilatera	0.26	70	71	69
H	Evolvulus alsinoides	0.73	65	43	77
H	Geigeria ornativa	0.62	65	86	54

continued on next page

Unit 1, 2005. Photo: B.J. Strohbach.

Unit 2, 2005. Photo: B.J. Strohbach.

(Raisin Bush) and *Acacia hebeclada* subsp. *hebeclada* (Candle-pod Acacia). *Acacia erioloba* does occur here, but with relatively low abundance. The grass sward in the more open patches is dominated by *Stipagrostis uniplumis* var. *uniplumis, Eragrostis rigidior*, and *Schmidtia pappophoroides*. The perennial, but unproductive *Eragrostis trichophora* (Hairy Love Grass) is characteristic of the herbaceous layer occurring in the shade under fairly dense (moderately closed to closed) canopy cover.

The *Terminalia sericea-Acacia erioloba* community (unit 2) is described by September (2006) as a moderately closed to closed bushland, dominated by *Acacia erioloba* and *Terminalia sericea* trees. The shrub layer contains *Acacia mellifera* subsp. *detinens*, albeit at far lower densities than in the previous community. *Grewia flava, Dichrostachys cinerea, Ozoroa paniculosa* (Common Resin Bush), and *Tarchonanthus camphorathus* (Camphor Bush) are also very common within the shrub layer. The grass sward is dominated by *Stipagrostis uniplumis* var *uniplumis* with *Schmidtia pappophoroides* being widespread, but at lower densities than in unit 1 (indicative of the lower loam content of the soil). *Aristida stipitata, Brachiaria nigropedata*, *Eragrostis pallens* (Broom Grass), and *Triraphis schinzii* (Needle Grass) are also associated with the sandy soils. Another species common in sandy areas is the geophytic creeper *Acanthosycios naudenianus* (gemsbokkomkommer).

The effects of reduced rainfall are clearly illustrated by comparing the *Terminalia sericea-Acacia erioloba* community with corresponding communities at the Mile 46/Mutompo and Sonop Observatories (the *Pterocarpus angolensis-Guibourtia coleosperma* community at Mile 46/Mutompo, and the *Terminalia sericea-Combretum collinum* community at Sonop). Whereas the Kavango woodlands are dominated by tall trees, with an understory of Combretaceae (specifically *Terminalia sericea* and various *Combretum* species) at Mile 46/Mutompo, only the latter dominate at Sonop, with only remnants of the woodlands (very occasional *Pterocarpus angolansis* trees, which are also far smaller in size) persisting. At Sandveld, *Terminalia sericea* remains a dominant species, albeit at far lower cover than at Sonop. The *Combretum* species do not occur here, and the sandy soils are populated by species typical of the loamier soils of the interdunal valleys at Sonop (e.g. *Acacia erioloba, Acacia mellifera* subsp. *detinens, Grewia flava*, and *Ozoroa paniculosa*). *Tarchonanthus camphorathus* does occur at Sonop Research Station, but only on extremely shallow, loamy soils (which were not present at the Observatory).

Classification table (continued)

Column		Cover	All	1	2
Number of relevés			**20**	**7**	**13**
Cmes	Indigofera daleoides	0.47	65	43	77
T	Heliotropium steudneri	0.46	65	86	54
n.a.	Elephantorrhiza elephantina	0.55	60	29	77
n.a.	Kohautia subverticillata ssp. subverticillata	0.34	60	86	46
T	Eragrostis nindensis	0.40	55	57	54
T	Tragus berteronianus	0.23	55	71	46
T	Hermannia modesta	0.19	55	71	46
H	Chascanum pinnatifidum	0.15	55	57	54
Cmes	Pollichia campestris	0.12	55	71	46
Cmes	Hermannia tomentosa	0.62	50	43	54
T	Monsonia angustifolia	0.16	50	43	54
H	Aristida effusa	0.69	45	71	31
H	Requienia sphaerosperma	0.69	45	71	31
T	Kyphocarpa angustifolia	0.26	45	71	31
Pmes	Ziziphus mucronata	0.95	40	14	54
Cmic	Limeum myosotis	0.29	40	43	38
T	Chamaecrista biensis	0.20	40	14	54
G	Cucumis africanus	n.a.	40	43	38
H	Aristida congesta	n.a.	40	71	23
Cmes	Ehretia rigida	0.73	35	57	23
H	Pogonarthria squarrosa	0.27	35	29	38
T	Cleome rubella	0.14	35	29	38
T	Tephrosia dregeana	0.83	30	29	31
Pnan	Solanum tettense var. renschii	0.17	30	43	23
L	Coccinia sessilifolia	0.08	30	57	15
T	Limeum pterocarpum var. pterocarpum	n.a.	30	43	23
H	Aristida meridionalis	0.72	25	14	31
n.a.	Solanum rigescentoides	0.28	25	29	23
T	Ipomoea sinensis	0.16	25	14	31
T	Eragrostis porosa	0.14	25	43	15
Pnan	Diospyros lycioides	0.80	20	43	8
T	Tribulus terrestris	0.30	20	43	8
H	Cyperus marginatus	0.20	20	.	31
T	Tricholaena monachne	0.20	20	29	15
H	Cynanchum orangeanum	0.10	20	29	15
Cmes	Indigofera bainesii	0.10	20	.	31
H	Cyperus margaritaceus	0.03	20	.	31
T	Limeum pterocarpum	0.03	20	14	23
n.a.	Kohautia virgata	0.53	15	14	15
H	Commelina africana	0.50	15	14	15
n.a.	Mariscus rehmannianus	0.40	15	14	15
Pnan	Asparagus suaveolens	0.40	15	14	15
n.a.	Hermbstaedtia linearis	0.37	15	29	8
Cmes	Acrotome inflata	0.20	15	29	8
G	Dipcadi longifolium	0.10	15	14	15
T	Pegolettia senegalensis	0.10	15	29	8
G	Eriospermum sp. 23235	0.07	15	29	8
Cmes	Hermbstaedtia argenteiformis	n.a.	15	14	15
T	Oxygonum alatum	n.a.	15	.	23

The *Terminalia sericea-Acacia erioloba* community is variable, with sometimes large trees of *Acacia erioloba* dominating.
Photo: B.J. Strohbach.

At some sites, the *Terminalia sericea-Acacia erioloba* community is dominated by smaller trees and shrubs of *Terminalia sericea*.
Photo: B.J. Strohbach.

Rueliopsis setosa. Photo: B.J. Strohbach.

Barleria macrostegia. Photo: B.J. Strohbach.

Portulaca kermesina. Photo: B.J. Strohbach.

Indigofera daleoides. Photo: B.J. Strohbach.

Requiena sphaerosperma. Photo: B.J. Strohbach.

Responsible authors: B.J. Strohbach & J. Luther-Mosebach

True bugs

Sampling period(s)	Methods	Family richness
2007/ I	Trapping (light, Malaise traps), net sweeping, beating of plants	16
Species richness	**Individuals sampled**	**Fisher's alpha diversity**
49	179	22.25

The families Miridae, Reduviidae, and Pentatomidae account for 51% of all collected species at the Sandveld Observatory (S41). These species are typical of the savanna biome and were also recorded at Otjiamongombe (S05), Toggekry (S04), and Mutompo (S02). The following species were only recorded at the Sandveld Observatory: *Oxycarenus hyalipennis* (Oxycarenidae), *Dermatinus limbifer* (Pyrrhocoridae), and *Sinuessa subinermis* (Tingidae). *Oxycarenus hyalipennis* is widespread and common. *Sinuessa subinermis* is widespread in tropical Africa. This species occurs in the eastern and northern part of Namibia, mainly near Otavi and in the Caprivi. *Dermatinus limbifer* is known from Mozambique and the eastern parts of South Africa.

Species richness of families

Family	***S***
Miridae	10
Reduviidae	9
Pentatomidae	6
Coreidae	4
Tingidae	4
Alydidae	3
Pachygronthidae	2
Pyrrhocoridae	2
Rhopalidae	2
Berytidae	1
Gerridae	1
Lygaeidae	1
Nabidae	1
Oxycarenidae	1
Rhyparochromidae	1
Scutelleridae	1
Total	**49**

Species abundance

Light traps

Species	**Family**	***N***	**%**
Oncocephalus spec.	Reduviidae	21	22
Miridae spec. 1	Miridae	8	8
Opistholeptus spec.	Pachygronthidae	8	8
Edocla vittipennis	Reduviidae	6	6
Miridae spec. 2	Miridae	5	5
Miridae spec. 3	Miridae	5	5
Stenozygum spec.	Pentatomidae	5	5
Nariscus spec.	Alydidae	4	4
Miridae spec. 4	Miridae	4	4
Miridae spec. 5	Miridae	4	4
Carbula atomarius	Pentatomidae	4	4
Miridae spec. 6	Miridae	3	3
Cysteochila spec.	Tingidae	3	3
Ectomocoris quadrimaculatus	Reduviidae	2	2
Philodoxus principalis	Reduviidae	2	2
Others (11)		11	12
Total		**95**	**100**

Responsible author: J. Deckert

Butterflies and moths

Sampling period(s)	Number of samples (moths)	Species richness (total)
2007/I	1	257
Species richness (butterflies)	Species richness (all moths)	Species richness (Microlepidoptera)
13	244	81
Species richness (Pyraloidea)	Species richness (Macrolepidoptera)	Species richness (Noctuidae)
63	33	67
Individuals sampled (moths)	Fisher's alpha diversity (moths)	
1541	81.5	

Butterflies

Chilades trochylus was a common species on the Observatory. These butterflies were observed flying over large patches of *Indigofera* species, the host plants of the caterpillars, growing on the sand pad bordering the eastern boundary of the Observatory. Only a few butterflies were encountered in the dense vegetation occurring in the middle of the Observatory (see Photo), with most species being recorded along the trails.

Moths

The sampling on this Observatory yielded a high number of Macrolepidoptera. *Thyretis caffra* (Arctiidae) and *Azygophlebs* sp. (Cossidae) were common species collected at the light traps. The large adult moth of *Gonometa postica* was observed sitting on tree trunks or in the grass (see photo) during the daytime but did not appear at the light traps or the light tower at night. The Pyraloidea are represented by a large number of species with 10 to 20 specimens. Two species of *Laodamia*, one *Haimbachia* and one *Sciota* species (Pyraloidea: Phycitinae) were the most abundant species. The sample also contained individuals of a new species and a new genus, and are currently being described (Mey 2010) (see photo). They also occur on the Observatory S05 (Otjiamongombe). *Eublemma* sp., *Felinopsis africana*, and *Acantholipes trimeni* were the dominant Noctuidae species. The Microlepidoptera are represented by many families with Gelechiidae being the most diverse. *Pyncostola iospila* (Gelechiidae) and *Scythis* sp. (Scythrididae) were the most abundant species.

Female of *Gonometa postica*. Photo: W. Mey

Female of undescribed *Pyralinae species*. Photo: W. Mey

Butterfly species and main food plants

Hesperiidae	
Spialia diomus ferax	Hermannia (Sterculiaceae), Hibiscus, Pavonia, Sida (Malvaceae)
Spialia mafa mafa	Hermannia (Sterculiaceae), Hibiscus, Pavonia (Malvaceae)
Spialia spio	Hermannia (Sterculiaceae), Hibiscus, Pavonia (Malvaceae)
Spialia delagoae	n.a.
Lycaenidae	
Aloeides damarensis mashona	Aspalathus (Fabaceae)
Zizeeria knysna	Tribulus (Zygophyllaceae), Amaranthus (Amaranthaceae)
Chilades trochylus	Indigofera (Fabaceae), Heliotropium (Boraginaceae)
Tarucus sybaris linearis	Zizyphus (Rhamnaceae)
Nymphalidae	
Danaus chrysippus aegyptius	Asclepias, Stapelia, Cynanchum (Asclepiadaceae)
Junonia hierta cebrene	Asystasia, Adhatoda, Barleria, Ruellia (Acanthaceae)
Byblia ilithya	Tragia, Dalechampia (Euphorbiaceae)
Pieridae	
Eurema brigitta brigitta	Hypericum (Hypericaceae), Chamaecrista (Caesalpiniaceae)
Satyridae	
Coenyropsis natalii natalii	n.a.

Dense vegetation cover with *Terminalia sericea* on Sandveld. Photo: W. Mey

Taxonomic spectrum of moths

Collection period: I/2007

Family	S	N
Adelidae	1	2
Nepticulidae	2	5
Tischeriidae	1	1
Tineidae	8	84
Eriocottidae	2	26
Psychidae	1	25
Bucculatricidae	3	5
Gracillariidae	1	1
Lyonetiidae	1	1
Bedelliidae	1	2
Lacturidae	1	2
Coleophoridae	1	2
Batrachedridae	1	2
Xyloryctidae	1	7
Ethmiidae	4	17
Scythrididae	7	103
Elachistidae	1	10
Oecophoridae	1	1
Lecithoceridae	2	3
Chrysopeleidae	5	29
Cosmopterigidae	1	19
Gelechiidae	27	134
Gelechiidae, indet.		40
Tortricidae	4	12
Pterophoridae	3	4
Alucitidae	1	1
Microlepidoptera	**81**	**538**
Pyralidae: Phycitinae	34	343
Pyralidae: Pyralinae	10	39
Pyralidae, indet.		57
Crambidae	19	84
Pyraloidea	**63**	**523**
Thyrididae	1	3
Cossidae	2	16
Limacodidae	3	6
Lasiocampidae	2	2
Saturniidae	1	1
Eupterotidae	1	6
Sphingidae	2	2
Geometridae	14	68
Arctiidae	4	18
Notodontidae	1	4
Lymantriidae	2	4
Noctuidae	67	348
Noctuidae, indet.		2
Macrolepidoptera	**100**	**480**
Total	**244**	**1541**

Responsible author: W. Mey

Vertebrates

Total species richness	Reptile species richness	Bird species richness
25	n.a.	25
Large mammal species richness	Small mammal species richness	
n.a.	n.a.	

Birds

Charadriiformes	**Gulls, terns, plovers, and other Shorebirds**
Turnix sylvaticus	Small Buttonquail
Vanellus coronatus	Crowned Plower
Passeriformes	**Perching birds**
Camaroptera fasciolata	Barred Warbler
Dicrurus adsimilis	Fork-tailed Drongo
Emberiza impetuani	Larklike Bunting
Hirundo rustica	Barn Swallow
Lamprotornis nitens	Cape Glossy Starling
Laniarius atrococcineus	Crimson-breasted Gonolek
Lanius minor	Lesser Grey Shrike
Sporopipes squamifrons	Scaly-fronted Weaver
Uraeginthus granatinus	Violet-eared Waxbill
Vidua regia	Shaft-tailed Whydah
Coraciiformes	**Kingfishers and relatives**
Coracias caudata	Lilac-breasted Roller
Tockus leucomelas	Southern yellow-billed Hornbill
Upupa epops africana	African Hoopoe
Merops hirundineus	Swallow-tailed Bee-eater
Cuculiformes	**Cuckoos and anis**
Cuculus gularis	African Cuckoo
Corythaixoides concolor	Grey go-away-Bird
Galliformes	**Fowl-like birds**
Francolinus adspersus	Red-billed Francolin
Numida meleagris	Helmeted Guineafowl
Strigiformes	**Owls**
Bubo lacteus	Verreaux's Eagle Owl
Accipitriformes	**Birds of prey**
Aquila rapax	Tawny Eagle
Melierax canorus	Pale chanting Goshawk
Columbiformes	**Doves and pigeons**
Oena capensis	Namaqua Dove
Stigmatopelia senegalensis	Laughing Dove

Pale chanting Goshawk (*Melierax canorus*). Photo: J. Deckert.

Fork-tailed Drongo (*Dicrurus adsimilis*). Photo: J. Deckert.

Responsible authors: J. Deckert, A. Hoffmann & A. Mills

Mapping the vegetation of the Sandveld Research Station (S41.01)

[Z.M. September & B.J. Strohbach]

As a part of the Vegetation Mapping Project of Namibia, the vegetation of the Sandveld Research Station in the eastern *Acacia* tree-and-shrub savanna (Camelthorn savanna) of the Kalahari in Namibia was classified and mapped. This station has been used as a cattle farm for over 80 years and as a government research station since 1968. Since 1984, the long-term systems trial occupied 66% or 5,516 ha of the station, investigating the sustainable stocking rate of ranched beef cattle.

A field survey was undertaken during the growing seasons of 2005 and 2006, sampling a total of 99 plots. 221 species were recorded during the study. The relevés were classified using various routines of JUICE, and six associations or vegetation units were identified: pond edges, calcrete veld (*Cenchrus ciliaris-Enneapogon cenchroides*), *Terminalia sericea* tree veld, dense *Terminalia sericea-Acacia* veld, open *Terminalia sericea-Tylosema esculentum* veld, and *Acacia erioloba* veld. The open *Terminalia sericea-Tylosema esculentum* veld and the *Terminalia sericea* thicket cover the majority of the farm. The pond edges and calcrete veld cover only a small area of the farm, whilst the *Acacia erioloba* veld, which is also limited on the farm, has been found more widespread on some of the adjacent farms. Landsat 7 ETM scene 177-075 dated 24 April 2000 was used to map the vegetation.

► *See also* **Article III.2.4**

September, Z.M. (2006): Mapping the vegetation of the Sandveld Research Station in Namibia with the aid of remote sensing. – BSc thesis in Botany. Pretoria: University of Pretoria.

General data

Number	Name	Alternative name(s)
S17	Alpha	Kalahari Trails
Implementation	**Country**	**Province/ region**
2001	South Africa	Northern Cape
District/ constituency	**Locality**	**Farm name**
Siyanda	Askham	Alpha
Latitude	**Longitude**	**Altitude**
26.760917 S	20.614021 E	896 m a.s.l.
Rainfall season	**Biome**	**WWF Ecoregion**
Summer	Thornbush Savanna	AT1309 Kalahari xeric savanna
Agro-Ecological Zone	**Relative intensity of land use**	**Tenure**
n.a.	Low	Private
Type and history of landuse	**Land owner**	
Conservation area, game farming	Private	

Alpha (S17)

The Alpha Observatory with Springboks moving through a dune valley. Photo: R. Christiaan.

The BIOTA Observatory Alpha (S17) is situated on the privately owned Kalahari Trails Nature Reserve in the Mier area of the Kalahari in South Africa, approximately 240 km north of Upington and 35 km south of the Kgalagadi Transfrontier Park. The landscape is dominated by latitudinal dunes that have a north-west/south-east orientation. The dunes are approximately 10 m high and are separated by broad dune valleys of 100 m to 300 m in diameter. This summer rainfall area, which is dominated by perennial grasses interspersed with sparse *Acacia* trees, belongs to the southern African Thornbush Savanna Biome.

Observatory Alpha was a commercial cattle farm until 1998. Since then it has become a private game reserve and is grazed by large indigenous herbivores like Gemsbok (*Oryx gazella*), Springbok (*Antidorcas marsupialis*) and Red Hartebeest (*Alcephalus busephalus caama*).

The Alpha BIOTA Observatory was established to obtain baseline information on the vegetation dynamics of the Thornbush Savanna on the deep Kalahari Sands in comparison to the central Namibian savannas. This Observatory was also used by the BIOTA researchers that developed ecological models on ecosystem processes in the Kalahari (see Chapter III.7).

Responsible authors: U. Schmiedel & D.H. Haarmeyer

Remote sensing and landscape

Geomorphology	Geological units	Lithological units
Dunes and interdunes	Kalahari Sands	Sands and Calcrete
Mean EVI	**EVI absolute range**	**Mean leaf area index**
0.118 (0.100–0.165)	0.090 (2008)–0.196(2009)	0.39

Grid map of Observatory

	0	1	2	3	4	5	6	7	8	9
0	52	6	65	34	9	44	68	4	74	100
1	93	11	23	1	31	56	36	66	79	67
2	94	55	41	39	49	42	8	96	14	38
3	64	78	88	30	89	54	24	2	43	60
4	7	87	99	18	33	58	72	90	13	27
5	70	17	51	21	57	86	84	19	45	37
6	53	26	35	76	28	73	92	32	10	61
7	59	91	63	48	82	46	83	77	15	81
8	95	5	80	22	25	69	62	47	98	29
9	20	71	97	40	12	3	85	16	75	50

1	Grass-dominated vegetation on interdune
2	Shrub-dominated vegetation on interdune
3	Mostly unvegetated interdune
4	Grass-dominated dune slope
5	Grass-dominated dune crest

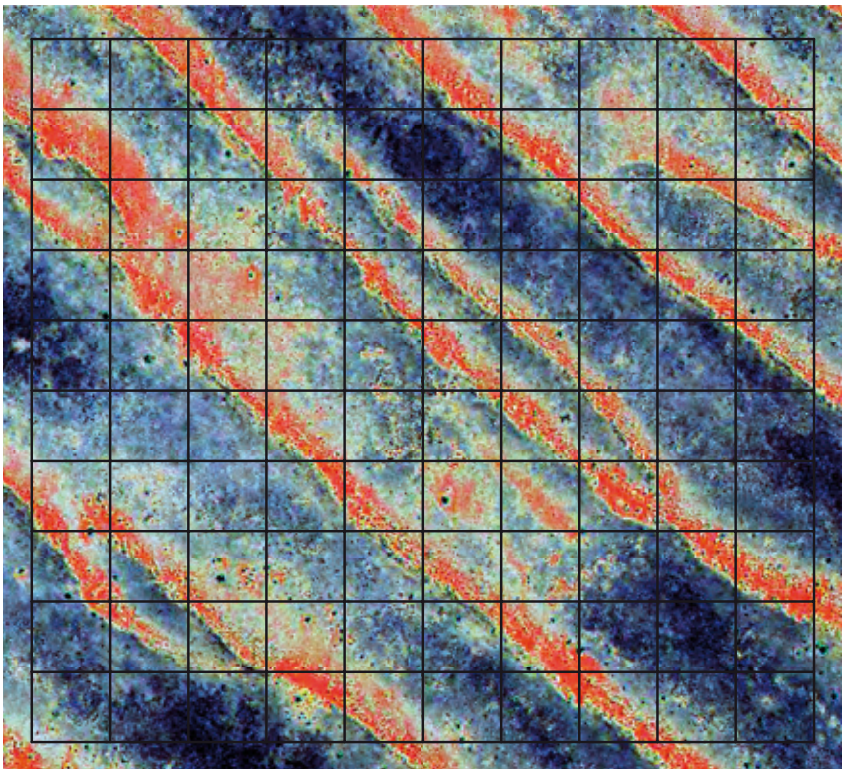
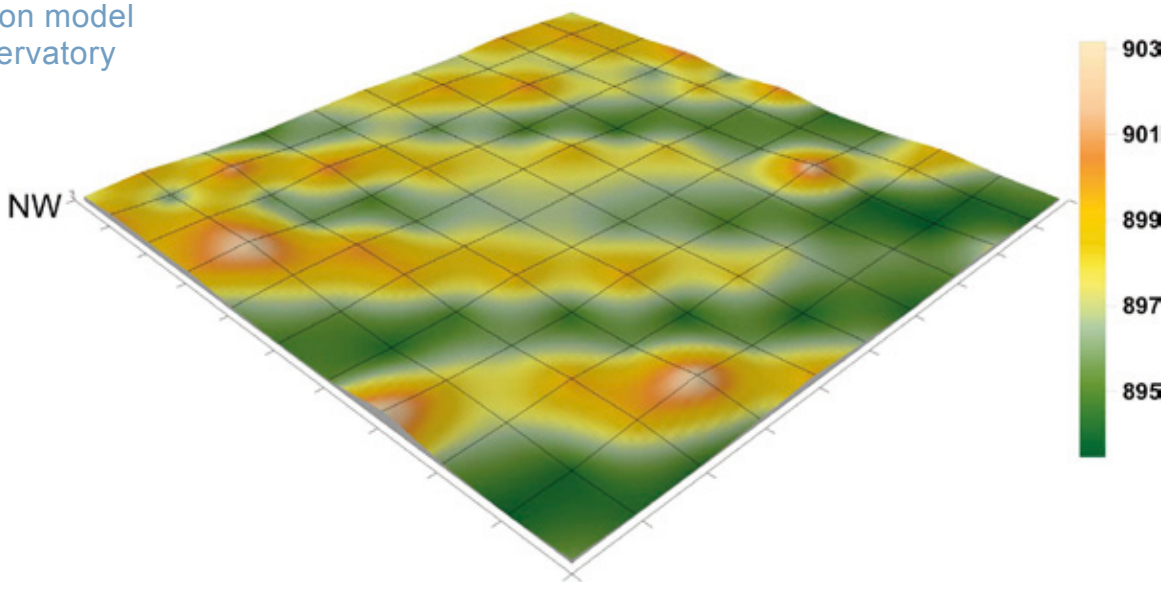


Image: IKONOS, 2004

Elevation model of Observatory



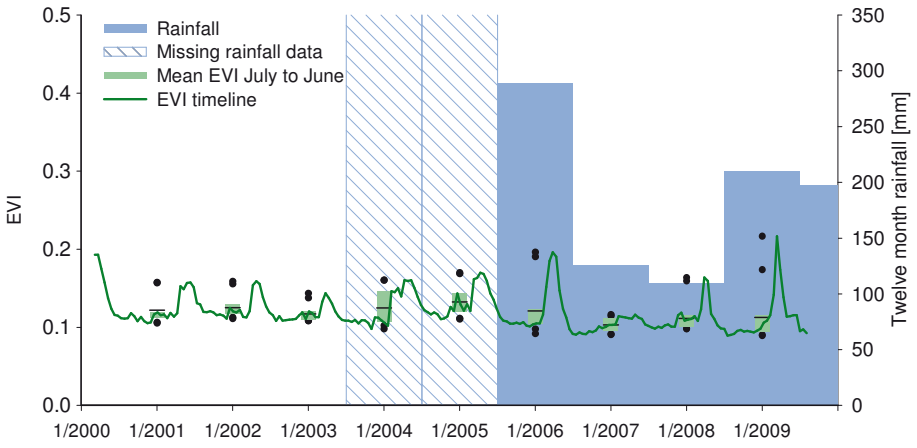
Landsat image

The satellite image shows the dune landscape of the Kalahari Desert around Alpha Observatory with the dune crests orientated mainly from the north-west to south-east. The valley of the Nossob River, which marks the border between South Africa and Botswana, passes the Observatory about 1 km to the east. The dune crests (illuminated from the north-east) show up as dark brown tones due to the woody vegetation on the crest lines, with bright green showing on the north-eastern slopes where there is no, or sparse, grass cover. Inter dune valleys are vegetated with a more or less dense grass cover (bright green, light red) or woody vegetation (dark green). White spots and bands indicate bare sandy surfaces and dry riverbeds.

Scene: 175/79, acquisition date: 27 April 2009

MODIS time series

Temporal patterns of annual rainfall, vegetation cover, and phenology



Responsible authors: M. Keil & T. Labitzky

Climate

Data from BIOTA weather station

Location	Recorded period	Mean temperature
Alpha (S17)	2003–2009	21.4 (-5.0–44.0) °C
Mean solar radiation	**Mean wind speed**	**Mean annual precipitation**
575 (287–904) MJ·m^{-2}·month^{-1}	1.9 (7.7) m·s^{-1}	192 (113–227) mm
Mean annual potential evapotranspiration	**Interannual precipitation variability**	**Mean relative humidity**
1667 mm	116%	39% (19–59%)
Aridity index (UNEP)		
0.12 (arid)		

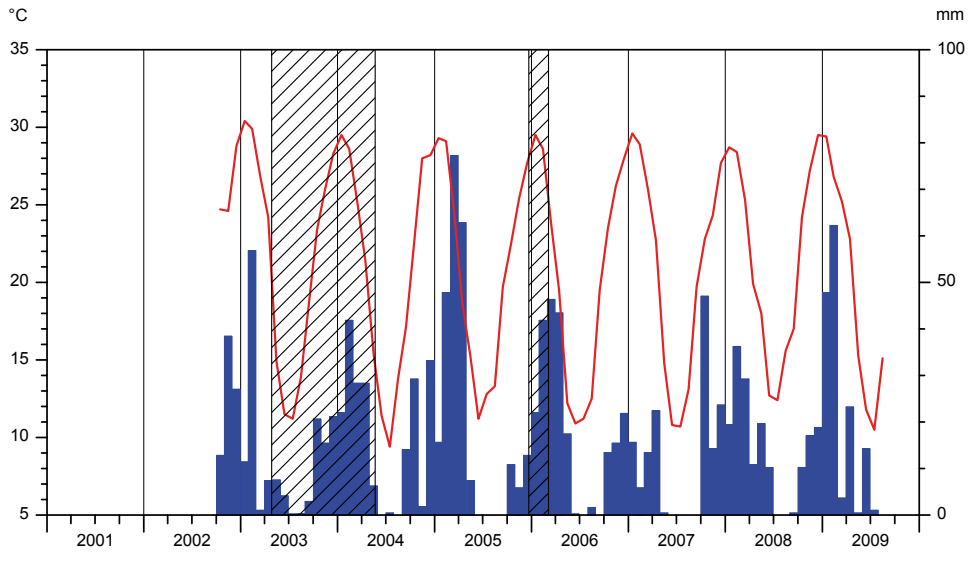
Modelled data

Mean temperature	Mean annual temperature range	Mean diurnal temperature range
20.0 (1.2–35.7) °C	15.1 °C	18.4 °C
Mean annual precipitation	**Precipitation seasonality**	**Percentage winter precipitation**
185 mm	76%	24% (summer)
Climate type	**Length of dry season**	**Aridity index (De Martonne)**
BWh	12 months	6.2 (dry)

The climate at the Observatory is characterised by arid conditions. Rainfall shows a moderate seasonality with the major portion of rain falling during the summer season, peaking in February. The mean annual rainfall over the observation period was 192 mm, which is drier than the average rainfall recorded for the entire transect and within the Thornbush Savanna. However, substantial interannual variability is evident. The observed near-surface air temperatures show a pronounced seasonal cycle. The mean annual temperature is 21.4°C and is therefore slightly warmer than the mean temperature of all Observatories, but is in line with the average values of the Observatories within this biome. The observed mean maximum temperature at the Observatory is 38.8°C, which is the warmest of all Observatories. The observed mean minimum temperature is above the freezing point, but there is still a possibility of the occurrence of frost during the months of May to September. Compared to the interpolated long-term data taken from the WorldClim dataset, a warmer mean annual temperature is observed at the BIOTA weather station. Furthermore, the station records of temperature extremes deviate substantially from the interpolated data, showing markedly warmer maximum and slightly cooler minimum temperatures than the WorldClim data. For precipitation, mean annual rainfall is slightly higher at the BIOTA weather station compared to the WorldClim data.

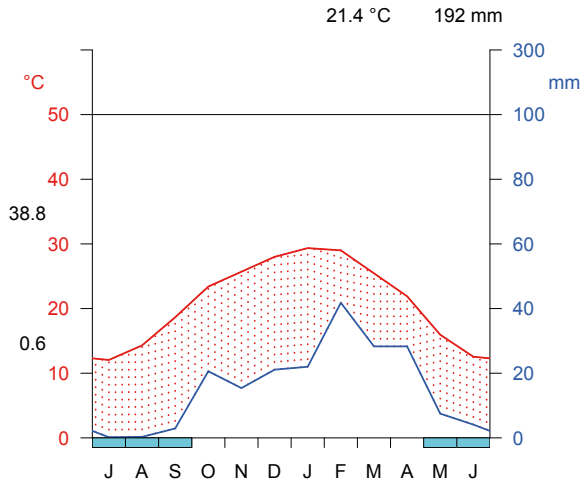
The observed near-surface winds at the Observatory are mainly constituted of north-northwesterly flows throughout the year. Mean wind speed is highest during the early afternoon, reaching about 10 km/h. Winds during that time of the day stay fairly constant throughout the year, whereas a moderate annual cycle is evident for the mean wind speed recorded during the mornings and evenings.

Time series: rainfall and temperature

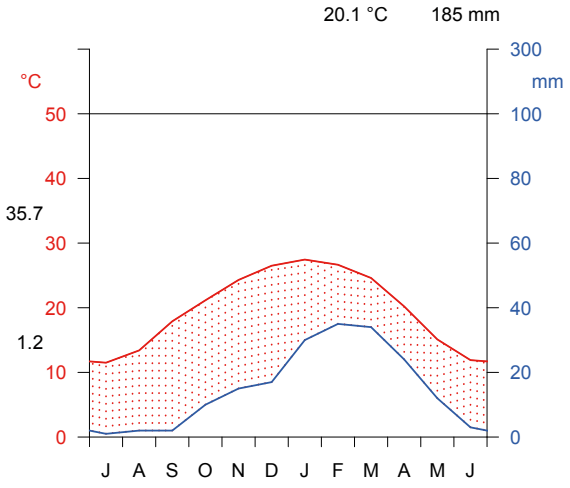


Climate diagrams

Recorded data (BIOTA)

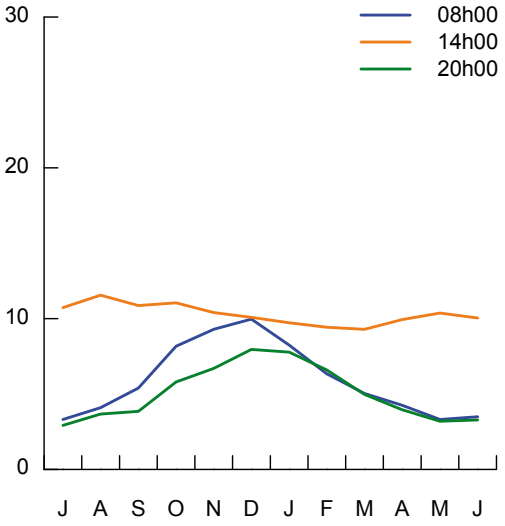


Modelled data (WorldClim)

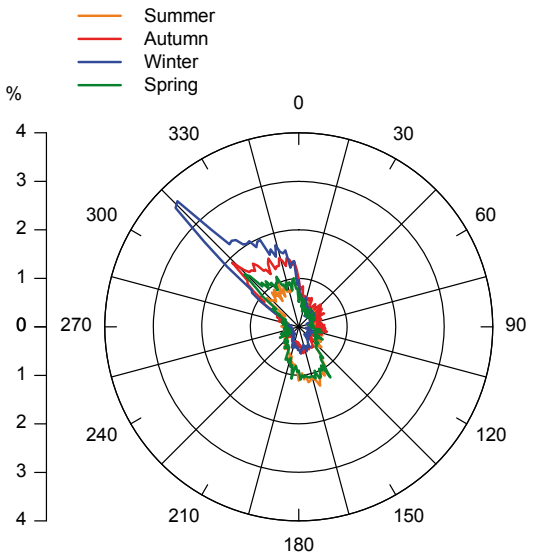


Wind diagrams

Speed



Directions



Responsible authors: K. Berger, A. Haensler & J. Luther-Mosebach

Soils

Year of sampling	Hectare plots sampled	SOTER unit
2002	25 (R1–25)	ZA461
Soilscape	**Dominant soil group(s)**	**Reference group richness**
Arenosols (AR)	Arenosol	2
Soil unit richness	**Soil unit evenness**	**Soil ecotype richness**
2	0.087	1
Parametric space	**pH**	**Electrical conductivity**
0.67	6.3 (5.0–7.2)	12 (6–152) µS·cm-1
Organic carbon		
0.09% (0.04–0.29%)		

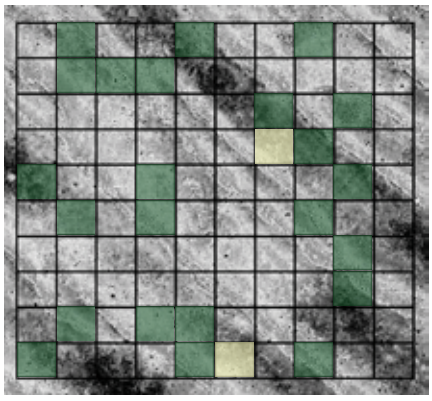
The dominant soil reference group of the Observatory is Arenosols. Except for two profiles with Calcisols, all profiles are classified as Ferralic Rubic Arenosols. This expresses the uniform character of the reddish and nutrient poor substrate of aeolian origin. With respect to their base saturation, the Arenosols can be qualified as 'Dystric', 'Eutric' or 'Hypereutric'. Hypercalcic Petric Calcisols occur in two positions of the inter-dune corridors.

The pH values show a relatively small range with a median at pH 6.0 and no variation with depths. Electrical conductivity was very low and varies only little, with slightly higher values in the topsoil. Few outliers with values above 50 µS cm^{-1} are found under trees or shrubs, which are the preferred shady locations for animals and are thus slightly higher in nutrients. The generally extremely low values suggest nutrient leaching, that may have been caused by sporadic strong rainfall events.

Within the topsoil layer, the total content of organic carbon is slightly higher, but in general, there is no variation. The fine particles (percentage of clay and silt) show no variation due to the pure sand substrate. The rooting space shows only small variations with the exception of two profiles with calcrete layers. With regard to the sand fractions, the samples are predominantly medium and fine sands. Coarse sand content is typically low, but a number of samples can be grouped as sands with higher coarse sand proportion. Coarse sands are slightly more frequent in the SW-exposed flanks and the neighbouring inter-dune. This is an indication of stronger wind impact and goes along with the asymmetry of steeper south-western flanks.

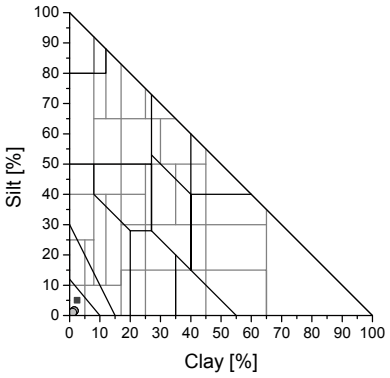
Pattern analogies in the soil and vegetation distribution are not very prominent, but evident and linked to topographic features. They override the soil chemical properties, which are nearly constant on the Observatory. The different aspects of inter-dunes that are evident on the Observatory reflect a combination of land-use history, game impact and soil physical conditions.

Map of soil profiles

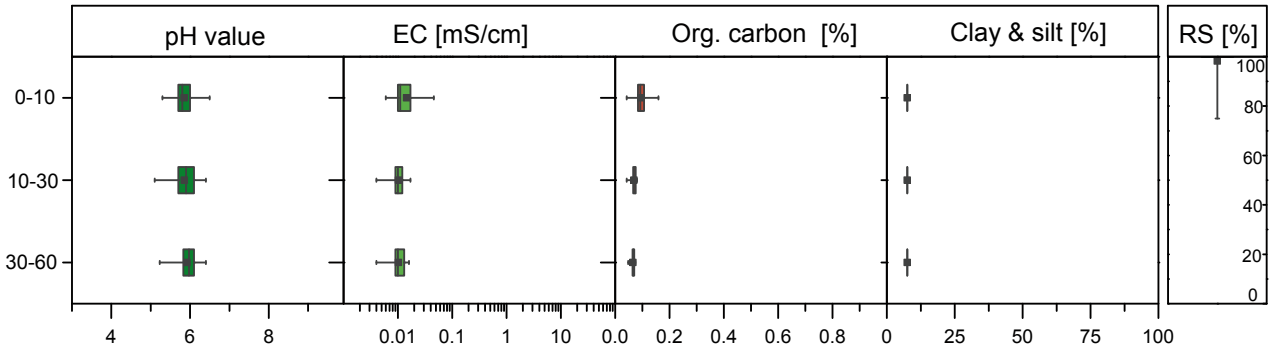


Ferralic Arenosol
Hypercalcic Calcisol

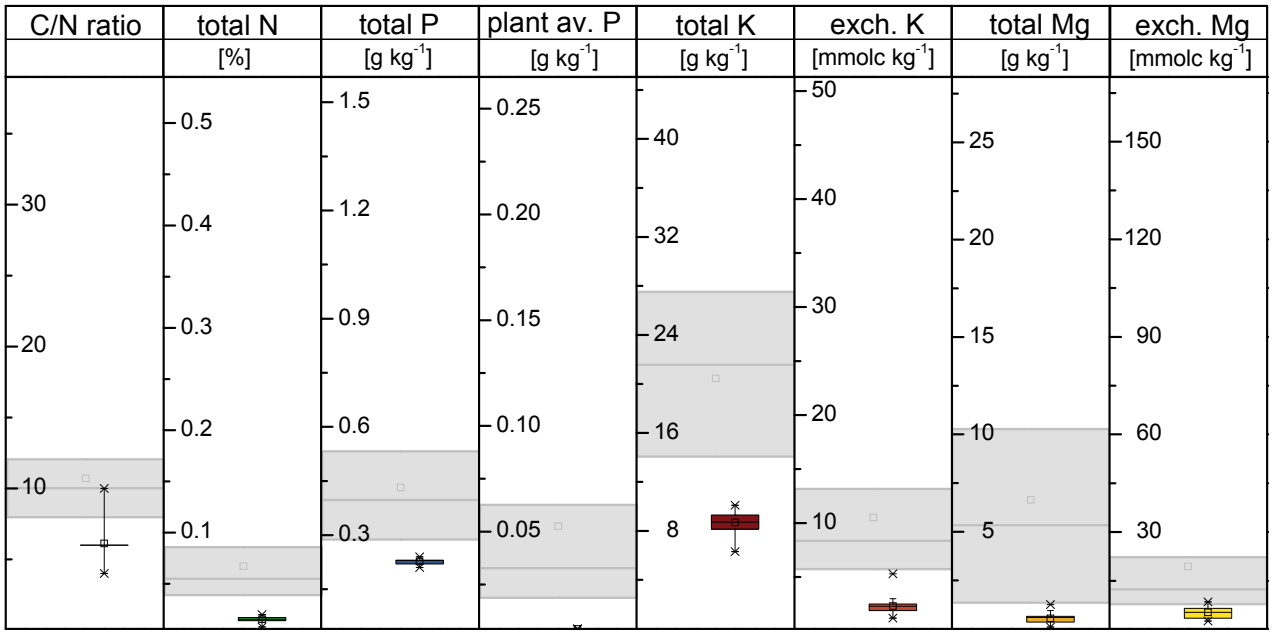
Soil texture triangle



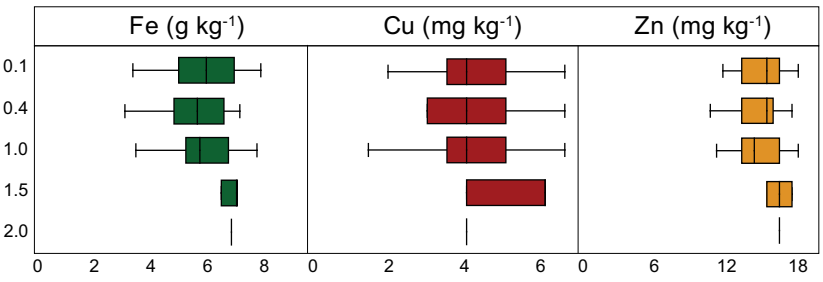
Soil characteristics



Soil nutrients



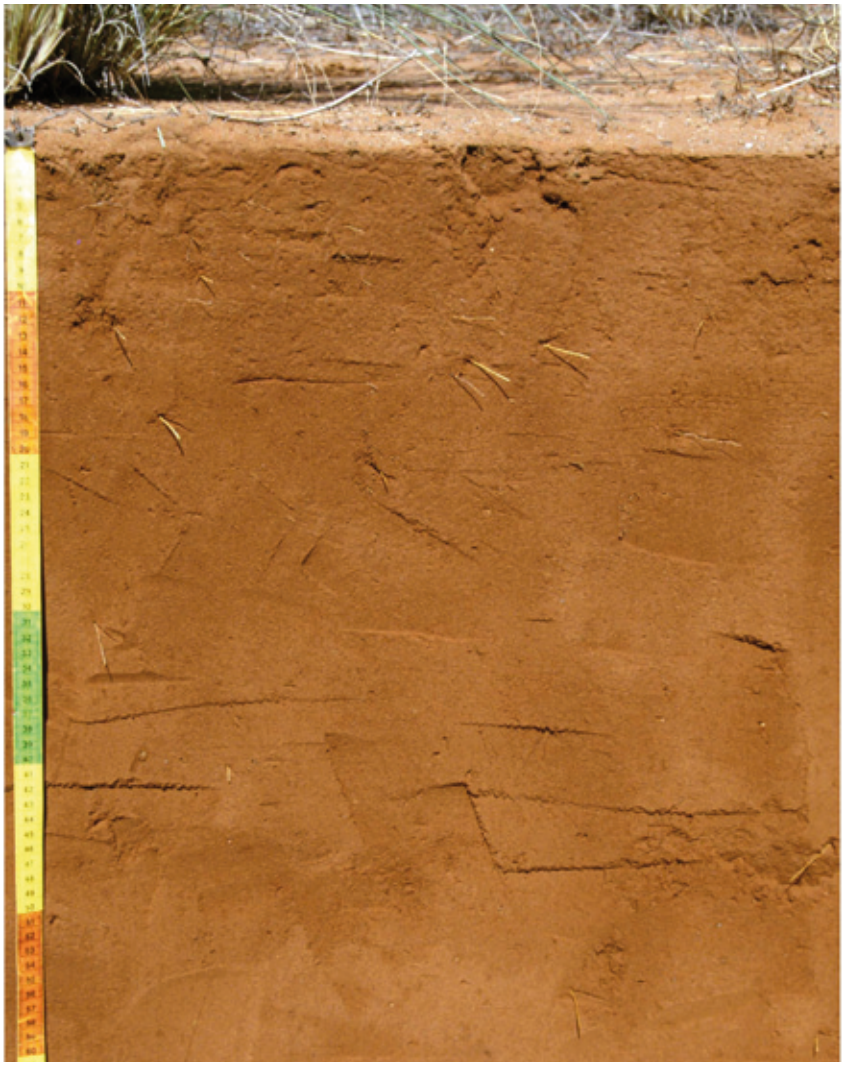
Soil micronutrients

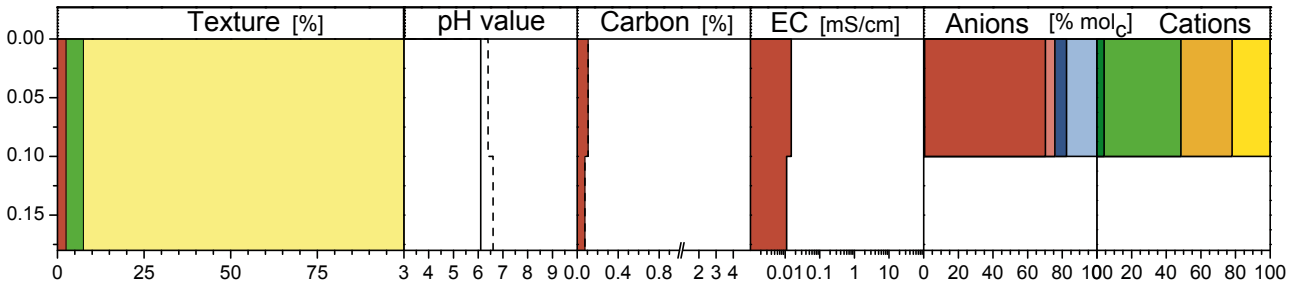


Reference profile (H94)

The **Ferralic Rubic Arenosol** is a characteristic example of the soils developed in pure and deep aeolian sands. The main texture of the profile is medium sand with only small amounts of silt and clay (< 3%). Typically, the soil surface has a coarse sand cover and is slightly aggregated by filamentous cyanobacteria. The soil properties are markedly homogenous with depth, no variations in texture occurs. The mean bulk density is 1.7 g cm^{-3} and the excavation difficulty is low. Rooting is very weak in the subsoil, while in the topsoil 11–20 roots dm^{-2} occur.

The electrical conductivity is very low with around 15 µS cm^{-1} and similar to the slightly acid soil reaction staying constant over depth. Total element content is low with highest values for potassium and iron, underlining the nutrient-poor, quartz-rich sandy substrate. However, compared to the Kalahari Sands of the northern Namibia Observatories S01 (Mile 46) and S02 (Mutompo), the sand is richer in nutrients.





Texture

- Fine silt
- Medium silt
- Coarse silt
- Clay
- Fine sand
- Medium sand
- Coarse sand

- pH ($CaCl_2$)
- pH (H_2O)
- Organic carbon
- Inorganic carbon
- Electrical conductivity

Water soluble ions

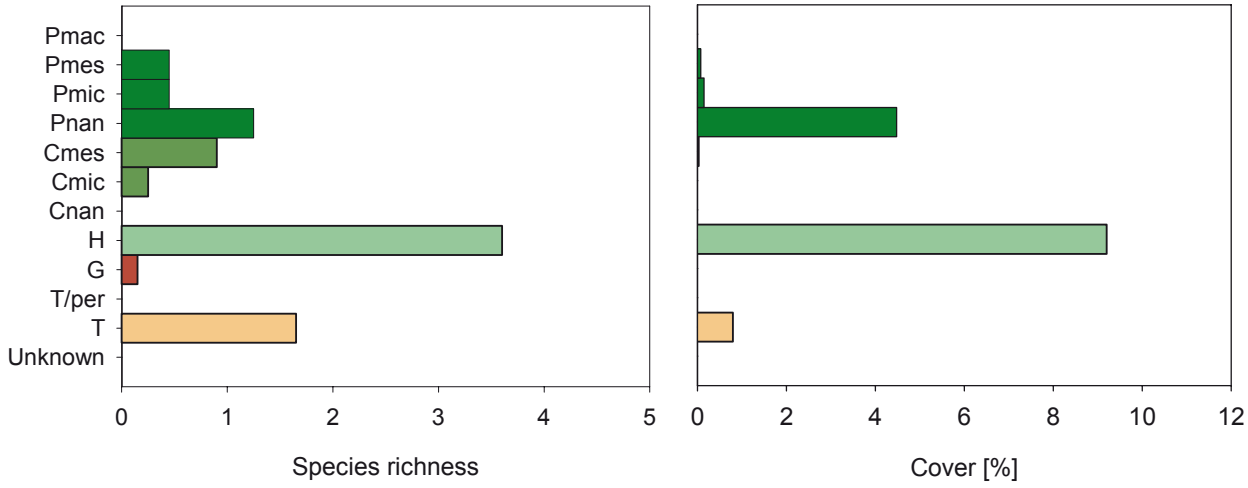
- Cloride
- Sulfate
- Nitrate
- Hydrocarbonate
- Fluoride, Bromide, Nitrite
- Calcium
- Magnesium
- Potassium
- Sodium

Responsible authors: U. Wisch, A. Petersen, A. Gröngröft & D. Mager

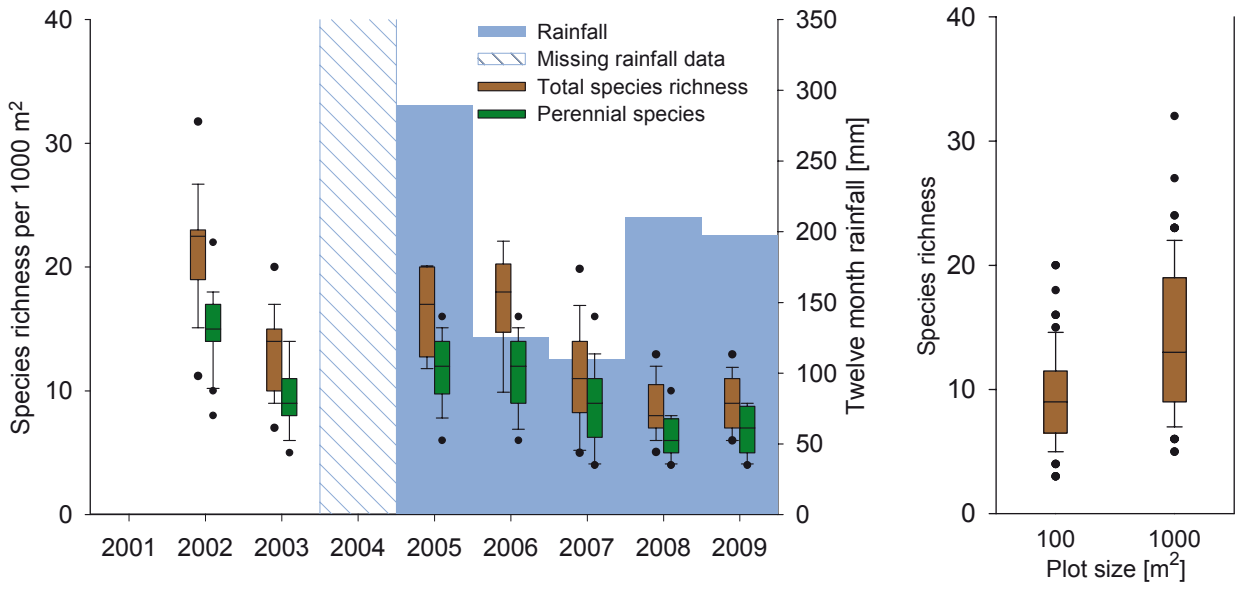
Vascular plants

Sampling period(s)	Hectare plots sampled	Biome
2002, 2003, 2005–2007	20 (R1–R20)	Thornbush Savanna
Vegetation unit (level 1)	**Vegetation unit (level 2)**	**Identification rate**
Kalahari Duneveld Bioregion	SVkd 1 Gordonia Duneveld	67% – 96% – 98%
Cumulative family richness	**Dominant families (cover)**	**Dominant families (richness)**
30	Poaceae, Bignoniaceae, Fabaceae	Fabaceae, Poaceae, Molluginaceae
Cumulative species richness (1 km²)	**Species richness (1000 m²)**	**Species richness (100 m²)**
109 – 39	15.7 (5–31)	9.4 (3–20)
***z*-value**	**Species richness change per year (1000 m²)**	**Evenness (1000 m²)**
0.225 (0.000–0.584)	-1.86	0.393 (0.115–0.683)
Evenness (100 m²)	**Simpson (1000 m²)**	**Simpson (100 m²)**
0.533 (0.072–0.780)	0.485 (0.094–0.827)	0.555 (0.045–0.820)

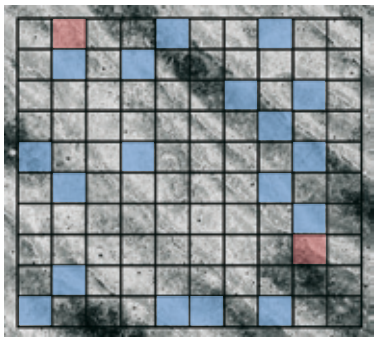
Life forms



Species richness



Map of vegetation units



The main structuring features in the landscape of the BIOTA Observatory Alpha are the parallel longitudinal dunes running from the southeast to the northwest. The relatively homogenous sandy soils of the dune valleys are shallow if underlain by superficial calcretes or deep otherwise. The vegetation, part of the Gordonia Duneveld (SVkd 1, Rutherford et al. 2006), is an open grassland with sparse occurrence of medium-sized trees such as *Acacia erioloba* (Kameeldoring), the Kalahari-endemic species *Acacia haemtoxylon* (Vaalkameeldoring), or tall shrubs such as *Lycium bosciifolium* (Slapkriedoring). Among the three most important families in terms of both species richness and cover are Poaceae and Fabaceae. Due to the high density of *Rhigozum trichotumum* (Driedoring) in some patches, the Bignoniaceae is the second most dominant plant family in terms of cover. With the vegetation being comparatively species poor, the site is among the least diverse Observatories along the BIOTA transect at all three spatial scales and has the lowest evenness of all Observatories. However, after good rainfall over the summer period, annual herbs can reach relatively high numbers and species richness.

The two vegetation units differentiated in this classification correspond to the dune and inter-dune habitats.

The *Limeum arenicolum-Stipagrostis amabilis* community (unit 1) is restricted to the parallel longitudinal dunes. Their crests are dominated by the perennial, much-branched, tall grass *Stipagrostis amabilis* (Duinriet), which is endemic to the Kalahari, the inconspicuous annual herb *Limeum areniculum* or the small shrub *Ptycholobium biflorum*. However, only *S. amabilis* reaches high cover values. *Acacia haematoxilon* occurs on the dune slopes and is thus recorded for both communities with higher consistency. The dune crests are partly semi-mobile dunes, due to disturbance by trampling and old vehicle tracks.

The *Stipagrostis ciliata-Rhigozum trichotomum* community (unit 2) dominates the broad dune valleys. The soil surface is more heterogeneous and often densely covered by soft and woody litter. Springbok (*Antidorcas marsupialis*) activity causes local trampling, which results in open patches of several meters in diameter. These open patches are often densely covered by the annual pioneer grass *Schmidtia kalahari* (Kalahari-suurgras). Besides the Kalahari-suurgras, only *S. ciliata* (Langeenboesmangras) and *R. trichotumum* (Driedoring) reach high cover values. Other species such as the smaller *Stipagrostis obtusa* (Kortbeenboesmangras) and the yellow flowering Fabaceae *Senna italica* (Elandsertjie) occur with high constancy but low cover values. The homogenous grass cover measuring up to 100 cm height is occasionally interspersed by trees such as *Acacia erioloba* and *Acacia haematoxilon*, the shrubby *Lycium bosciifolium,* or occasionally dense patches of *Rhigozum trichotumum*.

Classification table (2007)

Column		Cover	All	1	2
Number of relevés			**20**	**2**	**18**
Mean cover [%]			17.5	13.6	17.9
Mean species richness (1000 m²)			16.2	13.5	16.5
Mean soil pH			5.85	5.70	5.86
Mean electrical conductivity [µS·cm^{-1}]			14	8	15
Organic carbon [%]			0.09	0.05	0.10
Fine material			90.5	100	89.4
Soft litter			19.1	0.6	21.1
Unit 1: Limeum arenicolum-Stipagrostis amabilis community*					
T	Limeum arenicolum	0.01	10	100	.
Cmes	Ptycholobium biflorum	0.02	20	100	11
Pnan	Stipagrostis amabilis	7.00	20	100	11
Pmic	Acacia haematoxylon	0.32	45	100	39
Unit 2: Stipagrostis ciliata-Rhigozum trichotomum community*					
H	Eragrostis lehmanniana	1.23	90	.	100
Pnan	Rhigozum trichotomum	4.46	85	.	94
H	Stipagrostis obtusa	0.18	75	.	83
Pnan	Senna italica	0.03	65	.	72
T	Aristida adscensionis	0.17	55	.	61
Cmes	Aptosimum albomarginatum	0.13	50	.	56
H	Stipagrostis ciliata	10.01	95	50	100
Pmes	Acacia erioloba	0.16	45	.	50
**diagnostic species not tested for significance*					
Most frequent companions					
T	Schmidtia kalahariensis	0.74	95	100	94
H	Centropodia glauca	0.53	70	100	67
H	Requienia sphaerosperma	0.02	65	100	61
Cmes	Hermannia tomentosa	0.05	30	50	28
T	Sericorema remotiflora	0.02	30	50	28
Cmes	Lophiocarpus polystachyus	0.02	25	.	28
Cmic	Aptosimum elongatum	0.01	25	.	28
H	Indigofera alternans	0.01	25	.	28
H	Aristida meridionalis	0.18	15	.	17
G	Harpagophytum procumbens	0.01	15	.	17

Unit 1, H78, dune crest with sparse vegetation cover, 2008. Photo: R. Christiaan.

Unit 2, H95, dense grass cover in the dune valleys, 2006. Photo: R. Christiaan

Aptosimum albimarginatum, 2005. Photo: U. Schmiedel.

Senna italica, 2005. Photo: U. Schmiedel.

Aptosimum elongatum, 2007. Photo: R. Christiaan.

Responsible authors: U. Schmiedel & J. Luther-Mosebach

Vertebrates

Total species richness	Reptile species richness	Bird species richness
8	n.a.	8
Large mammal species richness	Small mammal species richness	
n.a.	n.a.	

Birds

Gruiformes	**Cranes, rails, coots, and allies**
Afrotis afra	Black Bustrard
Passeriformes	**Perching birds**
Cercomela tractrac	Tractrac Chat
Cisticola aridulus/Cisticola textrix	Desert Cisticola/Tink-Tink Cisticola
Mirafra africanoides	Fawn-coloured Lark
Mirafra apiata	Clapper Lark
Myrmecocichla formicivora	Southern Anteater Chat
Sporopipes squamifrons	Scaly-fronted Weaver
Struthioniformes	**Ostriches and relatives**
Struthio camelus	Ostrich

Scaly-fronted Weaver (*Sporopipes squamifrons*). Photo: J. Deckert.

Responsible authors: J. Deckert, A. Hoffmann & A. Mills

Seed bank dynamics in the southwestern Kalahari (S17.01)

[M.W. van Rooyen]

The seed bank dynamics of five habitats (dune crests, dune slopes, dune streets, calcrete outcrop, and riverbed) were studied on the farm Alpha. Soil samples were also collected along a grazing gradient from a watering point. Three methods of analysis were used to analyse the soil seed bank over four seasons in the year 2004. In all seasons, the dune crest habitat always had the smallest seed bank and the riverbed habitat always had the largest seed bank. The dune habitats had many species with transient seed banks while the riverbed was characterised by many species with short-term persistent and 'permanent' seed banks. Analyses of soil seed bank size along a grazing gradient showed that total seed densities derived by all examinations showed the highest seed densities closest to points of highest disturbance and lower seed densities further from the disturbance. Heavy grazing pressure favoured annual/opportunistic species such as *Schmidtia kalahariensis*, which formed very large seed banks in heavily trampled areas, whereas the occurrence of perennial grass species increased away from the watering point. The flotation method produced data mostly for hard-seeded species, while the seedling emergence methods produced data for species with small seeds, which were readily germinable.

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Functional groups related to grazing among dominant Kalahari plant species (S17.02)

[M.W. van Rooyen]

Common southern Kalahari plant species were investigated for a selection of traits and the changes in trait categories over a range condition gradient observed. The range condition gradient was established through a floristic analysis of a series of farms that have been subjected to differing grazing intensities. A selection of 112 Kalahari species was investigated for a set of vegetative and reproductive traits and the trait data set analysed by Principal Coordinates Analysis (PCoA). The distribution of the species according to trait categories in the ordination plane was used to identify functional groups. The functional groups represented species with similar trait scores. The functional groups were compared with the distribution of species in Canonical Correspondence Analyses (CCAs) over the range condition gradient. In this manner it was determined whether functional groups were associated with range condition in the dune crest, dune slope and dune street habitats. It was established that in general species within a functional group did not correspond with a specific range condition state. Functional groups at times responded differently to grazing intensity in different habitats.

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Photo: N. Dreber

Nama Karoo

Boundaries
- International Boundary
- Provincial Border

Hydrography
- River
- Periodical River
- Salt Pan
- Lake
- Wetland

Contour Levels
- up to 300 m
- up to 600 m
- up to 900 m
- up to 1200 m
- up to 1500 m
- up to 1800 m
- more than 1800 m

Communications
- Motorway
- Road
- Railway

Populated Places
- City
- Provincial Capital
- Capital

- Transect
- S32 Elandsberg — BIOTA Observatory

Uwe Ulrich Jäschke & Karen Langner • HTW - University of Applied Sciences Dresden

Farm in the Nama Karoo. Photo: N. Dreber.

Nama Karoo

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The Nama Karoo Biome is characterised by sparse vegetation composed of shrubs and grasses, which is comparatively species-poor and does not comprise many local endemics. The soils are shallow, weakly structured, and skeletal. Due to much lower annual rainfall than the adjacent Thornbush Savanna, taller trees are scarce and largely restricted to riverbeds. Farming with sheep and goats is the typical landuse type in this biome. Large parts of this biome with low economic potential have been assigned as communal farmland. Low productivity and high landuse pressure have resulted in degradation of these rangelands, which further reduces their productivity.

The BIOTA Observatories in the Nama Karoo cover the entire southern part of Namibia between Karios (S12) in the very south, to Narais (S39) and Duruchaus (S40) in the central region. The latter two Observatories are characterised by Nama Karoo vegetation although the geographic area is otherwise dominated by Thornbush Savanna vegetation. Two Observatory pairs (Narais and Duruchaus in central Namibia, and Gellap Ost (S10) and Nabaos (S11) in southern Namibia) represent two fence-line contrasts in the Nama Karoo that are the result of different landuse practices and intensities. [U. Schmiedel]

General data

Number	Name	Alternative name(s)
S39	Narais	n.a.
Implementation	**Country**	**Province/ region**
2004	Namibia	Khomas
District/ constituency	**Locality**	**Farm name**
Windhoek	near Rehoboth	Narais
Latitude	**Longitude**	**Altitude**
23.120380 S	16.896578 E	1624 m a.s.l.
Rainfall season	**Biome**	**WWF Ecoregion**
Summer	Nama Karoo	AT1309 Kalahari xeric savanna
Agro-Ecological Zone	**Relative intensity of land use**	**Tenure**
CPL3-7	Low	Private
Type and history of landuse	**Land owner**	
Farming with cattle	Private	

Narais (S39)

Grassy dwarf-shrub savanna at the Narais Observatory. Photo: J. Deckert.

The BIOTA Observatory Narais (S39) is situated in the Khomas region of Namibia close to the border of the Hardap region, 25 km northwest of the town Rehoboth. The area is flat to slightly undulating and at a height of approximately 1600 m a.s.l. Nearby mountain ranges at heights of more than 2000 m a.s.l. represent the southernmost peaks of the Central Namibian Highland. The area is situated at the transition zone between three major biomes: the Nama Karoo with shrub and dwarf shrub savanna in the south, the Highland- or Mountain Savanna in the north, and the Kalahari Sandveld in the west. Mean annual precipitation in this summer rainfall area is 289 mm.

The area around Rehoboth is inhabited by the Rehoboth Basters who farm mainly with cattle, sheep, and goats on privately owned land. In comparison to the neighbouring Observatory Duruchaus (S40), the Narais Observatory is situated on a comparatively large farm, which is only used for cattle and goat farming at low stocking densities. A clear and stable fence line contrast marks the difference in landuse between the two farms.

The Observatory was established together with the directly adjacent Observatory Duruchaus to monitor changes under different landuse intensities and management on privately owned farm land. Close to the Observatories, at the fence line between Narais and Duruchaus, grazing exclosures and experimental grazing plots of 1.4 ha each were fenced. Monitoring of these plots aims at providing information

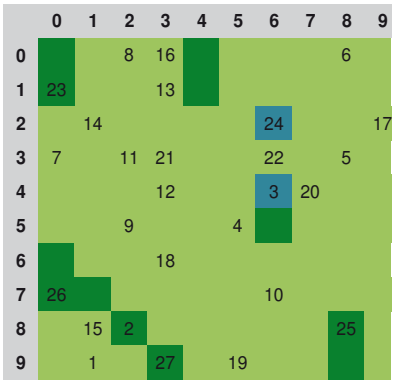
on changes in biodiversity and range condition following complete cessation of grazing, or rest for a limited time, under different baseline conditions.

Responsible authors: D. Wesuls & D.H. Haarmeyer

Remote sensing and landscape

Geomorphology	Geological units	Lithological units
Plain, pan, drainage line	Witvlei Group in Damara Supergroup and Gariep Complex	Limestones and sandstones
Mean EVI	**EVI absolute range**	**Mean leaf area index**
0.142 (0.109–0.230)	0.102 (2005)–0.281 (2008)	0.48

Grid map of Observatory



1 Chamaephytic shrubland/ grassy plains
2 Drainage lines
3 Vlei / pan

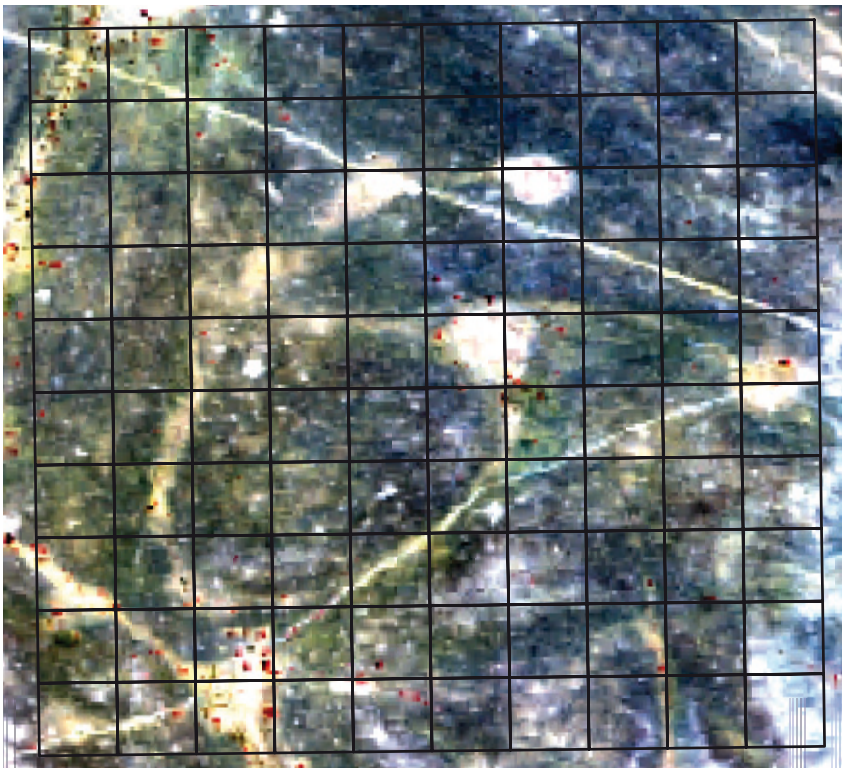
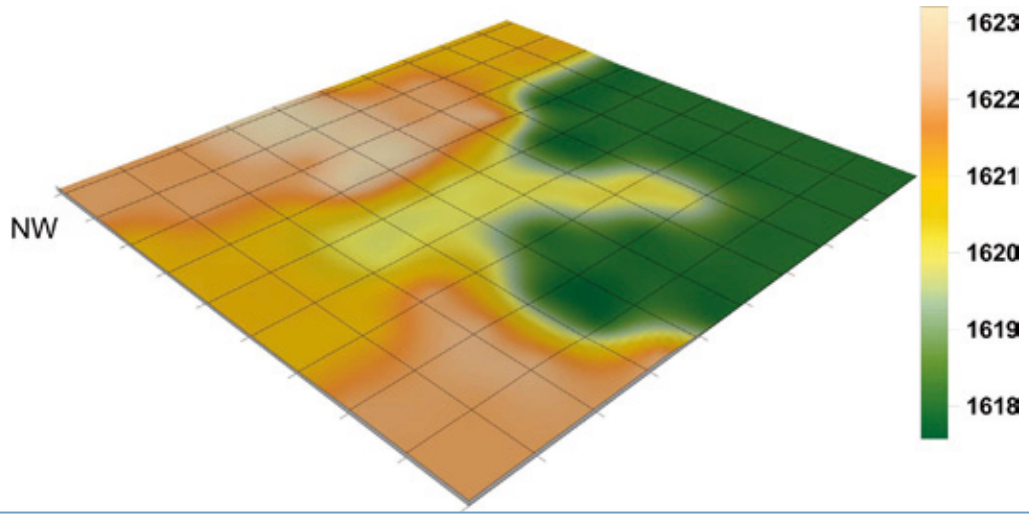


Image: HYMAP, 4 November 2005

Elevation model of Observatory



Landsat image

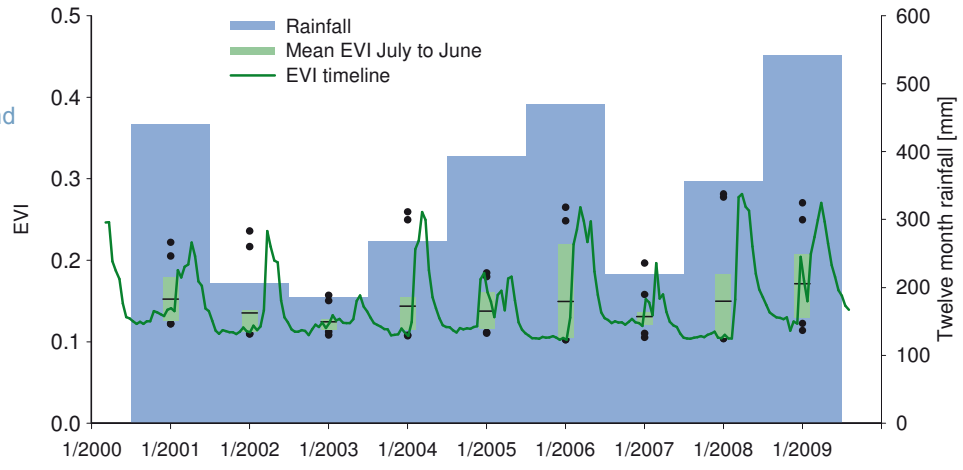
The plateau on which the Observatory is situated is intersected by the Oanob River, which crosses the area east of the Observatory and drains to the south. The predominantly dry river bed (at the end of April) can be identified by white tones, and remaining water by blue tones. A tributary of the Oanob River crosses the image in the south-west.

The reddish to brown colours on the mountain slopes indicate dense (shrub) vegetation, but are sometimes induced by the geology. Green colours indicate less dense mixed grass and shrub vegetation. The light green to light grey and blue-grey colours indicate scattered vegetation cover and a high percentage of bare soil (e.g. the area about 3 km southwest of the Narais Observatory). While the Narais Observatory and the surrounding farmlands show a dense vegetation cover (deep green tones) at the end of the rainy season in the south (end of April 2006), there is a clear fenceline contrast at the Duruchaus Observatory (with much lighter green and green-grey tones) indicating higher stocking rates at the farm Duruchaus.

Scene: 178/76, acquisition date: 24 April 2006

MODIS time series

Temporal patterns of annual rainfall, vegetation cover, and phenology



Responsible authors: M. Keil & T. Labitzky

Climate

Data from BIOTA weather station

Location	Recorded period	Mean temperature
Narais (S39)	2004–2009	19.1 (-2.4–34.7) °C
Mean solar radiation	**Mean wind speed**	**Mean annual precipitation**
562 (398–824) MJ·m^{-2}·month^{-1}	2.2 (9.2) m·s^{-1}	289 (108–570) mm
Mean annual potential evapotranspiration	**Interannual precipitation variability**	**Mean relative humidity**
1428 mm	176%	44% (13–86%)
Aridity index (UNEP)		
0.20 (semi-arid)		

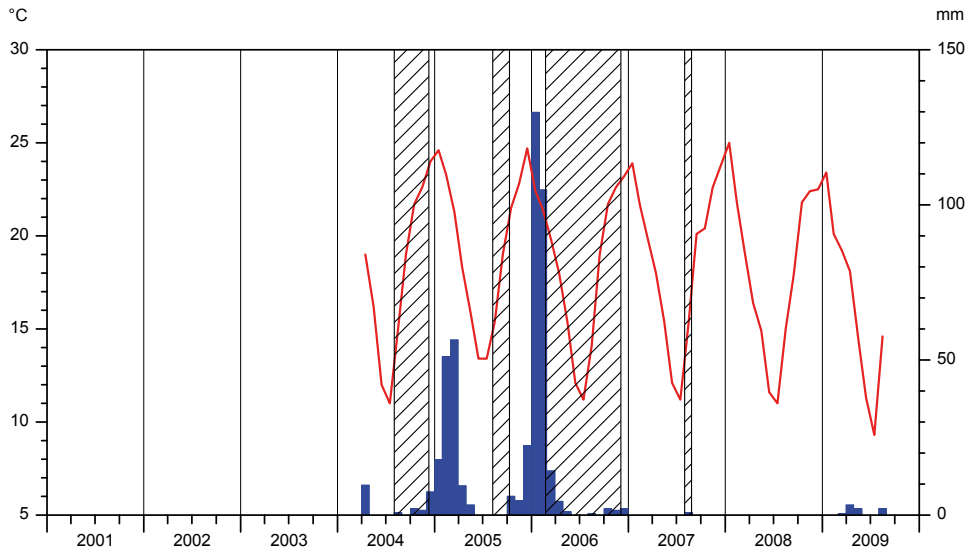
Modelled data

Mean temperature	Mean annual temperature range	Mean diurnal temperature range
18.6 (3.2–31.6) °C	10.8 °C	16.8 °C
Mean annual precipitation	**Precipitation seasonality**	**Percentage winter precipitation**
289 mm	108%	12% (strong summer)
Climate type	**Length of dry season**	**Aridity index (De Martonne)**
BWh	9 months	10.1 (semi-dry)

The climate at the Observatory is characterised by semi-arid conditions. Rainfall shows a strong seasonality with the major portion of rain falling during the summer season, peaking in February. The mean annual rainfall over the observation period was 289 mm, which approximates the average rainfall recorded at the Observatories in the region, but is the wettest within the Nama Karoo. However, substantial interannual variability is evident. The observed near-surface air temperatures show a moderate seasonal cycle. The mean annual temperature is 19.1°C, making this the coldest Observatory within this biome. The observed mean minimum temperature is above the freezing point, but there is still a possibility of the occurrence of frost during the months of May to August. Compared to the interpolated long-term data taken from the WorldClim dataset, a slightly warmer mean annual temperature is evident at the station. Temperature extremes of the station records also deviate from the interpolated data, showing warmer maximum and colder minimum temperatures. The mean annual rainfall observed at the BIOTA weather station corresponds to the amount derived from the WorldClim dataset. Rainfall data were recorded by the farm owner of Duruchaus and not from the BIOTA weather station.

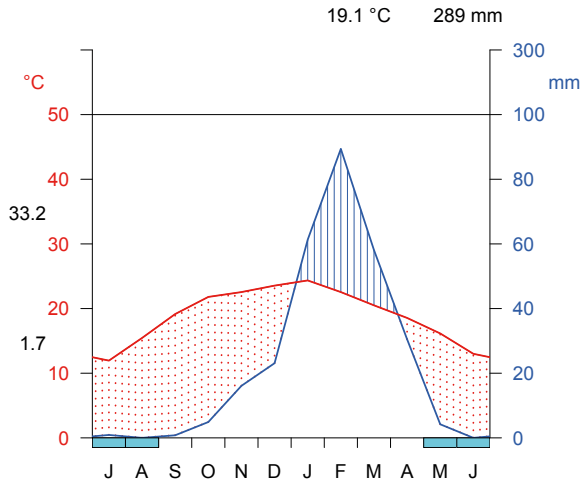
The observed near-surface winds at the Observatory are predominantly constituted of westerly flow throughout the year. Mean wind speed shows a pronounced annual cycle in the evenings and a moderate annual cycle in the mornings and early afternoons. Strongest winds occur in the afternoons during spring, reaching up to about 15 km/h.

Time series: rainfall and temperature

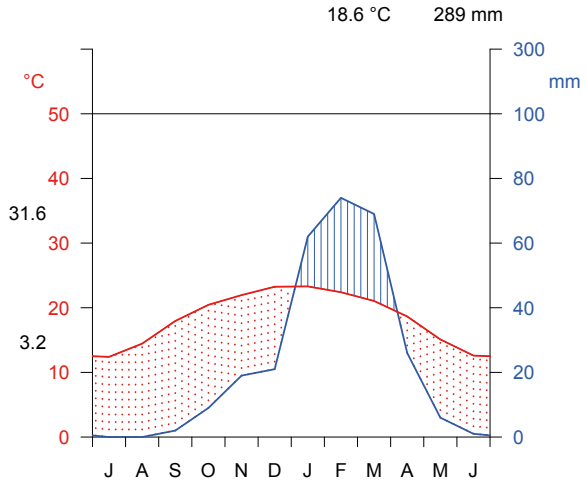


Climate diagrams

Recorded data (BIOTA)

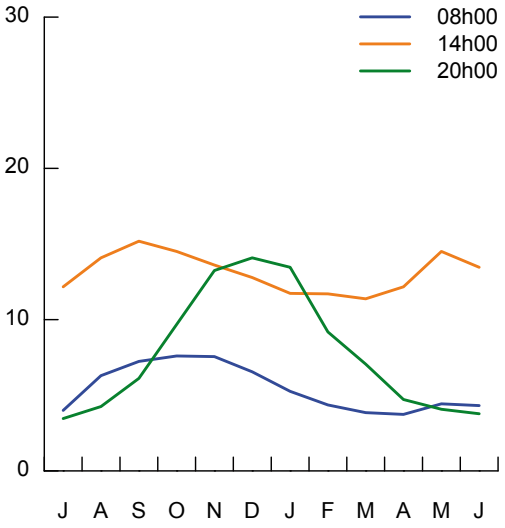


Modelled data (WorldClim)

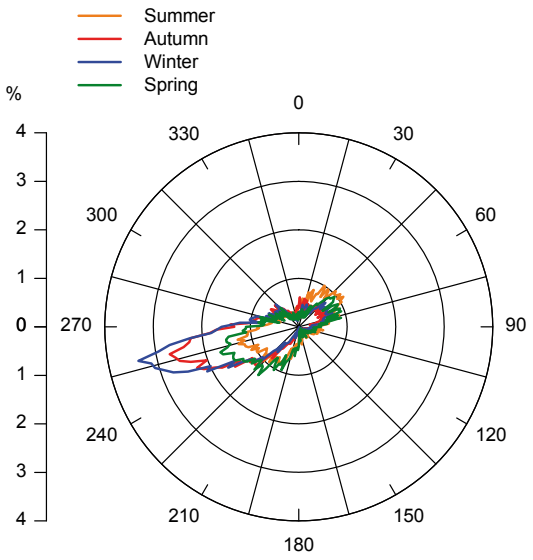


Wind diagrams

Speed



Directions



Responsible authors: K. Berger. A. Haensler & J. Luther-Mosebach

Soils

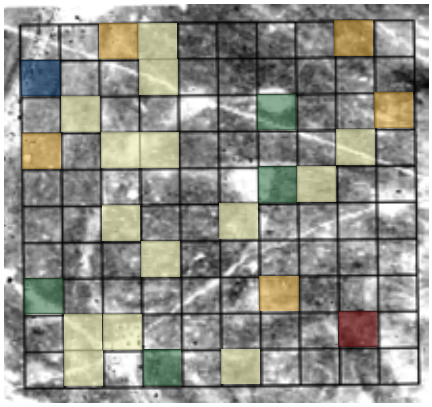
Year of sampling	Hectare plots sampled	SOTER unit
2005	25 (R1–25)	NA51
Soilscape	**Dominant soil group(s)**	**Reference group richness**
Calcisol	Calcisol	4
Soil unit richness	**Soil unit evenness**	**Soil ecotype richness**
5	0.372	13
Parametric space	**pH**	**Electrical conductivity**
3.34	7.9 (6.2–8.7)	74 (1–167) $\mu S \cdot cm^{-1}$
Organic carbon		
0.71% (0.35–1.29%)		

An unusually high number of reference groups (Calcisol, Leptosol, Regosol and Luvisol) can be found unevenly distributed on the Observatory.

The soils on the Observatory are characterised by the occurrence of an often shallow calcrete layer or a petrocalcic horizon which leads to a 76 % clear majority of Calcisols. Epipetric Calcisols are the dominant soil unit found on the plains. The petrocalcic horizon is 20–40 cm thick adjacent to a calcareous sandstone saprolith. One example for this soil type is the reference profile described in detail for Observatory S40 (Duruchaus). In parts where the dry river dissection leads to erosion of the petrocalcic horizon or where a loose calcrete structure is evident, Endoleptic Calcisols are characterised by a contact zone to the underlying sandstone and a high content of finely distributed calcium carbonate. In strongly eroded sections, these units are associated with shallow Leptosols. Cutanic Luvisols are found in pan situations. These heavily textured profiles are free of coarse rock fragments and show signs of clay movement and subsoil clay enrichment.

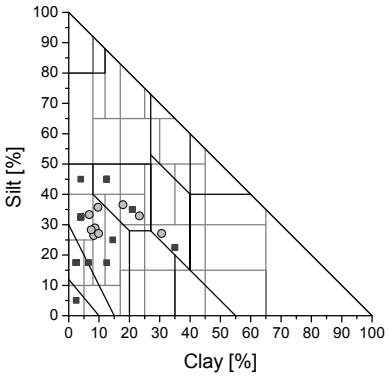
The pH values and the electrical conductivity display very low variability. Only the Luvisol-sites and a few calcium carbonate free topsoils have lower pH values and enhance the range slightly. The most important variations occur in the organic carbon, the texture, and the rooting space, affected by the depth of calcretes and the bedrock layer as well as the content of coarse rock fragments. Vertical differences in the profiles are relatively low, except for the slight decrease in organic carbon and the lower silt and clay content in the topsoil.

Map of soil profiles

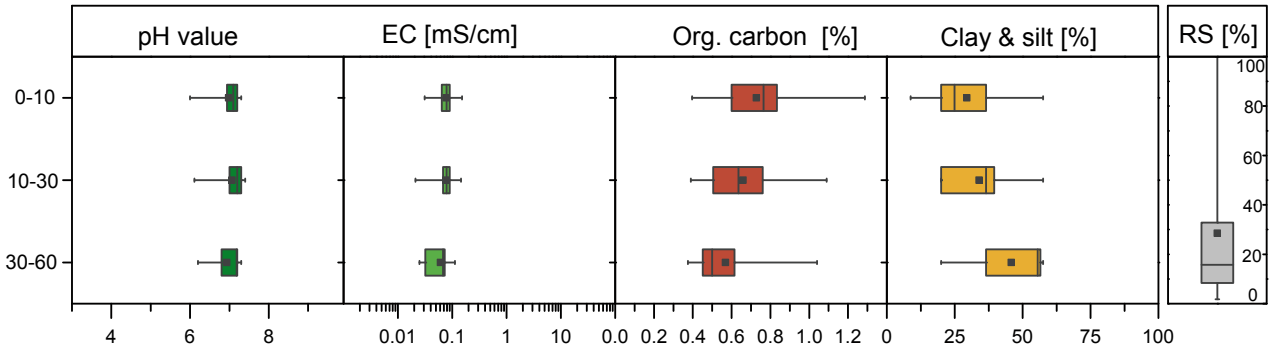


Endoleptic Calcisol
Hypercalcic Calcisol
Cutanic Luvisol
Endoleptic Regosol
Hyperskeletic Leptosol

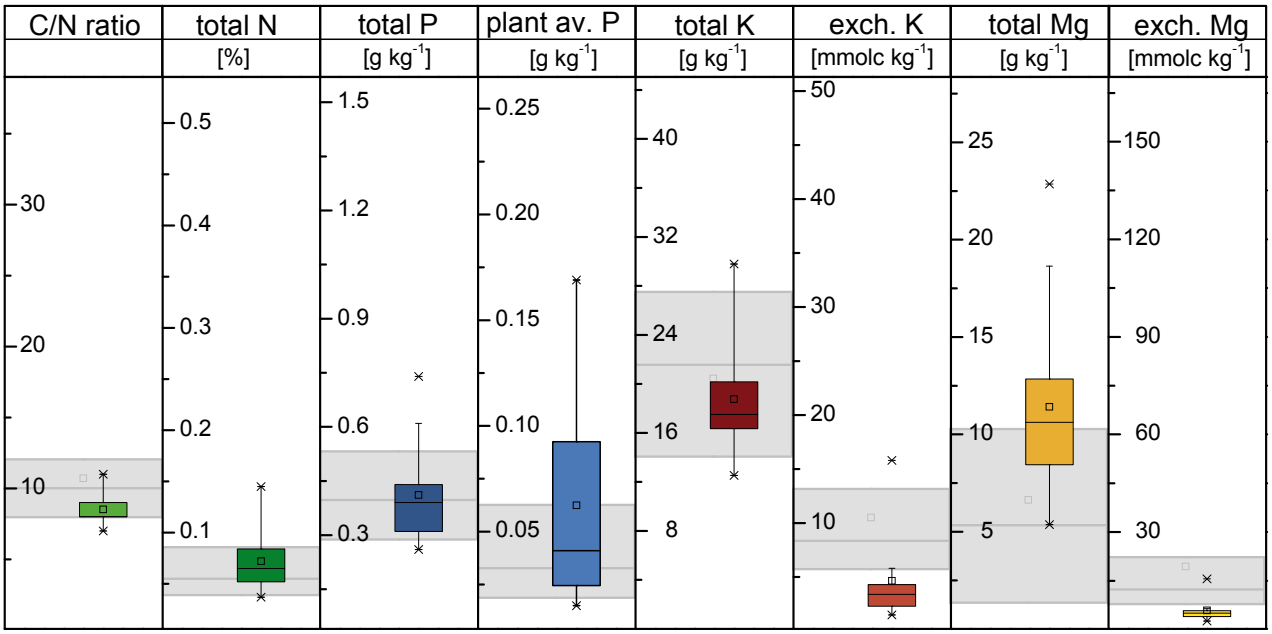
Soil texture triangle



Soil characteristics

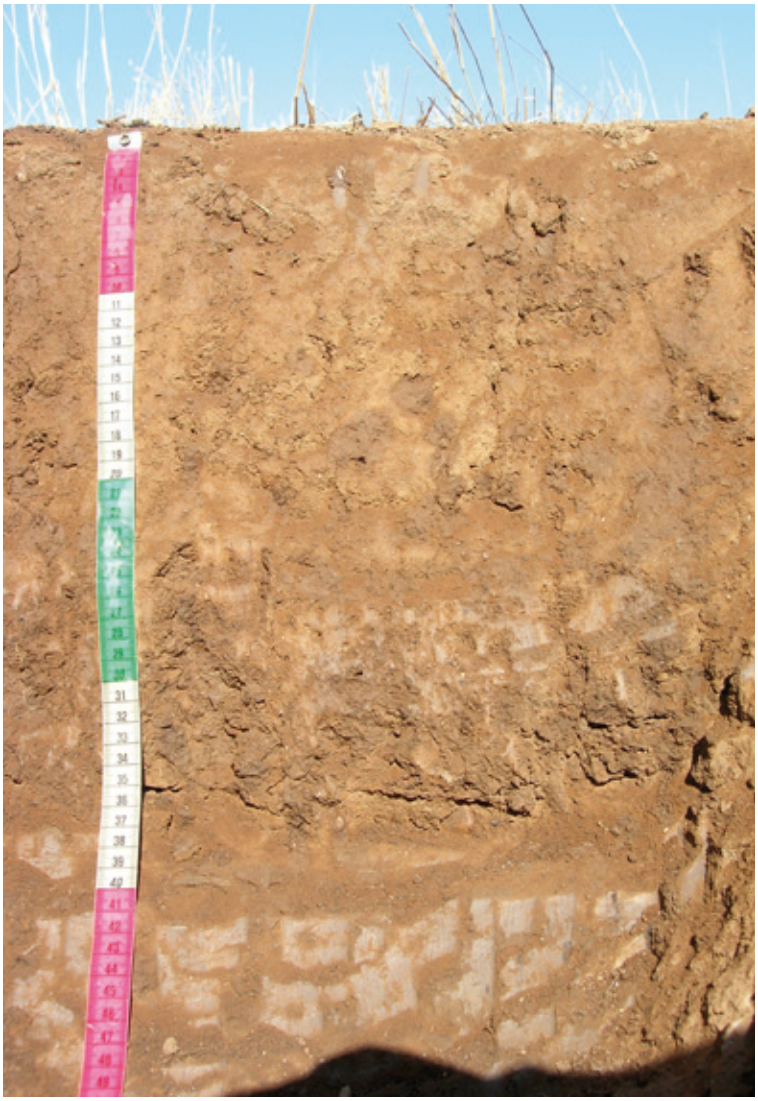


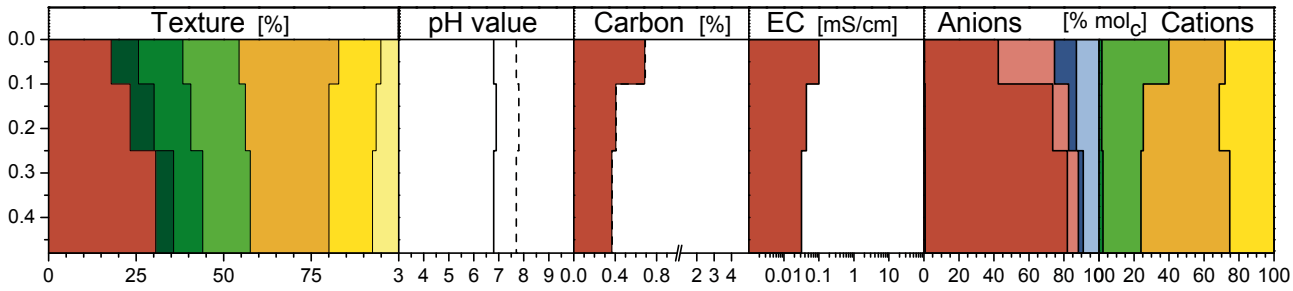
Soil nutrients

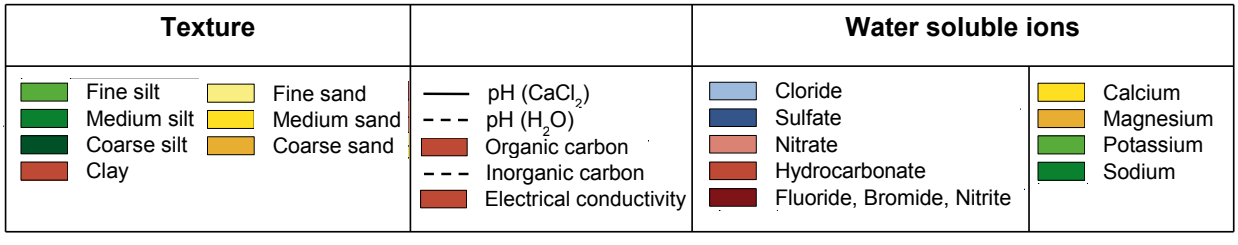


Reference profile (H46)

The **Cutanic Luvisol** is a typical example of pan soils. These soils differ strongly from the Calcisols due to the deep substrate and the lack of coarse rock fragments and calcic horizons.
The texture is loam to clay loam with a marked clay increase with depth. In the subsoil, clay coatings indicate clay movement. The soil structure is subangular-blocky with a moderate excavation difficulty. The soil reaction is slightly alkaline and pH values are significantly lower than in the Calcisols. The electrical conductivity is lower. The entire profile is free of calcium carbonate, which might be responsible for the lack of biological soil crusts.
Only few roots can be found (2–5 roots dm^{-2}). The content of water soluble ions is very low with 3–4 $mmol_c\ kg^{-1}$and exchangeable cations ranging from 85 to 140 $mmol_c\ kg^{-1}$.







Responsible authors: U. Wisch, A. Petersen, A. Gröngröft & D. Mager

Biological soil crusts

Sampling period(s)	Hectare plots sampled	Types of soil crusts
2004	3 (R31, R51, R99)	2, 3, 4, 5a
Crust thickness	**Cover**	**Carbon [weight %]**
> 4 mm	up to 30%	1.253
Nitrogen [weight %]	**Chlorophyll *a* [mg/m²]**	**Chlorophyll *a+b* [mg/m²]**
0.113	70	117

In this Observatory, a large variety of different crust types covers the soil between grass tufts (see Photo). Especially climax-stage soil crusts, like chlorolichen and moss-dominated crusts, are frequently found. As compared to Observatory S40 (Duruchaus), the crusts observed here are better developed and cover larger proportions of the area. Moderate grazing intensity allows crusts to flourish.

Cyanobacteria not yet treated.

Green algae: *Bracteacoccus giganteus, Chlorella* sp.1, *Chlorosarcinopsis* cf. *variabilis, Neospongiococcum granatum, Spongiochloris minor.*

Soil crust with a dense cover of a liverwort of the *Riccia*-group, dry leaflets in the closed position (open when wet). Photo: K. Deutschewitz.

The observatory is characterised by a dense crust coverage between grass tufts. Photo: K. Deutschewitz.

Biological soil crust characteristics

	H33	H82	H91
Soil characteristics	Brown very fine silt or clay; very few pebbles	Brown silty sand, few pebbles	Brown silty sand, few pebbles
Crust characteristics	Dark, partly very thick BSC with cyanobacterial and green-algal lichens (*Psora* sp.)	Widespread very thick and stable lichen-dominated BSC with green-algal lichens	Widespread stable lichen-dominated BSC with green-algal lichens
Chlorophyll a [mg/m²]	79.38	82.08	49.73
Chlorophyll a+b [mg/m²]	130.41	136.38	84.08
Carbon [weight %]	1.62	0.95	1.19
Nitrogen [weight %]	0.14	0.1	0.1

Responsible authors: B. Weber, K. Deutschewitz, S. Dojani, T. Friedl, T. Darienko, K. Mohr & B. Büdel

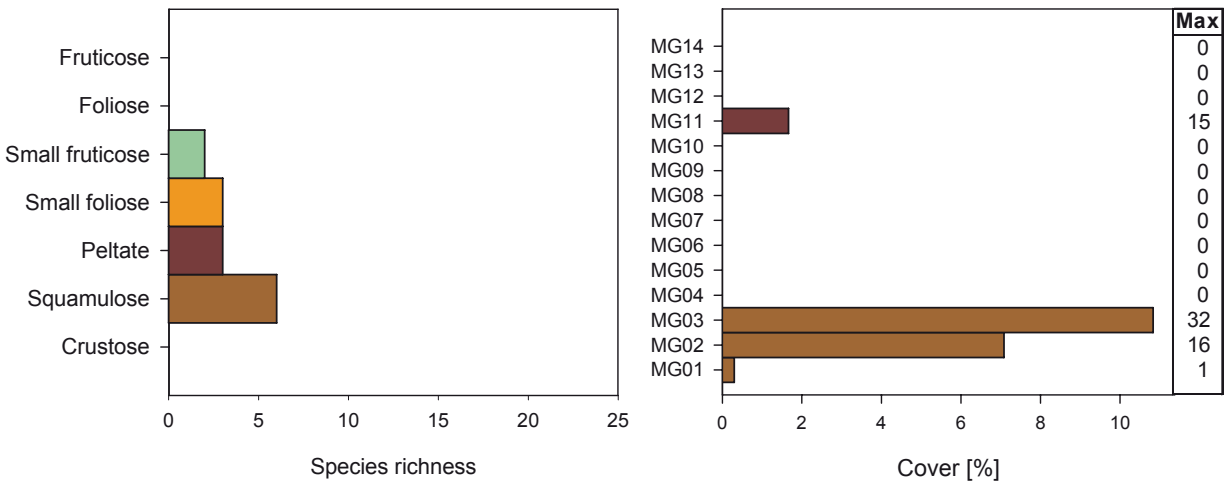
Lichens

Sampling period(s)	Hectare plots sampled	Cover
2006, 2009	12 (R1–R10, R51, R86)	20% (0–43%)
Total species richness	**Species richness on soil [1 km²]**	**Species richness on rock [1 km²]**
28	14 (50%)	10 (36%)
Species richness on plants [1 km²]	**Species richness on soil [1000 cm²]**	
4 (14%)	3 (0–7)	

This Observatory is one of the richest in terricolous lichens despite limited occurrence of fog and relatively low precipitation in this area. However, the location at high altitude favours dewfall during the early morning hours. The positive influence of dew as a water source for lichens is suggested by the dominance of the squamulose growth form among the soil-inhabiting taxa and by the fact that the photobionts are predominantly cyanobacteria. In addition, the calcareous soils present in several hectare plots, also have a positive influence on species richness and cover. Epiphytic lichens are less well-represented compared to other savanna sites, mainly due to the lower availability of potentially suitable plant substrates and of closed vegetation formations.

The mean cover of lichens is relatively high in the 12 investigated hectare plots, and is promoted by the relatively open vegetation, and favourable soil conditions. Hectare plots with high grass cover and acid soils (pH < 7.0) (i.e. H46) possess low lichen cover or lichens are completely absent. The most common lichen morphogroups are cyanolichens (MG03) and green algal lichens with a squamulose growth habit (MG02).

Life forms



Collema crispum.
Photo: M. Schultz,
L. Zedda & G. Rambold.

Heppia adglutinata.
Photo: M. Schultz,
L. Zedda & G. Rambold.

List of Taxa

Terricolous (on soil):

Collema coccophorum
Collema crispum
Collema tenax
Heppia adglutinata
Heppia arenacea
Heppia despreauxii
Lichinella stipatula
Peccania cf. subnigra
Peltula patellata
Peltula radicata
Placidium lacinulatum
Placidium squamulosum
Placidium tenellum
Psora crenata

Saxicolous (on rock):

Lichinella myriospora
Peltula obscurans var. deserticola
Peltula obscurans var. hassei
Peltula omphaliza
Psorotichia cf. murorum
Psorotichia cf. schaereri
Psorotichia frustulosa
Psorotichia hassei
Psorotichia sp.
Rinodina sp.

Epiphytic (on plants):

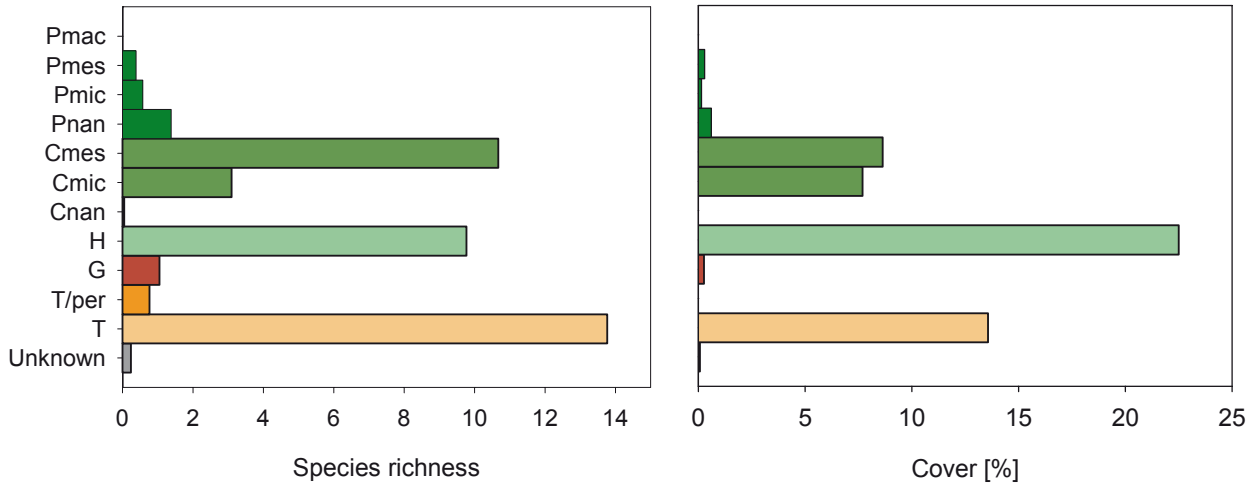
Candelaria concolor
Flavopunctelia flaventior
Peltula corticola
Pyxine cocoës

Responsible authors: L. Zedda & G. Rambold

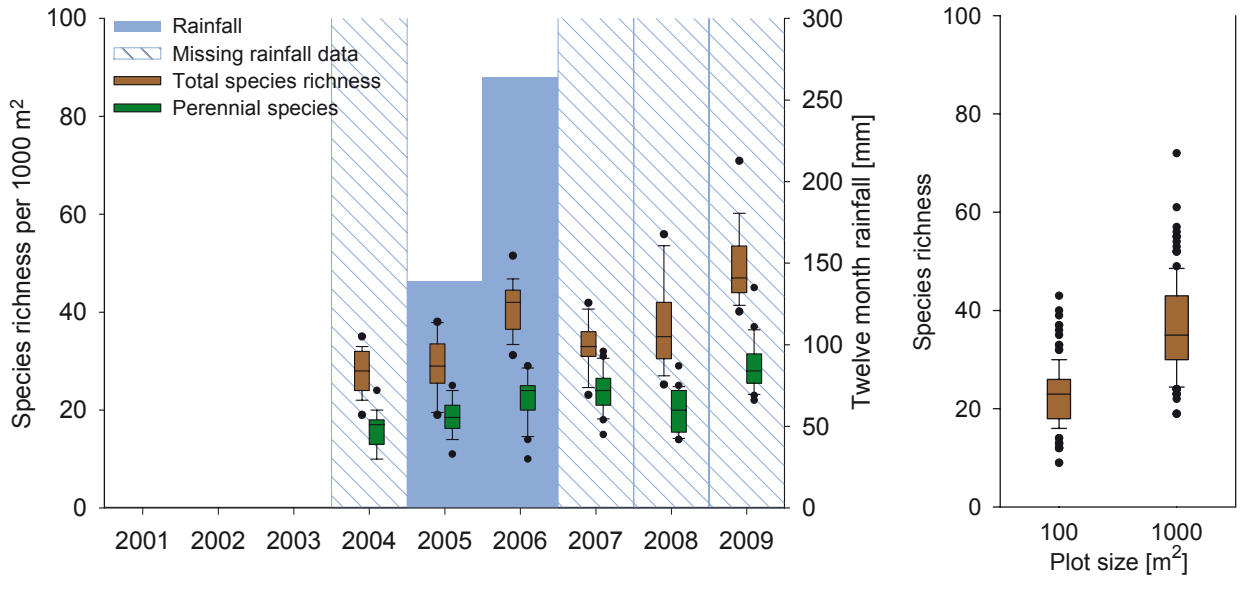
Vascular plants

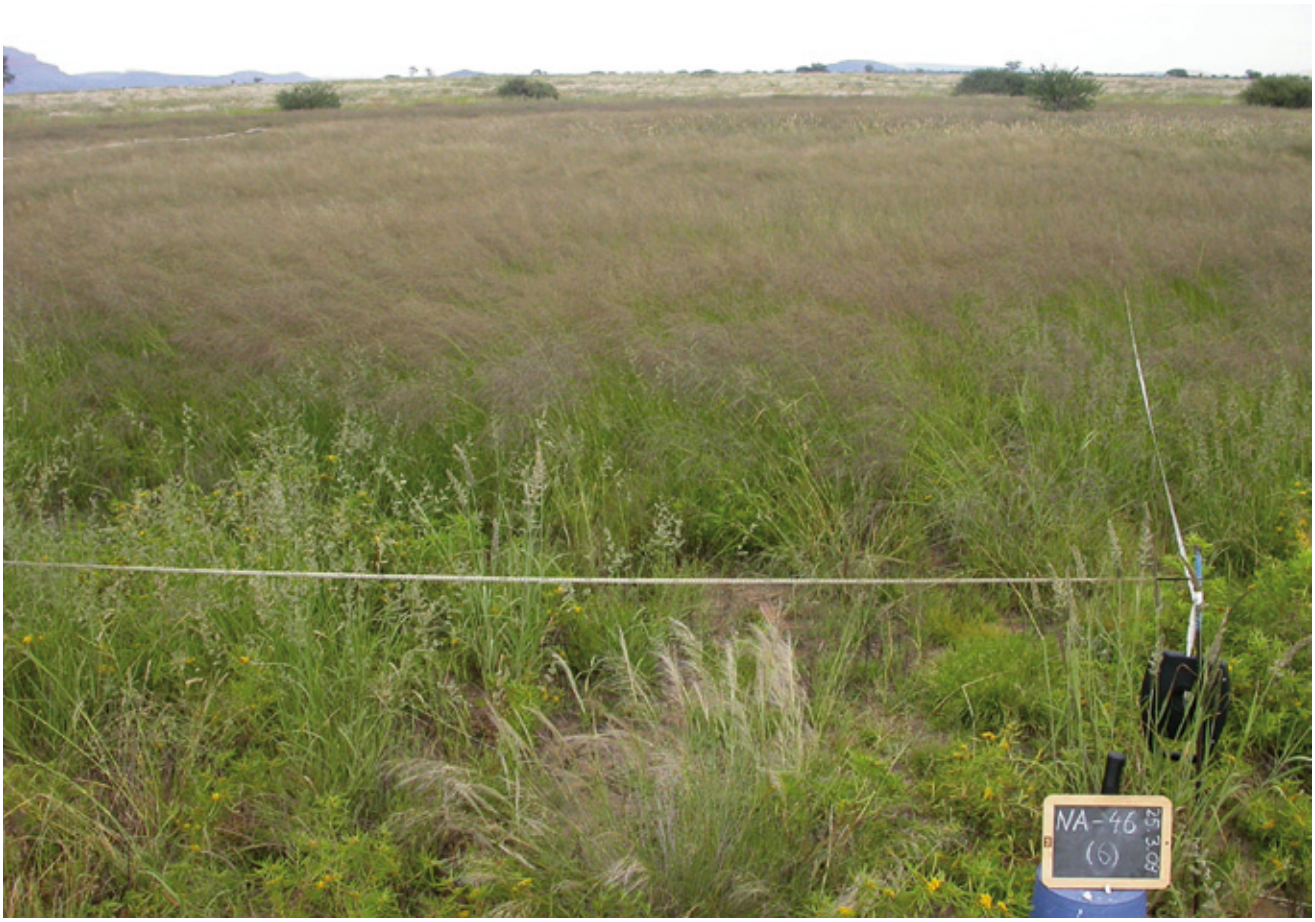
Sampling period(s)	Hectare plots sampled	Biome
2004–2009	20 (R1–R20)	Nama Karoo
Vegetation unit (level 1)	Vegetation unit (level 2)	Identification rate
Highland Savanna	n.a.	85% – 95% – 96%
Cumulative family richness	Dominant families (cover)	Dominant families (richness)
48	Poaceae, Amaranthaceae, Asteraceae	Poaceae, Asteraceae, Fabaceae
Cumulative species richness (1 km²)	Species richness (1000 m²)	Species richness (100 m²)
215 – 138	36.4 (19–72)	22.6 (9–43)
z-value	Species richness change per year (1000 m²)	Evenness (1000 m²)
0.206 (0.000–0.409)	1.12	0.601 (0.289–0.783)
Evenness (100 m²)	Simpson (1000 m²)	Simpson (100 m²)
0.612 (0.321–0.798)	0.794 (0.444–0.902)	0.752 (0.343–0.891)

Life forms



Species richness

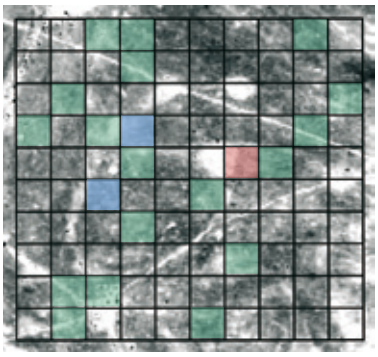




Unit 1 in a wet year, H46, 2009. Photo: D. Wesuls.

Unit 1 in a dry year, H46, 2007. Photo: J.Möller.

Map of vegetation units



The Vegetation on the Observatory Narais (S39) comprises elements of the Nama Karoo biome, and of the Thornbush and Highland savanna. Topographically, the area is an elevated plain surrounded by the most southerly peaks of the Khomas Highland of Namibia. It is a relatively flat area underlain by a massive calcrete layer, which is sometimes eroded away at drainage lines, and shallow circular depressions where rainwater collects—the so called "vleis" or pans. These habitats are characterised by higher soil clay content and distinct vegetation. The calcrete layer in the plains prevents the growth of taller shrubs and trees, which mostly occur along the shallow drainage lines and around the pans. Dwarf shrubs and grasses are adapted to grow on shallow calcareous soils and cover most of the Observatory area. Three vegetation units, occurring within three different habitat types, can be distinguished at the Observatory.

The *Eragrostis rotifer-Schkuhria pinnata* community (unit 1) is represented by only one plot (Ha 46), which is situated on a clay pan. Depending on rainfall, the pan is water-logged and completely covered with vegetation during years of good rainfall and is almost bare with only a few grasses and prostrate herbs during low rainfall years. The distribution and timing of rainfall also influences which species (e.g. the perennial *Eragrostis rotifer* also known as Vley Love-grass or the annual *Chloris virgata* also known as Vley Finger-grass) dominate the community in any given year. In some years,

Classification table (2009)

Column		Cover	All	1	2	3
Number of relevés			**20**	**1**	**2**	**17**
Mean cover [%]			56.4	*111*	60.6	52.9
Mean species richness (1000 m²)			49.2	*40*	57.5	48.8
Mean soil pH			7.1	*6.8*	7.20	7.09
Mean electrical conductivity [µS·cm^{-1}]			81.6	*100*	68	81
Organic carbon [%]			0.60	*0.69*	0.34	0.61
Nitrogen [%]			0.07	*0.08*	0.04	0.07
Inclination [°]			0.1	*0.0*	0.0	0.2
Fine material [%]			50.3	*17.0*	49.5	52.3
Gravel [%]			3.2	*1.0*	1.5	3.5
Stones 2-6 cm [%]			2.5	*1.0*	1.0	2.8
Stones 6-20 cm [%]			2.0	*1.0*	0.5	2.2
Stones 20-60 cm [%]			0.9	*0.0*	0.0	1.1
Soft litter			1.2	*10.0*	0.8	0.8
Biotic crust			28.6	*0.5*	25.0	30.6
Unit 1: Eragrostis rotifer-Schkuhria pinnata community						
Hper	Alternanthera pungens	0.50	5	*100*	.	.
T	Corchorus tridens	0.10	5	*100*	.	.
T	Indigofera holubii	0.10	5	*100*	.	.
T	Indigastrum argyroides	0.50	5	*100*	.	.
Hper	Indigofera vicioides	0.10	5	*100*	.	.
T	Hibiscus trionum	0.10	5	*100*	.	.
H	Cyperus sp.	0.10	5	*100*	.	.
Hper	Hypertelis bowkeriana	0.10	5	*100*	.	.
T	Schkuhria pinnata	0.50	5	*100*	.	.
H	Selago dinteri	0.10	5	*100*	.	.
Unit 2: Cyphostemma hereroense-Panicum lanipes community						
Pmic	Cyphostemma hereroense	0.10	10	.	100	.
H	Aristida congesta	0.18	24	.	100	17
T	Nelsia quadrangula	0.10	24	.	100	17
H	Panicum lanipes	0.23	14	*100*	100	.
Unit 3: Stipagrostis ciliata-Eriocephalus luederitzianus community						
Cmic	Aptosimum cf. lineare	0.22	81	.	.	94
H	Stipagrostis ciliata	0.58	76	.	.	89
T	Lotononis platycarpa	0.10	76	.	.	89
T	Tragus berteronianus	0.10	90	.	50	100
T/Hper	Kohautia cynanchica	0.10	57	.	.	67
Most frequent companions						
Cmic	Leucosphaera bainesii	7.39	100	*100*	100	100
H	Eragrostis echinochloidea	4.76	100	*100*	100	100
Cmes	Aizoon schellenbergii	3.81	100	*100*	100	100
Cmes	Eriocephalus luederitzianus	2.34	100	*100*	100	100
Hper	Geigeria pectidea	1.23	100	*100*	100	100
G	Pseudogaltonia clavata	0.26	100	*100*	100	100
T/Cmic	Sida ovata	0.16	100	*100*	100	100
T	Enneapogon desvauxii	10.0	95	.	100	100
T	Melinis repens	0.75	95	.	100	100
Cmes	Pentzia calva	0.57	95	*100*	100	94
T	Enneapogon cenchroides	0.44	95	*100*	100	94
H	Cenchrus ciliaris	0.37	95	.	100	100
Cmes	Melhania virescens	0.24	95	*100*	100	94
H	Stipagrostis obtusa	6.64	90	.	100	94
H	Stipagrostis uniplumis	2.97	90	*100*	100	89
Cmes	Melolobium microphyllum	0.49	90	.	100	94
Hper	Dicoma capensis	0.12	90	.	100	94
Cmes	Barleria rigida	0.23	86	.	100	89
T	Euphorbia inaequilatera	0.12	86	.	100	89

Continued on next page

Unit 2, H30, 2008. Photo: D. Wesuls.

Unit 3, H76, 2005. Photo: D. Lübsen.

species such as *Geigeria pectidea* (Rivier Vermeerbos), *Schkuhria pinnata*, or the prostrate legume *Indigastrum argyroides* can cover most of the area. Shrubs such as *Acacia hebeclada* and *Phaeoptilum spinosum* occur around the circular pan. This community is the most variable in terms of species composition, and when rainfall is sufficient, it can be the most productive in terms of biomass.

The *Cyphostemma hereroense-Panicum lanipes* community (unit 2) characteristically occurs along shallow drainage lines. These drainage lines can be relatively wide because the inclination of the plain is not very steep, which causes a relatively slow runoff after rainfall. Runoff is further weakened by the presence of a dam built by the Narais farmer south of the Observatory. The plant community is therefore composed of plants which are adapted to short-term water logging and which have higher water requirements, e.g. the perennial, rhizomatous grasses *Panicum lanipes* and *Sporobolus nervosus*. Erosion of the calcrete layer along the drainage lines allows for the growth of taller shrubs and trees, e.g. *Acacia erioloba*. A few herbaceous annual plants, which occur in the understorey below trees, are also characteristic of this community (e.g. *Nelsia quadrangula, Erucastrum arabicum* and *Chenopodium amboanum*, to name just a few).

The *Stipagrostis ciliata-Eriocephalus luederitzianus* community (unit 3) covers the largest part of the Observatory. The physiognomy of this community is characterised by varying proportions of dwarf shrubs such as *Eriocephalus luederitzianus* and *Leucosphaera bainesii,* and perennial grasses such as *Stipagrostis ciliata* and *Stipagrostis obtusa*. The matrix soil is often covered by a pronounced biological soil crust. In patches where dwarf shrubs dominate, the inter-shrub matrix is often covered by mats of *Enneapogon desvauxii,* a short annual or weak perennial grass. The common name "Eight-day Grass" refers to the quick germination and growth of this plant, which contributes to the first fresh green fodder shortly after the first rains.

Classification table (continued)

Column		Cover	All	1	2	3
Number of relevés			**20**	**1**	**2**	**17**
Cmes	Tribulus zeyheri	0.10	86	.	100	89
H	Sporobolus nervosus	3.88	81	*100*	100	78
Cmac	Aptosimum albomarginatum	0.35	81	.	50	89
T	Eragrostis porosa	0.19	81	*100*	100	78
Cmes	Lycium cf. cinereum	0.17	81	.	100	83
T	Nidorella resedifolia	0.10	81	.	100	83
Hper	Hermannia abrotanoides	0.10	81	.	50	89
H	Fingerhuthia africana	0.94	76	.	50	83
H	Oropetium capense	0.18	76	.	100	78
T	Eragrostis nindensis	2.28	71	.	100	72
T	Trianthema parvifolia	0.15	71	.	100	72
T	Aristida adscensionis	0.13	71	*100*	100	67
Cmes	Pteronia mucronata	0.76	67	.	50	72
Pnan	Pteronia glauca	0.68	62	.	50	67
T	Sericorema sericea	0.10	62	.	50	67
T	Erucastrum arabicum	0.10	62	.	50	67
Hper	Chascanum pinnatifidum	0.20	57	*100*	100	50
H	Stipagrostis hirtigluma	0.13	57	.	100	56
Cmes	Gnidia polycephala	0.22	52	.	100	50
T	Anthephora schinzii	0.21	52	*100*	100	44
Cmes	Peliostomum leucorrhizum	0.10	52	.	100	50
Cmic	Polygala leptophylla	0.10	48	.	.	56
Cmes	Felicia clavipilosa	0.10	48	.	100	44
T	Geigeria ornativa	0.10	48	.	50	50
Hper	Platycarpha carlinoides	0.28	43	*100*	100	33
T/Hper	Indigofera auricoma	0.20	43	.	.	50
Cmic	Pegolettia pinnatilobata	0.10	43	.	.	50
Pmes	Acacia erioloba	0.74	38	.	100	33
H	Eragrostis trichophora	0.16	33	.	100	28
Cmic	Limeum aethiopicum	0.10	33	.	.	39
H	Cyperus amabilis	0.10	33	.	50	33
Pmic	Acacia mellifera ssp. detinens	0.30	29	.	50	28
Hper	Helichrysum candolleanum	0.10	29	*100*	.	28
H	Chloris virgata	0.48	24	*100*	50	17
Hper	Osteospermum muricatum	0.46	24	*100*	100	11
Cmes	Aptosimum tragacanthoides	0.18	24	*100*	100	11
T	Ipomoea sinensis	0.10	24	*100*	100	11
T	Chenopodium amboanum	0.10	24	.	50	22
Hper	Corchorus asplenifolius	0.10	24	.	50	22
Pnan	Phaeoptilum spinosum	0.68	19	.	50	17
H	Eragrostis truncata	0.30	19	.	.	22
Pmic	Acacia hebeclada ssp. hebeclada	0.20	19	*100*	.	17
H	Schmidtia pappophoroides	0.10	19	.	50	17
T	Eragrostis pilgeriana	0.10	19	*100*	100	6
Hper	Cleome suffruticosa	0.10	19	.	.	22
H	Aristida meridionalis	0.10	19	.	.	22
Cmes	Hermannia modesta	0.10	19	.	50	17
T	Pogonarthria fleckii	0.10	19	*100*	.	17
Pnan	Pechuel-loeschea leubnitziae	0.10	19	*100*	.	17
Hper	Convolvulus argillicola	0.10	19	*100*	.	17
n.a.	Barleria sp.	0.37	14	*100*	50	6
T	Kyphocarpa angustifolia	0.10	14	.	.	17
Cmes	Tapinanthus oleifolius	0.10	14	.	.	17
Pnan	Catophractes alexandri	0.10	14	.	.	17

The Narais Observatory, 2005. Photo: D. Wesuls.

View from Narais to the southern peaks of the Khomas Highland, 2005. Photo: D. Wesuls.

Responsible authors: D. Wesuls & J. Luther-Mosebach

Termites

Taxon richness	Abundance index	Dominant (sub-) family
6	14	Hodotermitidae

In total, six termite species were encountered at this Observatory. Among them, *Hodotermes mossambicus* (see Photo) was found most frequently. This species is know as the "harvester termite" (Afrikaans: Grasdraertermiete) and belongs to the few termite species that forage uncovered on the soil surface. It feeds mainly on dry grass and small twigs which are stored in several food chambers. The chambers may be located only a few centimetres beneath the soil surface but may also be deeper in the soil close to the underground hives. Several galleries interconnect several hives. This species does not build mounds, but surface signs can be observed in the form of soil dumps where workers deposit soil particles presumably during construction work on the nest and gallery system (see Photo). Fresh material that is deposited on top of these dumps can be distinguished by the darker colour caused by the higher water content (see picture in the termite chapter of the Observatory S35/Gobabeb).

H. mossambicus is a widespread species and is of economic importance as it attacks crops. Because new colonies establish most successfully in areas that have been heavily denuded of grass cover, they often damage land that is affected by overgrazing or droughts. However, this species promotes soil turnover and is an important decomposer, especially in arid regions. As it often occurs in great abundance, it is a valuable food source for predators like the bat-eared fox (*Otocyon megalotis*), numerous smaller insectivorous mammals, birds, and reptiles, which in turn play a part in controlling the numbers of harvester termites.

Soil dumps of *Hodotermes mossambicus*. Photo: C. Grohmann.

Hodotermes mossambicus workers collecting grass which was coloured to aid in locating the chambers used for food storage. Photo: C. Grohmann.

List of taxa

Taxon	(Sub-)family	Frequency Index	Feeding substrate
Hodotermes mossambicus	Hodotermitidae	0.36	g
Odontotermes sp. 1	Termitidae (Macrotermitinae)	0.18	f (g, l, w)
Amitermes	Termitidae (Termitinae)	0.09	s, w, g
Angulitermes	Termitidae (Termitinae)	0.09	s, w, g
Psammotermes allocerus	Rhinotermitidae	0.09	w, d
Trinervitermes	Termitidae (Nasutitermitinae)	0.09	s, w, g, l, m

Responsible authors: C. Grohmann & K.E. Linsenmair

Vertebrates

Total species richness	Reptile species richness	Bird species richness
5	n.a.	5
Large mammal species richness	Small mammal species richness	
n.a.	n.a.	

Birds

Gruiformes	**Cranes, rails, coots, and allies**
Afrotis afra	Black Bustrard
Pteroclidiformes	**Sandgrouse**
Pterocles namaqua	Namaqua Sandgrouse
Passeriformes	**Perching birds**
Prinia flavicans	Black-chested Prinia
Myrmecocichla formicivora	Southern Anteater Chat
Parisoma subcaeruleum	Chestnut-vented Tit-Babbler

Responsible authors: J. Deckert, A. Hoffmann & A. Mills

The people

Study period	Size of study area	Mean age of farmers
2004–2006	14,642 km²	59 (30–84) years
Education of farmers	**Ethnicity of farm owners**	**Ethnicity of farm workers**
From no formal education to university degree	Baster	Nama, Damara, Ovambo
Markets		
Auctions, livestock traders, local abattoirs		

The socio-cultural and institutional background of the Rehoboth farmlands

The region of Rehoboth is inhabited by the Basters, who represent about 2% of the Namibian population. This former homeland comprises the town of Rehoboth, the seventh largest city in Namibia, and farmlands, which were used exclusively by Baster farmers for animal husbandry until the independence of Namibia in 1990. Although anyone is entitled to own a farm in this area today, most farmers are still Basters. Around 1895 the Basters started to distribute land to community members and thus initiated private land ownership. According to a survey estimate for the year 2000, there existed 753 privately owned farms in the Rehoboth area, covering about 1.303.000 ha (Lang 2005). The surveyed farm boundaries are registered in the deeds office in Rehoboth town. Besides freehold title land, the region also includes small areas of communal land as well as state owned land. Due to a long-running fragmentation process the private farmland in Rehoboth is characterised by small farm sizes. Detailed information about the farm system, the fragmentation process and the accompanied effects are provided in Chapter IV.3.

The agricultural sector is dominated by men, with only four of the 30 land users interviewed within the social anthropological study conducted within the BIOTA framework being female. All of them were widows, who took over the farm management after their husbands had passed away. The average age of farmers is 59 years, with many of them possessing many years of experience in the field of animal husbandry. Most land users do not rely solely on income from farming, and part-time farming is a widespread phenomenon within the region. Many land users, including owners of large farms, have an additional income besides farming, and are for instance shop owners, teachers or medical doctors. Only some farmers are members of one of the three local farmer unions with only one third of the interviewed land users stating that they are actively involved in a union and regularly visit meetings.

Local biodiversity knowledge

A description of the inhabitant's local ecological knowledge and their perceptions of degradation is provided in Chapter IV.3.

Responsible authors: C. Limpricht & C. Naumann

Landuse

Observatory farm		
Sampling period	Size of Observatory farm	Recommended stocking rate
2004–2006	88 km²	2 ha·SSU^{-1}
Actual stocking rate	Number of camps	Number of farm worker households
2.8–3.3 ha·SSU^{-1}	22	5
Number of boreholes		
6		

Study area		
Size of study area	Size of commercial farmland	Number of farms (total)
14,642 km²	13,030 km²	Approx. 753
Number of farms surveyed	Mean number of camps per farm	Mean farm size
30	5 (0–22)	27 km²
Mean number of farm worker households per farm	Mean number of boreholes per farm	Farming activities
2 (0–7)	3 (1–6)	Mixed animal husbandry
Agricultural products		
Mutton, goat meat, calves		

The Rehoboth farms are almost exclusively used for animal husbandry, predominantly for cattle, sheep and goat farming. Common cattle breeds are Simmbrah (cross breed between Simmentaler and Brahman), Brahman, Simmentaler, Bonsmara, Hereford, Ngunie, and Afrikaner. Cattle marketing is mainly done through auctions, however some farmers sell their animals directly to abattoirs or to private livestock traders. Dominant sheep breeds are Dorper, Damara, and Van-Rooien; Boergoat and Kalahari-Rooi are the main goat breeds. Small stock is predominantly sold at auctions, and to traders or abattoirs. More recently, some farmers have also started farming with game species, such as springbok, ostrich, and kudu.

Table 39.1 indicates that traditional types of livestock, i.e. cattle, sheep, and goats, are most common. From a sample of 30 land users eight farmed predominantly with cattle and eleven primarily kept small stock. The cattle farms had an average size of 4120 ha and were thus considerably larger than small stock farms (averaging 1753 ha). On 10 of the sampled farms, large and small stock were kept in almost equal parts. Although traditional types of livestock are dominant, Table 39.1 indicates that game is becoming more important. There was even one farmer within our sample who kept game exclusively on his land, however he regarded the farm as a luxury rather than a source of income.

Overstocking is a widespread problem in the Rehoboth area. In particular, small farms with multiple owners tend to be over-utilised and often show clear signs of degradation. Rotational grazing (i.e. rotation of herds between camps in order to allow the rangeland a resting period) is only practised by some land users. Many farmers are not able to apply a rotational grazing system, since their farms lack adequate infrastructure such as fenced camps and watering points.

Land management at the Observatory farm

Covering an area of 8762 ha and possessing 22 camps, the privately owned farm Narais is one of the largest and best equipped in the Rehoboth area. The owner farms with cattle, goats, and game. The average stocking rate varies between 3.3 ha/SSU (20 ha/LSU) and 2.8 ha/SSU (17 ha/LSU) in years with good rainfall and is thus lower than the recommended stocking rate of 2 ha/SSU (12 ha/LSU). Goats graze without being accompanied by a herdsman. Cattle are divided into several herds, and are rotated from one camp to another. During the rainy season cattle are shifted in two-week cycles, and during the dry season, in one or two-month cycles, depending on pasture condition. From the owner's point of view a short grazing period during the rainy season is very important. After utilisation, grasses are able to recover and cattle are therefore able to graze the most palatable species for a longer period. The Observatory camp was purchased by the owner of Narais in 1967. Today, this part of the farm is only used by cattle and springbok.

Table 39.1:
Stock occurrence on the 30 studied Rehoboth farms (source: Naumann 2009).

	Number of animals	Number of farms (n=30)
Cattle	3398	28
Sheep	5492	20
Goat	3590	19
Sheep and goat*	6347	9
All small stock	15,929	29
Springbok (*Antidorcas marsupialis*)	1534	10
Ostrich (*Struthio camelus*)	106	5
Steenbok (*Raphicerus campestris*)	139	3
Gemsbok (*Oryx gazella*)	123	2
Blesbok (*Damaliscus dorcas phillipsi*)	55	2
Kudu (*Tragelaphus strepsiceros*)	30	2
Impala (*Aepyceros melampus*)	15	1
Horse	217	26
Donkey	152	21
Mule	1	1

**Some land users provided the number of goats and sheep separately, and others in total.*

Photo 39.1: Small stock auction in Rehoboth.
Photo: C. Naumann.

Photo 39.2: Observatory camp. Photo: D. Wesuls.

Responsible authors: C. Limpricht & C. Naumann

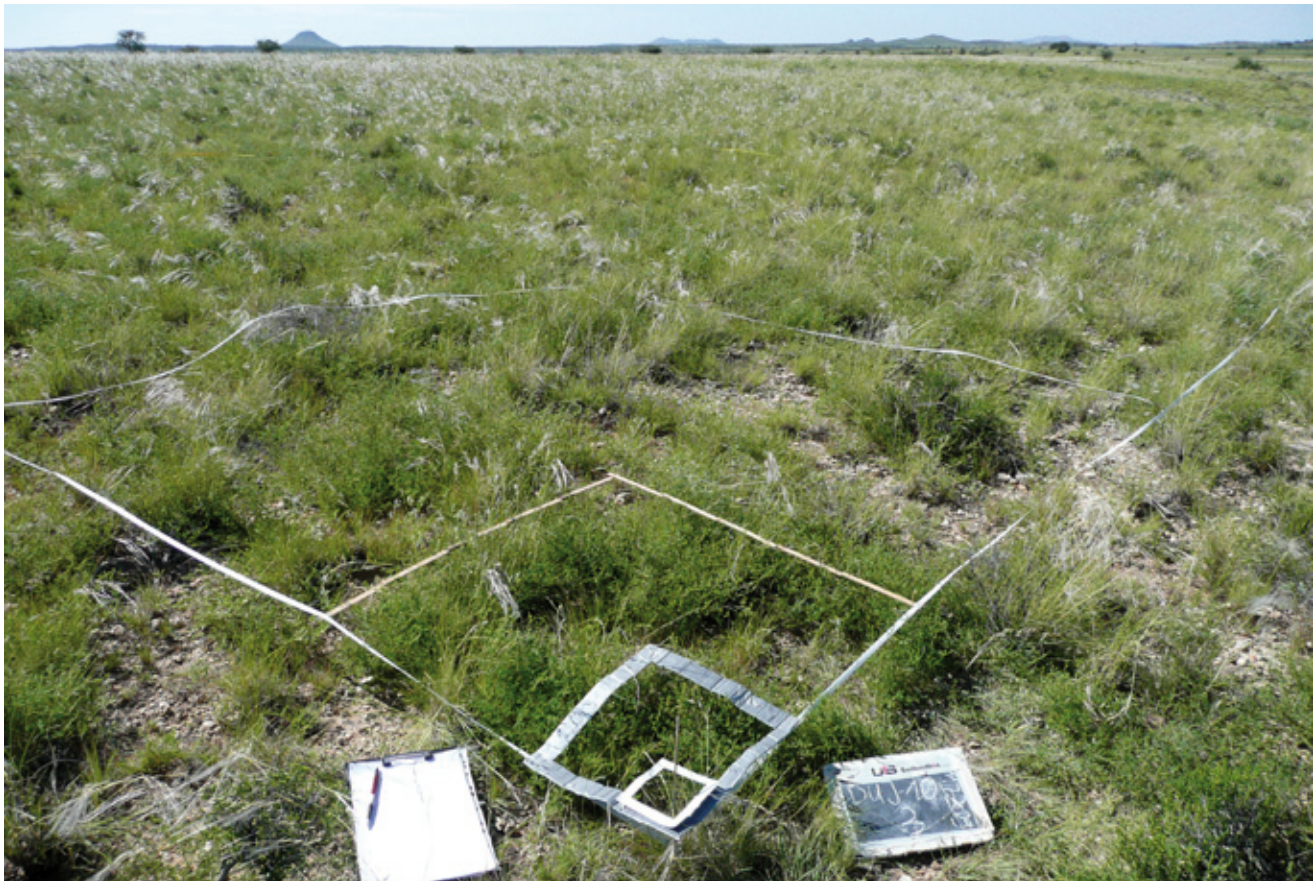
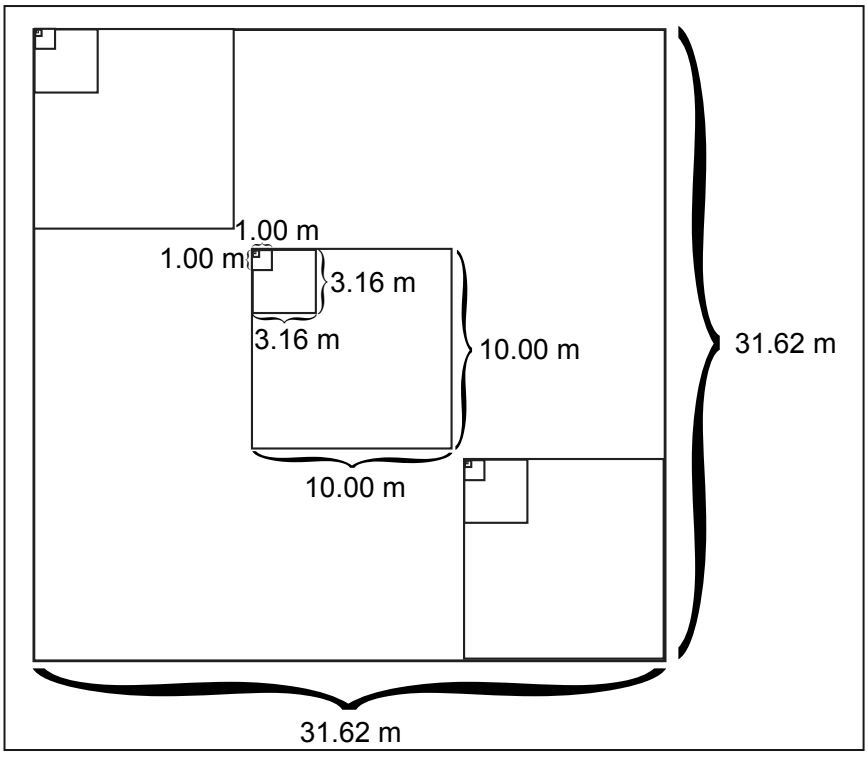


Photo SSS39.01: Nested-plot vegetation sampling on the Observatory S40/Duruchaus. The figure below explains the precise layout of the sampling design. Photo: J. Peters, 17 March 2009.

Plant diversity patterns at different spatial scales in semi-arid savannas of central Namibia (S39.01)

[J. Peters, D. Wesuls & J. Dengler]

This study on the twin Observatories Narais (S39: low-intensity grazing) and Duruchaus (S40: high-intensity grazing) had three major goals: (i) to identify differences between the Observatories regarding vegetation composition, diversity, and site conditions; (ii) to give an estimate of the total plant species richness of each Observatory by applying and comparing three different extrapolation methods commonly used in biodiversity research (species-area relationships = SARs; species-sampling relationships = SSRs; non-parametric richness estimators); and (iii) to test the influence of time effort on the degree of



comprehensiveness of floristic inventories at the 1-ha scale.

During the rainy season of 2009, all vascular plants were sampled on 20 completely randomly distributed 1000-m² plots on both Observatories. Within each plot, subplots of 0.01 m², 0.1 m², 1 m², 10 m², and 100 m² were nested and replicated (Photo SSS39.01). Soil samples were taken and analysed from all 100-m² subplots. Additionally, ten 1-ha plots were sampled in a standardised way with plenty of time, registering the point of time whenever a new species was encountered.

A permutation test was used to analyse potential differences in parameter means between the Observatories. SARs were fitted by 12 different models (power, logarithm, asymptotic) and SSRs by six asymptotic models. Further, six non-parametric richness estimators were applied. The curves of species encounters vs. sampling time were fitted with the same set of six asymptotic functions as the SSRs in order to determine the total richness within a specific hectare plot. Finally, we compared our species lists for hectare plots to those gained with BIOTA "standard" sampling.

There was hardly any difference between the differently grazed Observatories in species richness at the different spatial scales, while species composition strongly deviated. The SAR approach with power or quadratic power functions worked best for extrapolation to the Observatory scale (1 km²), while all other methods substantially underestimated the total species richness. Our species-time approach proved to be an appropriate tool to specify the total species richness of a distinct area and to provide information on the completeness of vegetation censuses. Species overlooked during BIOTA "standard" sampling mostly were low-growing, annual forbs or graminoids.

Peters, J. (in prep.): Plant diversity patterns at different spatial scales in semi-arid savannas of central Namibia. – Diplom thesis in Landscape Ecology. Greifswald: University of Greifswald.

Peters, J., Wesuls, D., Dengler, J., Manthey, M. (2010): Different ways to estimate 'realistic' plant species richness on 1 km² – A case study from a semi-arid savanna in Namibia. – Poster at the 9th international Meeting on Vegetation Databases, 24–26 February 2010 in Hamburg. http://www.botanik.uni-greifswald.de/fileadmin/workshop/2010/Post_Symposium/contrib/Poster_45.pdf

Modelling of species and trait responses curves depending on grazing (S39.02)

[M. Pellowski, D. Wesuls & J. Dengler]
Grazing has great effects on vegetation patterns, especially in semi-arid regions. Gradient analysis can reveal regularities in this patterning and thus can help to indentify indicators for a certain degree of grazing disturbance, which is relevant for land management decisions.

We investigated the distribution of vascular plant species and plant functional traits along grazing gradients using Huisman-Olff-Fresco (HOF) modelling – a set of hierarchical regression models. The study was conducted in 2007 and 2008 on the Observatory farms Narais (S39) and Duruchaus (S40) as well as on five other farms up to 60 km to the south. Plant species response was assessed along transects around livestock watering points on two different spatial scales: we compared short transects (150 m) and long transects (1500 m). The responses of the traits life form, life cycle, and growth form were modelled along the short transects. We calculated optima and niche ranges of single species and traits for both transect lengths.

Total cover of vascular plants decreased with grazing pressure. Distribution patterns and response curves varied widely between the species with possibility to distinguish between increaser, decreaser, and bimodal species curves. Most species showed a stronger response to grazing along the short transects compared to the long transects. The area of major disturbance was dominated by annual grasses like *Schmidtia kalahariensis* and prostrate forbs like *Tribulus terrestris*. Woody, perennial species increased in cover with increasing distance. Geophytes and therophytes were frequent around the watering point, whereas chamaephytes and phanerophytes avoided this highly disturbed area.

Our results provide a baseline for naming indicator key species and traits for grazing impact in the studied region, which can be used by farmers for assessing the condition of their rangeland.

Pellowski, M. (2009): Verteilung von Pflanzenarten und ihren funktionellen Merkmalen entlang von Beweidungsgradienten in Zentralnamibia. – Staatsexamen thesis in Biology. Hamburg: University of Hamburg.

Pellowski, M., Wesuls, D., Dengler, Suchrow, S., Oldeland, J., Jansen, F. (2010): Modelling plant species and trait response curves along grazing gradients in central Namibia. – Poster at the 9th international Meeting on Vegetation Databases, 24–26 February 2010 in Hamburg. http://www.botanik.uni-greifswald.de/fileadmin/workshop/2010/Post_Symposium/contrib/Poster_44.pdf

Connecting spectral indices, constrained ordination and fuzzy classification as an innovative approach for mapping vegetation types (S39.03)

[J. Oldeland, W. Dorigo, L.A.B. Lieckfeld & N. Jürgens]
Vegetation mapping of plant communities at fine spatial scales is increasingly supported by remote sensing technology. However, combining ecological ground truth information and remote sensing datasets for mapping approaches is complicated by the complexity of ecological datasets. In this study, we present a new approach that uses hyperspectral datasets with high spatial resolution to map vegetation units of a semiarid rangeland in central Namibia. Field vegetation surveys made on the Observatories Narais (S39) and Duruchaus (S40) provide the input to the workflow presented in this study. The collected data were classified by hierarchical cluster analysis into seven vegetation units that reflect different ecological states occurring in the study area. Spectral indices covering vegetation and soil characteristics were calculated from hyperspectral remote sensing imagery and used as environmental variables in a constrained ordination by applying redundancy analysis (RDA). The resulting statistical relationships between vegetation data and spectral indices were transferred into images of ordination

axes, which were subsequently used in a supervised fuzzy c-means classification approach relying on a *k*-NN distance metric. Membership images for each vegetation unit as well as a confusion image of the classification result allowed a sound ecological interpretation of the resulting hard classification map. The resulting maps were made for an area of around 17.5 km² with the BIOTA Observatories in the centre. Classification results were validated with two independent reference datasets provided by the Observatories on the farms. For an internal and external validation dataset, overall accuracy reached 98% and 64% with kappa values of 0.98 and 0.53, respectively. Critical steps during the mapping workflow are highlighted and compared with similar mapping approaches.

Oldeland, J., Dorigo, W., Lieckfeld, L., Jürgens, N. (2010): Connecting spectral indices, constrained ordination and fuzzy classification as an innovative approach for mapping vegetation types. – Remote Sensing of Environment **114**: 1155–1166.

Plant trait response to livestock grazing across habitats and years in semi-arid African savannas (S39.04)

[D. Wesuls]

Trait-based approaches are useful tools to facilitate generalisations of organismic response to environmental change. One key question of these approaches is to relate species traits to the environment through species distribution among plots and to find consistent trait responses to main environmental gradients, which may be masked by other environmental variation.

The response of 21 quantitative and categorical plant traits of 87 species was analised along grazing gradients on the Observatory farms Narais (S39) and Duruchaus (S40) as well as on eight other farms in semi-arid savannas of central Namibia in different habitat types and two different years. With the aim to remove the confounding effects of temporal and environmental variation besides grazing, a new partial direct approach for analysing the trait-environment relation, called partial RLQ analysis was applied.

The first axis of the partial RLQ revealed the pronounced influence of environmental parameters related to grazing across different habitat types and sampling years. The fourth-corner statistic was used to quantify the relation between the grazing axis and the quantitative and categorical traits. On the level of whole categorical traits, life cycle, leaf blade fragmentation, dispersal mode, and clonality showed significant grazing responses. Many traits negatively correlated with increasing grazing pressure could be related to perennial grasses (long leaves, perennial life cycle, anemochorous dispersal, entire leaves, belowground clonality, rhizomes). The traits positively correlated with grazing were from herbaceous, annual plants with a prostrate-creeping habit, compound leaves, high SLA, and exo- or endozoochorous dispersal.

The results show that in semi-arid savannas despite a strong influence of grazing, trait responses can vary under different environmental conditions and in different years. With the approach suggested here (partial RLQ and fourth corner statistic), a new tool for the interpretation of consistent trait responses is offered. This could be particularly useful with regard to analyses of trait patterns on a larger geographical scale.

Wesuls, D., Oldeland, J., Dray, S. (2010): Plant trait response to livestock grazing across habitats and years in a semi-arid African savanna. – Poster at the 9th international Meeting on Vegetation Databases, 24–26 February 2010 in Hamburg. http://www.botanik.uni-greifswald.de/fileadmin/workshop/2010/Post_Symposium/contrib/Poster_63.pdf

Influence of soil features on soil lichen diversity in the summer-rainfall biomes

► See S03.02

Further studies

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Limpricht, C., Lang, H. (1997): Der Treck der Rehobother Baster. – Archäologische Informationen: Mitteilungen zur Ur- und Frühgeschichte **20(1)**: 49–59.

Limpricht, C., Lang, H. (2008): Farms and families: land tenure in Rehoboth. – In: Limpricht, C., Biesele, M. (eds.): Heritage and cultures in modern Namibia: in-depth views of the country. A TUCSIN-Festschrift: 141–154. Windhoek & Goettingen: Klaus Hess Publishers.

Naumann, C. (2009): Weidemanagement und ethnobotanisches Wissen bei den Rehobother Bastern. – Master thesis in Social Anthropology. Hamburg: University of Hamburg.

Wesuls, D., Lang, H. (2010): Perceptions and measurements: the assessment of pasture states in a semi-arid area of Namibia. – Human Ecology **38**: 305–312.

Wesuls, D., Naumann, C., Limpricht, C. (2009): Algemeene plante in die Rehoboth streek: veld gids vir plaasboere. Common plants in the Rehoboth area: a farmers field guide. – Hamburg & Windhoek: BIOTA Southern Africa.

General data

Number	Name	Alternative name(s)
S40	Duruchaus	n.a.
Implementation	**Country**	**Province/ region**
2004	Namibia	Khomas
District/ constituency	**Locality**	**Farm name**
Windhoek	near Rehoboth	Duruchaus
Latitude	**Longitude**	**Altitude**
23.133184 S	16.899996 E	1614 m a.s.l.
Rainfall season	**Biome**	**WWF Ecoregion**
Summer	Nama Karoo	AT1309 Kalahari xeric savanna
Agro-Ecological Zone	**Relative intensity of land use**	**Tenure**
CPL3-7	Medium	Private
Type and history of landuse	**Land owner**	
Farming with cattle and goats	Private	

Duruchaus (S40)

Dwarfshrub plains landscape at Duruchaus Observatory. Photo: J. Peters.

The BIOTA Observatory Duruchaus (S40) is situated in the Khomas region of Namibia, 25 km northwest of Rehoboth and 100 km southwest of Windhoek. The area is flat to slightly undulating and at a height of approximately 1600 m a.s.l. Nearby mountain ranges at heights of more than 2000 m a.s.l. represent the southernmost peaks of the Central Namibian Highland. The Oanob River crosses the Farm Duruchaus and ends in the Oanob Dam close to the town of Rehoboth. The area is situated at the transition zone between three major biomes: the Nama Karoo with shrub and dwarf shrub savanna in the south, the Highland- or Mountain Savanna in the north, and the Kalahari Sandveld in the west. Mean annual rainfall is 289 mm and falls during the summer months from December to April.

The area around Rehoboth is inhabited by the Rehoboth Basters who farm mainly with cattle, sheep, and goats on privately owned land. In contrast to the neighbouring Observatory Narais (S39), the Duruchaus Observatory is used for cattle, sheep, and goat farming at relatively high stocking densities. The size of the farm Duruchaus is only half that of the farm Narais. A clear and temporally stable fence line contrast marks the difference in landuse between the two farms.

The presence of the fence line contrast marking the border between the farms Duruchaus and Narais, which is even visible on satellite images, was the

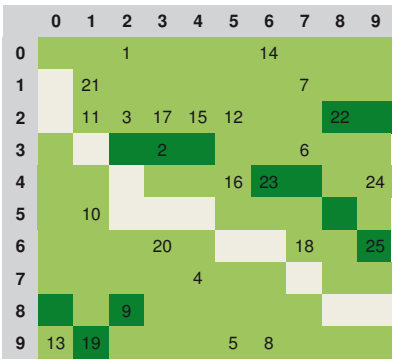
reason for establishing two Observatories here, with the aim of documenting changes under climate change and contrasting management on privately owned farm land. Close to the Observatories, at the fence line between Narais and Duruchaus, grazing exclosures and experimental grazing plots of 1.4 ha each were fenced. Monitoring of these plots aims at providing information on changes in biodiversity and range condition following complete cessation of grazing, or rest for a limited time, under different baseline conditions.

Responsible authors: D. Wesuls & D.H. Haarmeyer

Remote sensing and landscape

Geomorphology	Geological units	Lithological units
Plain, drainage line	Witvlei Group in Damara Supergroup and Gariep Complex	Limestones and sandstones
Mean EVI	**EVI absolute range**	**Mean leaf area index**
0.135 (0.107–0.195)	0.099 (2007)–0.223 (2009)	0.43

Grid map of Observatory



1 Chamaephytic shrubland / grassy plains
2 Drainage lines
3 Road (excluded from ranking)

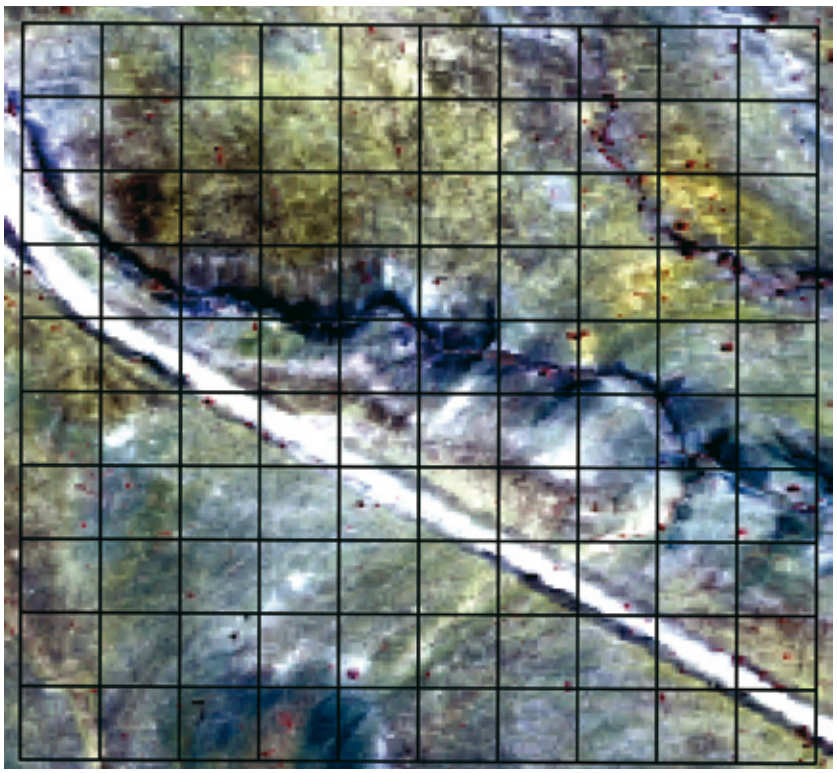
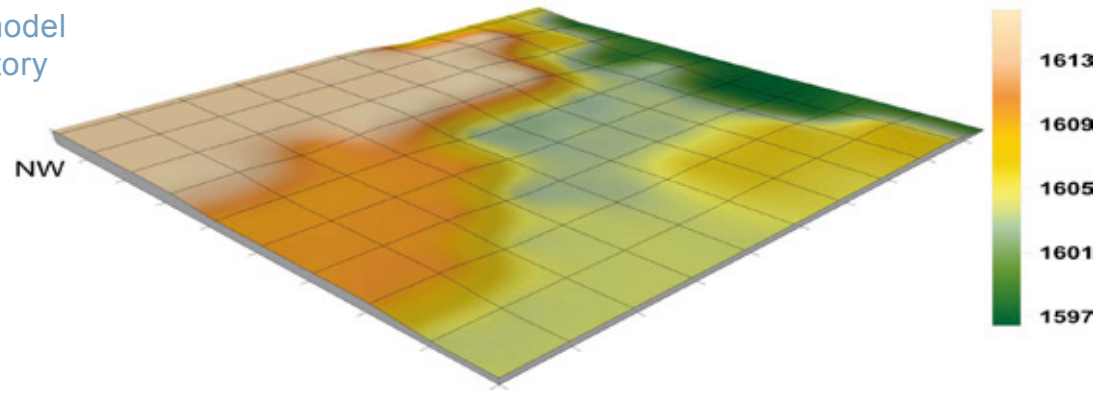


Image: HYMAP, 14 November 2005

Elevation model of Observatory



Landsat image

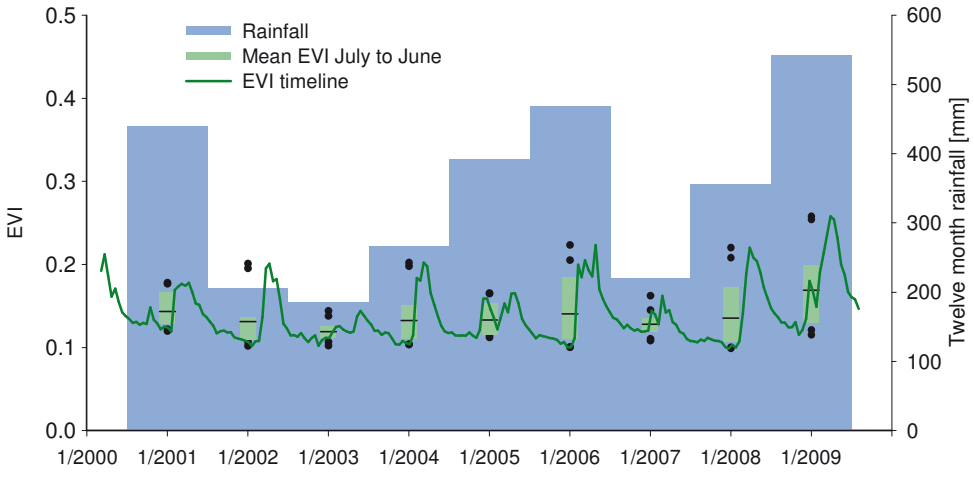
The plateau on which the Observatory is situated is intersected by the Oanob River, which crosses the area east of the Observatory and drains to the south. The predominantly dry river bed (at the end of April) can be identified by white tones, and remaining water by blue tones. A tributary of the Oanob River crosses the image in the south-west.

Reddish to brown colours on the mountain slopes indicate dense (shrub) vegetation, but are sometimes induced by the geology. Green colours indicate less dense mixed grass and shrub vegetation. The light green to light grey and blue-grey colours indicate scattered vegetation cover and a high percentage of bare soil (e.g. the area about 2 km southwest of the Duruchaus Observatory). In comparison to the Narais Observatory (vegetation indicated by deep green tones) situated north of Duruchaus, the vegetation cover at the farm Duruchaus (vegetation indicated by light green tones) is much lower due to the higher stocking rates at this farm. A clear fence line contrast illustrates the differences in the grazing intensity between these two Observatories.

Scene: 178/76, acquisition date: 24 April 2006

MODIS time series

Temporal patterns of annual rainfall, vegetation cover, and phenology



Responsible authors: M. Keil & T. Labitzky

Climate

Data from BIOTA weather station

Location	Recorded period	Mean temperature
Narais (S39)	2004–2009	19.1 (-2.4–34.7) °C
Mean solar radiation	**Mean wind speed**	**Mean annual precipitation**
562 (398–824) MJ·m^{-2}·month^{-1}	2.2 (9.2) m·s^{-1}	289 (108–570) mm
Mean annual potential evapotranspiration	**Interannual precipitation variability**	**Mean relative humidity**
1428 mm	176%	44% (13–86%)
Aridity index (UNEP)		
0.20 (semi-arid)		

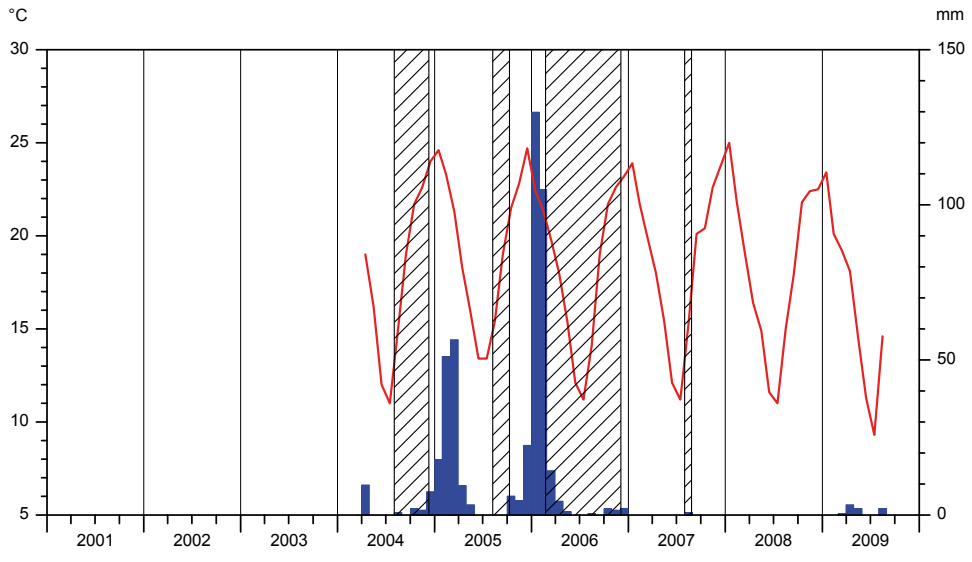
Modelled data

Mean temperature	Mean annual temperature range	Mean diurnal temperature range
18.6 (3.2–31.6) °C	10.9 °C	16.8 °C
Mean annual precipitation	**Precipitation seasonality**	**Percentage winter precipitation**
287 mm	112%	12% (strong summer)
Climate type	**Length of dry season**	**Aridity index (De Martonne)**
BWh	9 months	10.0 (semi-dry)

The climate at the Observatory is characterised by semi-arid conditions. Rainfall shows a strong seasonality with the major portion of rain falling during the summer season, peaking in February. The mean annual rainfall over the observation period was 289 mm, which approximates the average rainfall recorded at the Observatories of the region, but is the wettest within the Nama Karoo. However, substantial interannual variability is evident. The observed near-surface air temperatures show a moderate seasonal cycle. The mean annual temperature is 19.1°C, which is the coldest in this biome. The observed mean minimum temperature is above the freezing point, but there is still a possibility of the occurrence of frost during the months of May to August. Compared to the interpolated long-term data taken from the WorldClim dataset, a slightly warmer mean annual temperature is evident at the BIOTA weather station. The station records of extreme temperatures also deviate from the interpolated data, showing warmer maximum and colder minimum temperatures. The mean annual rainfall observed at the station corresponds to the amount derived from the WorldClim dataset. Rainfall data were recorded by the farm owner of Duruchaus and not from the BIOTA weather station.

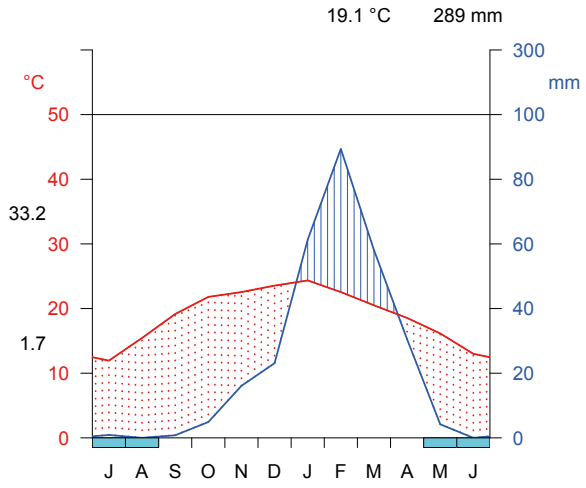
The observed near-surface winds at the Observatory are predominantly constituted of westerly flows throughout the year. Mean wind speed shows a pronounced annual cycle in the evenings, and a moderate annual cycle in the mornings and early afternoons. Strongest winds occur in the afternoons during spring, reaching up to about 15 km/h.

Time series: rainfall and temperature

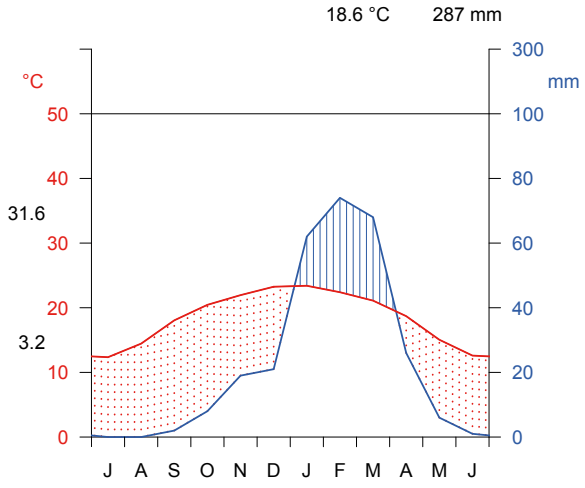


Climate diagrams

Recorded data (BIOTA)

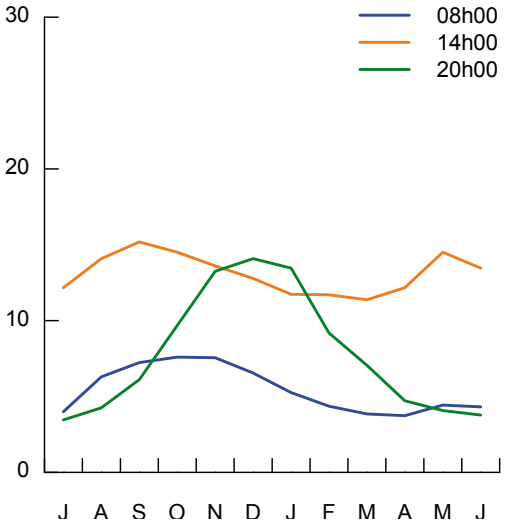


Modelled data (WorldClim)

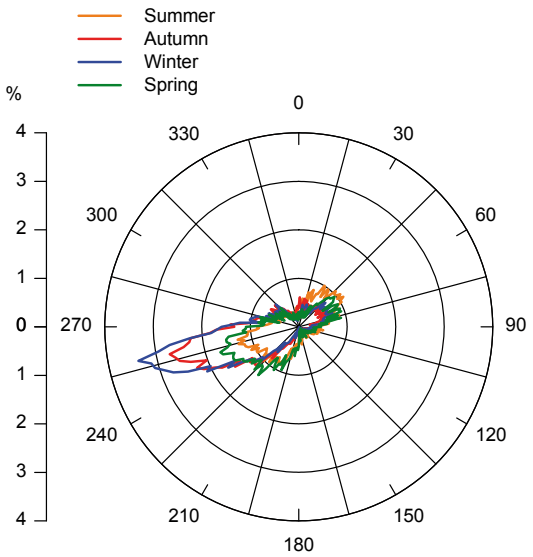


Wind diagrams

Speed



Directions



Responsible authors: K. Berger, A. Haensler & J. Luther-Mosebach

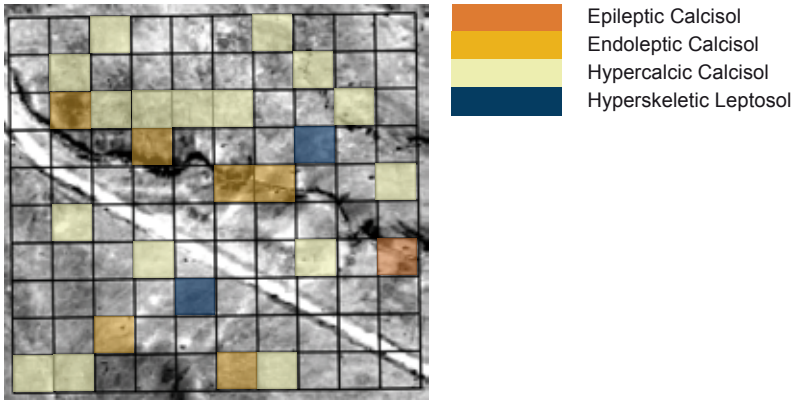
Soils

Year of sampling	Hectare plots sampled	SOTER unit
2005	25 (R1–25)	NA51
Soilscape	**Dominant soil group(s)**	**Reference group richness**
n.a.	Calcisol	2
Soil unit richness	**Soil unit evenness**	**Soil ecotype richness**
7	0.509	10
Parametric space	**pH**	**Electrical conductivity**
2.80	8.3 (7.4–8.7)	75 (6–201) $\mu S \cdot cm^{-1}$
Organic carbon		
0.77% (0.30–1.74%)		

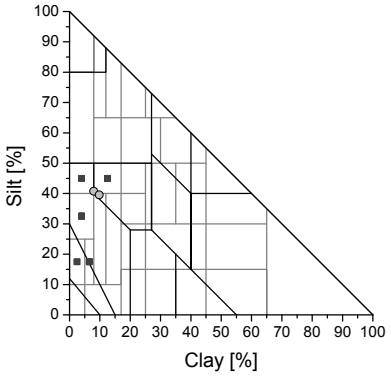
Except two Leptosols, only Calcisols can be found on the Observatory. As on Observatory S39 (Narais), the Epipetric Calcisols are the dominant soil unit found on the plains, followed by Endoleptic Calcisols. Biological soil crusts (see section Biological soil crusts) are widely distributed.

The variability of soil chemical properties is even lower than on Narais (S39). Especially the pH values and the electrical conductivity display very low ranges, due to the strong dominance of Calcisols. Like on Narais (S39), the most important variations occur in the organic carbon, the texture, and the rooting space, limited by either calcretes or bedrock.

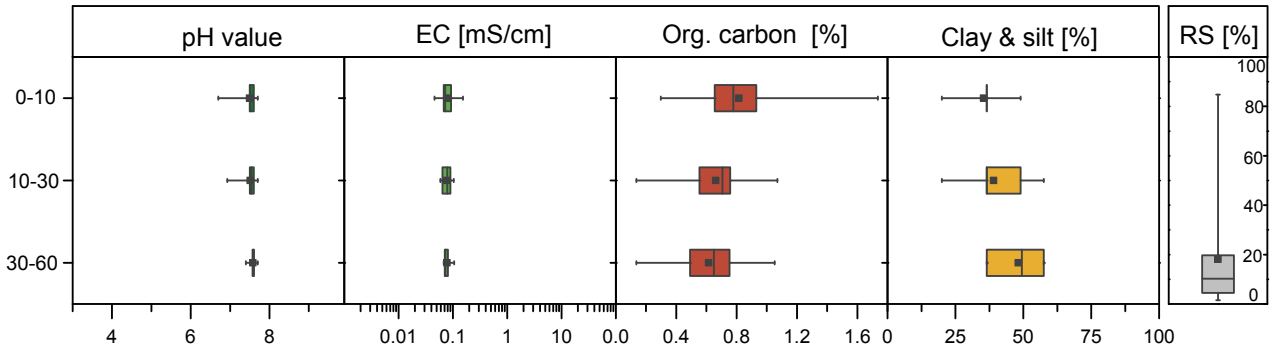
Map of soil profiles



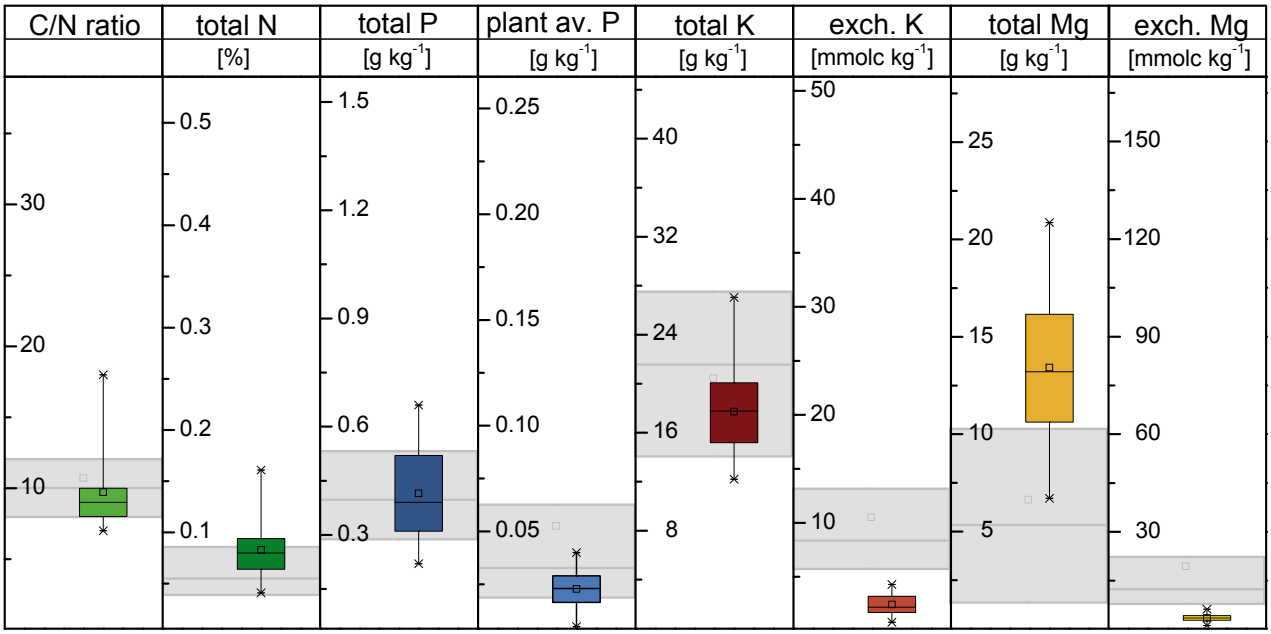
Soil texture triangle



Soil characteristics



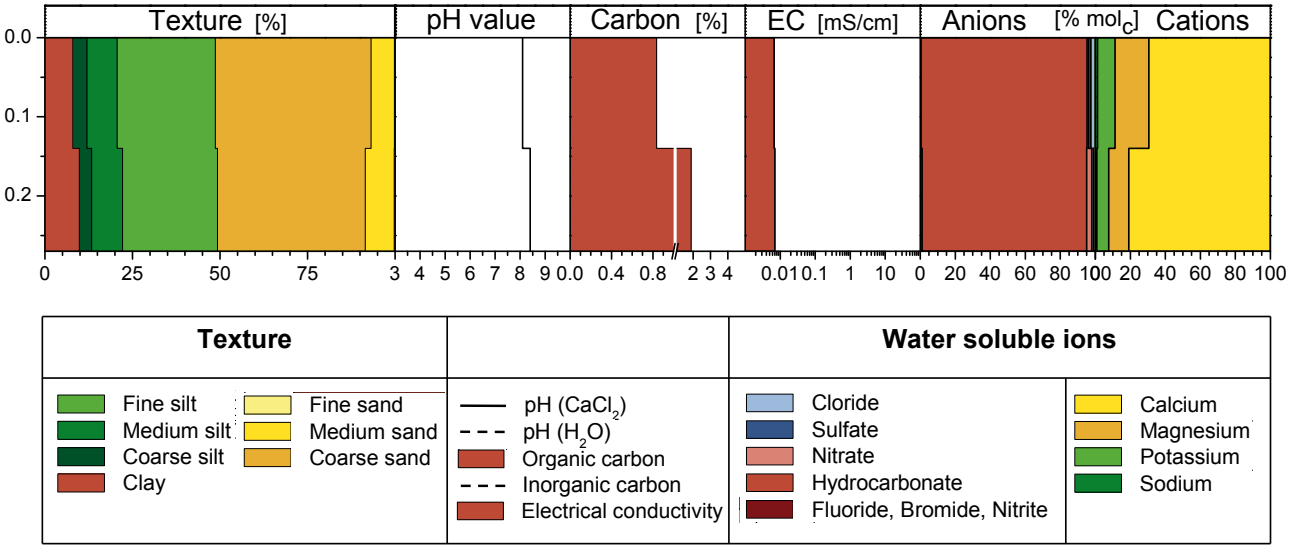
Soil nutrients



Reference profile (H51)

The **Hypercalcic Epipetric Calcisol (Episkeletic)** is a typical example of a soil in the plain habitats with a massive petrocalcic horizon in the upper 50 cm. There is a continuous transition into the group of Endoleptic Calcisols, which only have a nodular calcic horizon that allows the penetration of roots. In the case of the Petrocalcic Calcisols such root penetration is extremely limited as the massive calcretes often have a laminar surface.

The transition zone to the petrocalcic horizon starts at approx. 28 cm with coarse rock fragments, mainly calcrete nodules, which amount to 50% of the soil volume above the petrocalcic horizon. The texture of the fine earth is sandy loam dominated by fine sand and coarse silt. The soil reaction is moderately alkaline across the entire profile while the electrical conductivity is low. The soil is covered by biological soil crusts as well as with a gravel cover of about 30%.



Responsible authors: U. Wisch, A. Petersen, A. Gröngröft & D. Mager

Biological soil crusts

Sampling period(s)	Hectare plots sampled	Types of soil crusts
2004	3 (R14, R65, R84)	2, 3, 4, 5a
Crust thickness	**Cover**	**Carbon [weight %]**
3–4 mm	up to 30%	0.815
Nitrogen [weight %]	**Chlorophyll *a* [mg/m²]**	**Chlorophyll *a+b* [mg/m²]**
0.060	65	112

In addition to well-established cyanobacteria-dominated soil crusts, similar to the Observatory S39 (Narais), climax-stage crusts, like green-algal lichen and moss-dominated crusts, occur frequently. In contrast to the moderately grazed twin Observatory Narais, there are patches of bare soil where intense grazing and trampling have most likely caused a decline in biological soil crust cover.

Cyanobacteria not finally treated yet.
Green algae:
Bracteacoccus giganteus
Chlorella cf. *sorokiniana*
Chlorella sp.1
Chlorosarcinopsis cf. *variabilis*
Eustigmatos magnus
Neospongiococcum granatum
Scenedesmus sp. 4
Spongiochloris sp.

Well established soil crusts, up to 30% coverage. Photo: K. Deutschewitz.

Cyanobacterial crusts with a high percentage of green algal lichens (*Psora* sp.). Photo: K. Deutschewitz.

Biological soil crust characteristics

	H02	H22	H33
Soil characteristics	Light brown fine sand; very rich in mica; very few pebbles	Brown fine sand with mica	Light grey silty sand with soft, strongly weathered mica schist particles
Crust characteristics	Widespread dark BSC with few lichens)	Widespread well-developed BSC with lichens	Widespread dark BSC with green-algal lichens (*Psora* sp.)
Chlorophyll a [mg/m²]	28.0	102.71	64.85
Chlorophyll a+b [mg/m²]	45.8	179.03	112.17
Carbon [weight %]	0.82	0.69	0.93
Nitrogen [weight %]	0.06	0.06	0.06

Responsible authors: B. Weber, K. Deutschewitz, S. Dojani, T. Friedl, T. Darienko, K. Mohr & B. Büdel

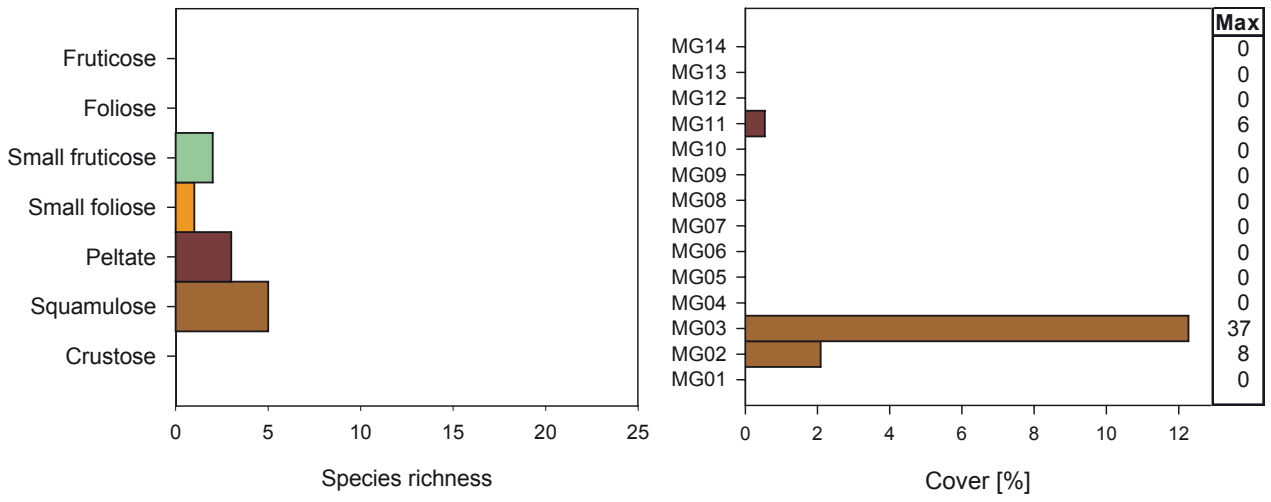
Lichens

Sampling period(s)	Hectare plots sampled	Cover
2006, 2009	10 (R1–R10)	14% (0–42%)
Total species richness	**Species richness on soil [1 km²]**	**Species richness on rock [1 km²]**
28	11 (39%)	11 (39%)
Species richness on plants [1 km²]	**Species richness on soil [1000 cm²]**	
6 (22%)	1.6 (0–3)	

This Observatory possesses a high diversity of soil-inhabiting lichens which is similar to the neighbouring Observatory 39 (Narais), despite lower air humidity and less rainfall. The high altitude of the site, favouring dewfall during the early morning hours, may explain this high diversity. This assumption is supported by the abundance of squamulose and peltate growth forms, and lichens with the dominance of cyanobacterial photobionts. In addition, the presence of calcareous soils could also be responsible for lichen growth in several plots. Epiphytic lichens are less well-represented compared to other savanna sites, mainly due to the lower availability of potentially suitable woody plants and of closed vegetation formations. This Observatory is the type locality for a newly described lichenicolous species, *Zwackhiomyces namibensis* (Diederich & Schultz 2009). A few other species were reported for the first time from Namibia and in some cases the whole of Africa (e.g. *Heppia arenacea*, new to Africa) (Schultz et al. 2009).

The mean cover of lichens (14%) in the investigated hectare plots is slightly lower than at the twin Observatory Narais (S39: 20%), as is the number of morphological groups recorded at the 1000 cm² sampling plots (three on Duruchaus compared to four on Narais). This indicates the possible negative influence of human-induced disturbance on soil lichens, as this Observatory is more intensively grazed compared to Narais. Lichens are completely absent in some plots or their cover is very low, even when soil conditions are favourable for growth (H17, H22, H74, H82, H96). Again this may be due to destructive impact caused by livestock. The most common morphogroups are cyanolichens (MG03) and green algal lichens with a squamulose growth habit (MG02). The species forming these morphogroups are widely distributed and have wide ecological tolerance limits.

Life forms



List of Taxa

Terricolous (on soil):

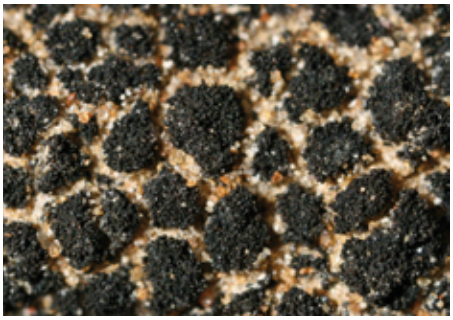
Collema coccophorum
Heppia adglutinata
Heppia arenacea
Heppia despreauxii
Lichinella stipatula
Peccania cf subnigra
Peltula patellata
Phloeopeccania sp.
Placidium squamulosum
Placidium tenellum
Psora crenata

Saxicolous (on rock):

Buellia sp.
Caloplaca sp.
Catapyrenium sp.
Lichinella cf. granulosa
Peccania cf. tiruncula
Phloeopeccania cf. hispanica
Peltula inversa
Peltula obscurans
Psorotichia cf. schaereri
Psorotichia hassei
Zwackhiomyces namibensis

Epiphytic (on plants):

Candelaria concolor
Flavopunctelia flaventior
Peltula corticola
Pyxine cocoës
Pyxine nubila
Caloplaca sp.



Lichinella stipatula.
Photo: M. Schultz, L. Zedda & G. Rambold.

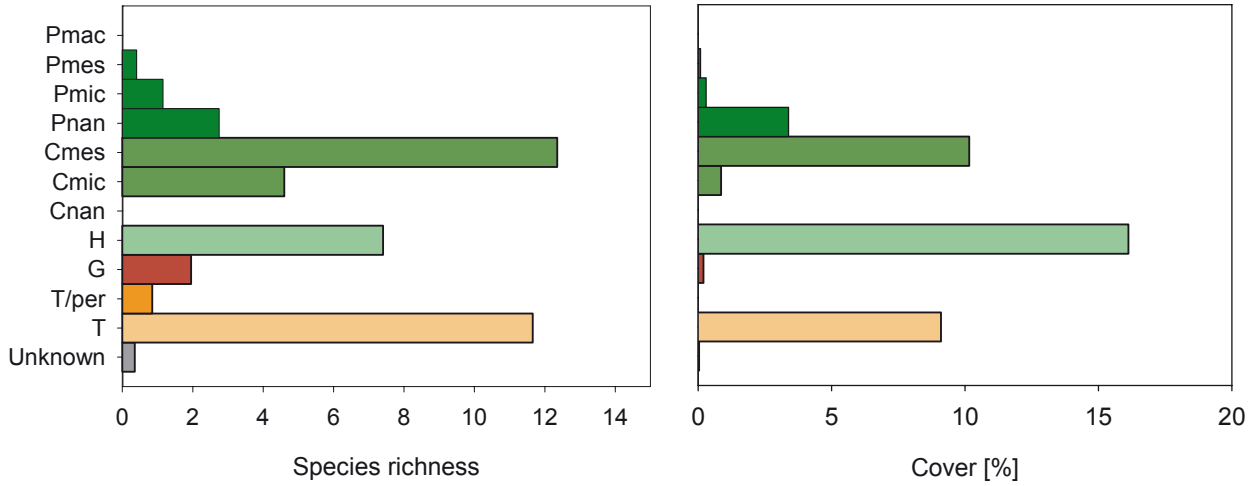
Psorotichia hassei. Photo: M. Schultz, L. Zedda & G. Rambold.

Responsible authors: L. Zedda & G. Rambold

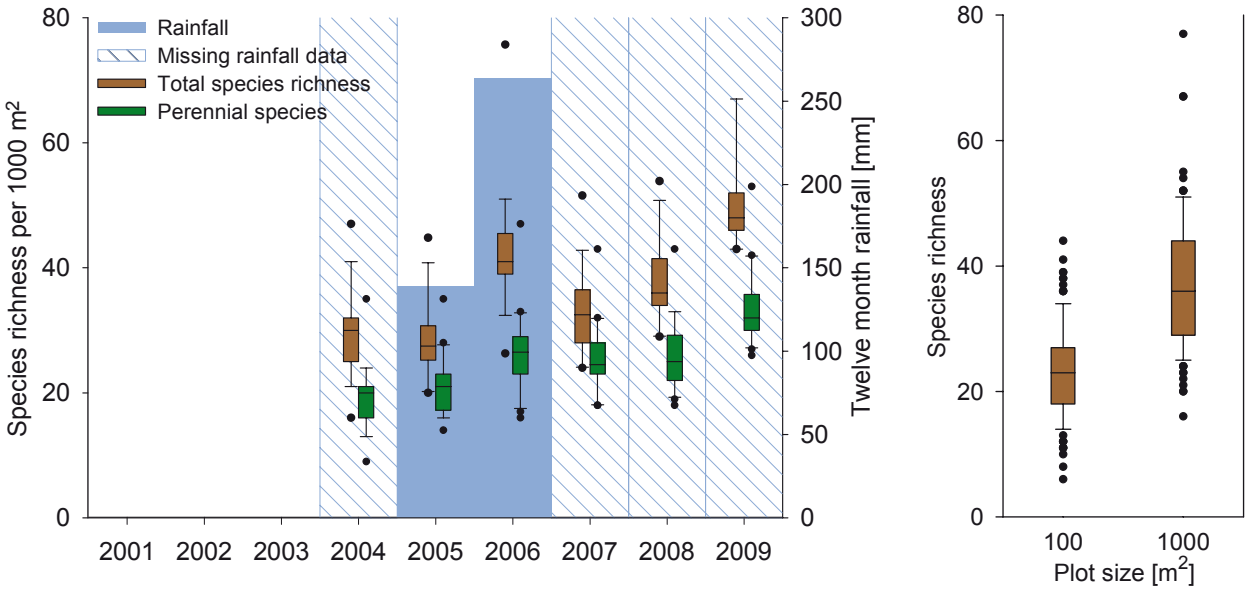
Vascular plants

Sampling period(s)	Hectare plots sampled	Biome
2004–2009	20 (R1–R20)	Nama Karoo
Vegetation unit (level 1)	**Vegetation unit (level 2)**	**Identification rate**
Highland Savanna	n.a.	82% – 93% – 95%
Cumulative family richness	**Dominant families (cover)**	**Dominant families (richness)**
50	Poaceae, Acanthaceae, Asteraceae	Poaceae, Asteraceae, Fabaceae
Cumulative species richness (1 km²)	**Species richness (1000 m²)**	**Species richness (100 m²)**
223 – 129	37.3 (16–83)	23.2 (6–44)
***z*-value**	**Species richness change per year (1000 m²)**	**Evenness (1000 m²)**
0.207 (0.019–0.699)	1.33	0.576 (0.336–0.780)
Evenness (100 m²)	**Simpson (1000 m²)**	**Simpson (100 m²)**
0.590 (0.290–0.801)	0.757 (0.412–0.923)	0.722 (0.281–0.903)

Life forms



Species richness

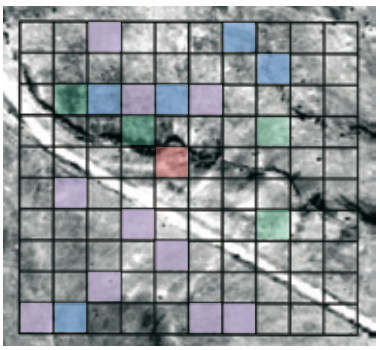


The vegetation at the Observatory Duruchaus differs from that of the wider area by being only sparsely covered with taller shrubs and trees. Dwarf shrubs and grasses dominate, which is characteristic of large parts of the Nama Karoo biome. The Observatory area is a slightly undulated plain gently sloping down towards the Oanob River in the southeast. The area is dissected by drainage lines, which are considerably more deeply cut into the plain compared to the drainage lines at the neighbouring Observatory Narais (S39). The lack of trees and taller shrubs is due to a calcrete layer in the soil, which is broken only by the drainage lines. Good water supply and deeper soils along the drainage lines allow for the growth of a species rich community composed of specialised riverine species, annuals, and woody elements. A fenced-off district road crosses the Observatory and divides it into a south-western and a north-eastern part. Besides the road (which was excluded from sampling), there are another two habitat types and four different vegetation units were differentiated on the Observatory.

The *Heteropogon contortus-Ziziphus mucronata* community (unit 1) is characteristic of the deeply incised drainage lines. The drainage lines begin as gullies that become deep grooves cut into the plain, which may be 5 m deep. Large individuals of woody species such as *Ziziphus mucronata* and *Rhus lancea* and the tough perennial grasses *Heteropogon contortus* and *Hyparrhenia hirta* occur at the bottom of these drainage lines. Additionally, a rich flora of annual species occurs when rainfall is sufficient. Typical examples are the Asteraceae *Schkuhria pinnata* or the grass *Urochloa brachyura*.

Farm Duruchaus, view to south east, 2006. Photo: D. Wesuls.

Map of vegetation units



Plants that grow on the steep walls of the drainage line have a lower demand for water, e.g. the perennial grass *Anthephora pubescens*, which is a valuable fodder plant, and the dwarf shrub *Pentzia monocephala*, with its long flower stalks.

The *Aptosimum spinescens-Sporobolus nervosus* community (unit 2) and the *Eragrostis nindensis-Lapeirousia coerulea* community (unit 3) are influenced by the proximity of drainage lines. They either mark the transition between drainage lines and the plains or they represent very shallow and wide drainage lines. Unit 3 only occurs in the north-western part of the Observatory. Characteristic species are the perennial rhizomatous grass *Eragrostis nindensis* and the geophyte *Lapeirousia coerulea,* with its light blue coloured flowers. Unit 2 hosts species that are adapted to short-term water-logging such as *Sporobolus nervosus*, a mat forming, short-leaved perennial grass and *Platycarpha carlinoides*, a rosette plant with a distinctive pink coloured flower head. Woody species such as the shrub *Acacia mellifera* and the dwarf shrub *Aptosimum spinescens* typically occur in this community.

The *Stipagrostis obtusa-Limeum aethiopicum* community (unit 4) is the dominant vegetation type on the Observatory and can be found on the plain areas. It is comparable to the *Stipagrostis ciliata-Eriocephalus luederitzianus* community on the neighbouring Observatory Narais (S39) and can be regarded as a slightly degraded form of the latter: the biological

Classification table (2009)

Column		Cover	All	1	2	3	4
Number of relevés			**20**	**1**	**5**	**4**	**10**
Mean cover [%]			43.9	*42.9*	46.9	47.6	41.0
Mean species richness (1000 m²)			51.9	*71.0*	59.2	48.5	47.7
Inclination [°]			2.0	*15.0*	1.4	3.3	0.5
Mean soil pH			7.48	*7.66*	7.45	7.53	7.45
Mean electrical conductivity [µS·cm^{-1}]			81	*153*	75	96	72
Organic carbon [%]			0.81	*0.76*	0.65	1.13	0.77
Fine material [%]			27.1	*10.0*	27.2	20.5	31.4
Gravel [%]			10.0	*12.0*	5.4	19.5	8.2
Stones 2-6 cm [%]			5.8	*5.0*	3.2	12.8	4.4
Stones 6-20 cm [%]			3.6	*2.0*	1.4	6.5	3.7
Stones 20-60 cm [%]			1.7	*1.0*	1.4	2.3	1.7
Blocks [%]			0.7	*0.0*	0.4	1.3	0.6
Rock outcrops [%]			0.5	*10.0*	0.0	0.0	0.0
Biotic crust			14.1	*25.0*	15.0	11.8	13.5
Unit 1: Heteropogon contortus-Ziziphus mucronata community							
T	Schkuhria pinnata	0.10	5	*100*	.	.	.
Hper	Merremia palmata	0.50	5	*100*	.	.	.
H	Heteropogon contortus	0.10	5	*100*	.	.	.
Pmic	Rhus lancea	0.10	5	*100*	.	.	.
T	Ipomoea hackeliana	0.10	5	*100*	.	.	.
Pnan	Crotalaria spartioides	0.10	5	*100*	.	.	.
H	Eragrostis lehmanniana	0.10	5	*100*	.	.	.
H	Anthephora pubescens	0.10	5	*100*	.	.	.
Cmes	Blepharis mitrata	0.10	5	*100*	.	.	.
H	Deverra sp.	0.10	5	*100*	.	.	.
H	Eragrostis rotifer	0.10	5	*100*	.	.	.
H	Hyparrhenia hirta	0.50	5	*100*	.	.	.
Hper	Senna italica	0.10	5	*100*	.	.	.
H	Eragrostis cf. jeffreysii	0.10	5	*100*	.	.	.
T	Urochloa brachyura	0.10	5	*100*	.	.	.
Cmes	Jamesbrittenia canescens var. seineri	0.50	5	*100*	.	.	.
H	Trichoneura grandiglumis	0.10	5	*100*	.	.	.
T	Monandrus squarrosus	0.10	5	*100*	.	.	.
T/Hper	Kohautia caespitosa ssp. brachyloba	0.10	10	*100*	20	.	.
T	Tagetes minuta	0.10	10	*100*	20	.	.
Pmic	Ziziphus mucronata	0.50	10	*100*	20	.	.
Cmes	Pentzia monocephala	0.30	10	*100*	.	25	.
G	Chlorophytum calyptrocarpum	0.10	15	*100*	.	25	10
Cmes	Asparagus sp. 19368	0.10	30	*100*	20	0	40
Hper	Platycarpha carlinoides	0.30	20	*100*	60	0	0
T	Eragrostis pilgeriana	0.10	20	*100*	60	0	0
H	Panicum lanipes	0.65	20	*100*	40	25	0
Hper	Convolvulus argillicola	0.10	20	*100*	20	50	0
Hper	Aizoon giessii	0.16	35	*100*	0	25	50
T	Enneapogon cenchroides	0.10	30	*100*	40	50	10
Hper	Osteospermum muricatum ssp. muricat	0.10	30	*100*	60	50	0
Unit 2: Aptosimum spinescens-Sporobolus nervosus community							
Cmic	Aptosimum spinescens	0.10	15	.	60	.	.
H	Cyperus amabilis	0.10	15	.	60	.	.
H	Sporobolus nervosus	2.60	35	.	80	25	20
Cmes	Aptosimum tragacanthoides	0.10	35	.	80	25	20
Unit 3: Eragrostis nindensis-Lapeirousia coerulea community							
G	Lapeirousia coerulea	0.10	25	.	.	75	20
H	Schmidtia pappophoroides	0.10	10	.	.	50	.

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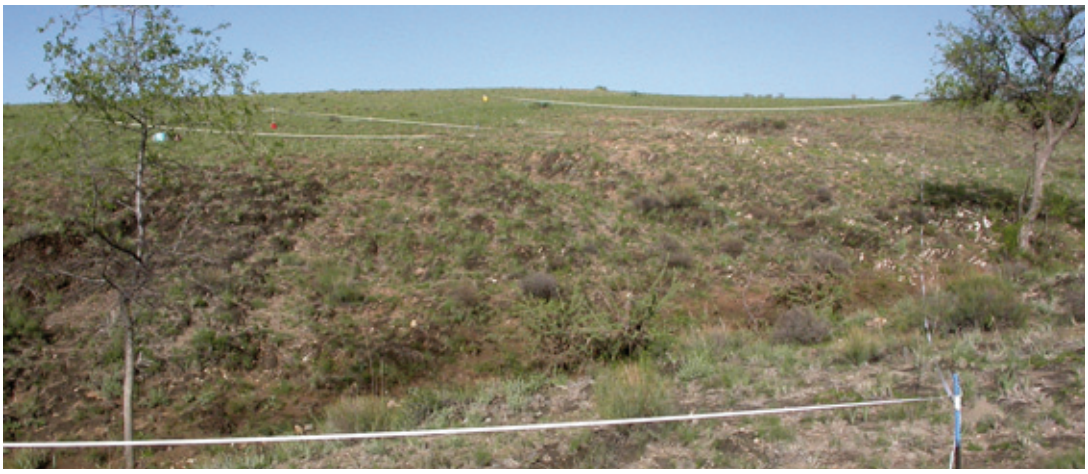

Unit 1, H45, 2008.
Photo: D. Wesuls.

Unit 2, H91, 2005.
Photo: D. Lübsen.

Unit 3, H33, 2006.
Photo: J. Ehrhart.

Unit 4, H2, 2005.
Photo: D. Lübsen.

soil crust is less pronounced and the cover proportions of dominant species are different. The most important perennial grass in this community is *Stipagrostis obtusa,* which is highly palatable and can tolerate a moderate grazing intensity. Besides grasses, dwarf shrubs such as the slender *Limeum aethiopicum* and more robust species such as *Aptosimum albomarginatum, Pteronia mucronata* or *Monechma genistifolium* are dominant within this community. Other typical species are *Indigofera auricoma*, a prostrate annual legume, and *Melhania virescens,* an annual or weak perennial species that is an indicator of calcareous soils.

Classification table (continued)

Column		Cover	All	1	2	3	4
Number of relevés			**20**	**1**	**5**	**4**	**10**
Unit 4: Stipagrostis obtusa-Limeum aethiopicum community							
Cmic	Limeum aethiopicum	0.10	20	.	.	.	40
T	Sericorema sericea	0.10	65	.	60	25	90
Cmes	Peliostomum leucorrhizum	0.10	55	.	40	25	80
G	Ornithoglossum viride	0.10	60	*100*	.	50	90
T	Lotononis platycarpa	0.81	80	*100*	40	75	100
Cmes	Melolobium adenodes	2.06	65	*100*	.	75	90
Most frequent companions							
H	Stipagrostis obtusa	10.9	100	*100*	100	100	100
T	Enneapogon desvauxii	5.11	100	*100*	100	100	100
H	Stipagrostis ciliata	3.03	100	*100*	100	100	100
Pnan	Monechma genistifolium	2.91	100	*100*	100	100	100
Cmac	Aptosimum albomarginatum	1.94	100	*100*	100	100	100
T	Geigeria ornativa	0.67	100	*100*	100	100	100
Cmes	Melhania virescens	0.43	100	*100*	100	100	100
H	Eragrostis echinochloidea	0.35	100	*100*	100	100	100
T	Eragrostis porosa	0.16	100	*100*	100	100	100
Cmes	Aizoon schellenbergii	1.09	95	.	100	100	100
Cmes	Pteronia mucronata	0.50	95	*100*	100	100	90
Cmic	Leucosphaera bainesii	0.37	95	.	100	100	100
Cmic	Aptosimum cf. lineare	0.16	95	*100*	80	100	100
Cmes	Felicia clavipilosa	0.14	95	*100*	100	75	100
Cmic	Polygala leptophylla	0.10	95	*100*	80	100	100
G	Pseudogaltonia clavata	0.10	95	.	100	100	100
Cmes	Pentzia calva	4.51	90	.	100	100	90
Cmes	Tribulus zeyheri	0.12	90	.	100	75	100
Hper	Dicoma capensis	0.10	90	*100*	80	75	100
T	Eragrostis nindensis	1.91	85	*100*	80	100	80
Pnan	Pteronia glauca	0.29	85	*100*	100	100	70
Cmes	Melolobium microphyllum	2.14	80	.	100	50	90
Cmes	Barleria rigida	0.33	80	.	100	100	70
Cmes	Lycium cf. cinereum	0.31	80	*100*	100	100	60
Cmic	Pegolettia pinnatilobata	0.13	80	*100*	100	50	80
Hper	Geigeria pectidea	0.28	75	*100*	80	25	90
T/Cmic	Sida ovata	0.13	75	*100*	80	50	80
T	Melinis repens	0.10	75	*100*	80	50	80
T/Hper	Indigofera auricoma	0.54	70	*100*	20	100	80
T	Trianthema parvifolia	0.27	70	.	100	50	70
H	Cenchrus ciliaris	0.21	70	*100*	100	50	60
Cmes	Gnidia polycephala	0.19	70	*100*	60	100	60
T	Tragus berteronianus	0.10	70	*100*	100	25	70
T/Hper	Kohautia cynanchica	0.10	70	.	60	50	90
H	Fingerhuthia africana	0.25	65	*100*	40	100	60
T	Aristida adscensionis	0.25	65	.	100	75	50
T	Nidorella resedifolia	0.10	65	*100*	80	75	50
H	Oropetium capense	0.35	60	.	100	100	30
Cmic	Thesium lacinulatum	0.20	60	*100*	20	100	60
Cmes	Eriocephalus luederitzianus	0.13	60	.	60	75	60
T	Hirpicium gazanioides	0.10	60	*100*	60	100	40
Hper	Cleome suffruticosa	0.14	55	*100*	40	50	60
Hper	Hermannia abrotanoides	0.10	55	.	40	50	70
H	Eragrostis truncata	0.31	50	*100*	80	50	30
Pmic	Acacia hebeclada ssp. hebeclada	0.26	50	*100*	60	25	50
Hper	Chascanum pinnatifidum	0.10	50	*100*	100	25	30
T	Kyphocarpa angustifolia	0.10	45	.	60	50	40
Pmic	Acacia mellifera ssp. detinens	0.25	40	.	80	50	20
Pmes	Acacia erioloba	0.20	40	.	80	25	30
Pnan	Catophractes alexandri	0.10	40	.	40	.	60
Hper	Aizoon giessii	0.16	35	*100*	.	25	50
Cmes	Hermannia modesta	0.10	30	.	20	25	40

The Duruchaus Observatory, view to the east, 2006. Photo: D. Wesuls.

Fenceline between Duruchaus (right) and Narais (left), 2009. Photo: D. Wesuls.

Responsible authors: D. Wesuls & J. Luther-Mosebach

Termites

Taxon richness	Abundance index	Dominant (sub-)family
5	36	Hodotermitidae

The same taxa were encountered at this Observatory as on the twin Observatory S39 (Narais). Specimens of the genus *Trinervitermes* were found only occasionally. However, some mounds built by this genus were found on the Observatory, and they are numerous in the eastern parts of the farm Duruchaus. Trinervitermes is a relatively common termite genus in southern Africa, except in drier parts where *Baucaliotermes* dominates. It can often be collected from mounds of other termite species, and was frequently observed in abandoned mounds of *Macrotermes michaelseni* on the Observatory S04 (Toggekry). Four of the five species in this genus in southern Africa feed mainly on grass. Only *T. rapulum*, which is mainly found in the north-eastern region of Namibia, also feeds on dead wood. Like *Baucaliotermes hainesi* (see Observatory S10/Gellap), *Trinervitermes* belongs to the subfamily Nasutitermitinae. The soldiers of this subfamily are called "snouted termites" and can easily be distinguished in the field as the front part of their head capsule is elongated into a pointed protrusion. *T. trinervoides* builds dome-shaped mounds, which are usually less than 1 m in height and very abundant in some parts of the savanna regions of southern Africa. The inner walls of these mounds are often greyish-black in colour due to faecal deposits. The other species of the genus *Trinervitermes* either do not build mounds at all or only build small mounds which are rarely more than 30 cm in height.

Trinervitermes workers and soldiers (dimorphic) carrying grass to the entrance of their nest; the picture was taken near Toggekry at night. Photo: C. Grohmann.

List of Taxa

Taxon	(Sub-)family	Frequency Index	Feeding substrate
Hodotermes mossambicus	Hodotermitidae	0.64	g
Psammotermes allocerus	Rhinotermitidae	0.27	w, d
Amitermes	Termitidae (Termitinae)	0.09	s, w, g
Odontotermes sp. 1	Termitidae (Macrotermitinae)	0.09	f (g, l, w)
Angulitermes	Termitidae (Termitinae)	r	s, w, g
Trinervitermes	Termitidae (Nasutitermitinae)	r	s, w, g, l, m

Mound of *Trinervitermes* cf. *trinervoides*. Photo: C. Grohmann.

Responsible authors: C. Grohmann & K.E. Linsenmair

Vertebrates

Total species richness	Reptile species richness	Bird species richness
1	n.a.	1
Large mammal species richness	**Small mammal species richness**	
n.a.	n.a.	

Birds

Passeriformes	**Perching birds**
Ptyonoprogne fuligula	Rock Martin

Responsible authors: J. Deckert, A. Hoffmann & A. Mills

The people

Study period	Size of study area	Mean age of farmers
2004–2006	14,642 km²	59 (30–84) years
Education of farmers	**Ethnicity of farm owners**	**Ethnicity of farm workers**
From no formal education to university degree	Baster	Nama, Damara, Ovambo
Markets		
Auctions, livestock traders, local abattoirs		

The socio-cultural and institutional background of the Rehoboth farmlands

► For general information about the Rehoboth farmlands see Observatory S39 (Narais).

Local biodiversity knowledge

► A description of the inhabitant's local ecological knowledge and their perceptions of degradation is provided in Chapter IV.3.

Responsible authors: C. Limpricht & C. Naumann

Landuse

Observatory farm

Sampling period	Size of Observatory farm	Recommended stocking rate
2004–2006	41 km²	2 ha·SSU^{-1}
Actual stocking rate	**Number of camps**	**Number of farm worker households**
1.6–2 ha·SSU^{-1}	7	4
Number of boreholes		
3		

Study area

Size of study area	Size of commercial farmland	Number of farms (total)
14,642 km²	13,030 km²	ca. 753
Number of farms surveyed	**Mean number of camps per farm**	**Mean farm size**
30	5 (0–22)	27 km²
Mean number of farm worker households per farm	**Mean number of boreholes per farm**	**Farming activities**
2 (0–7)	3 (1–6)	Mixed animal husbandry
Agricultural products		
Mutton, goat meat, calves		

► For general information about land use in the Rehoboth area see Observatory S39 (Narais).

Land management at the Observatory farm

With an area of 4093 ha divided between seven camps, the farm Duruchaus is considerably smaller than the neighbouring farm Narais (S39). The land is used for cattle, sheep and goat farming with an average stocking rate of between 2 ha/SSU (12 ha/LSU) and 1.6 ha/SSU (10 ha/LSU), which exceeds the recommended stocking rate of 2 ha/SSU (12 ha/LSU).

Small stock range widely and are accompanied by herders. Cattle are divided into several herds which are sometimes shifted from one camp to another, although there is no strict rotational grazing system. At least three or four camps are stocked for most of the year. Cattle, sheep, and goats stay in camps until the pasture has been grazed down to about 7 to 15 cm and then move on to other camps with better grazing. The Observatory camp has predominantly been used by small stock, except during a period of temporary change in management in 2004.

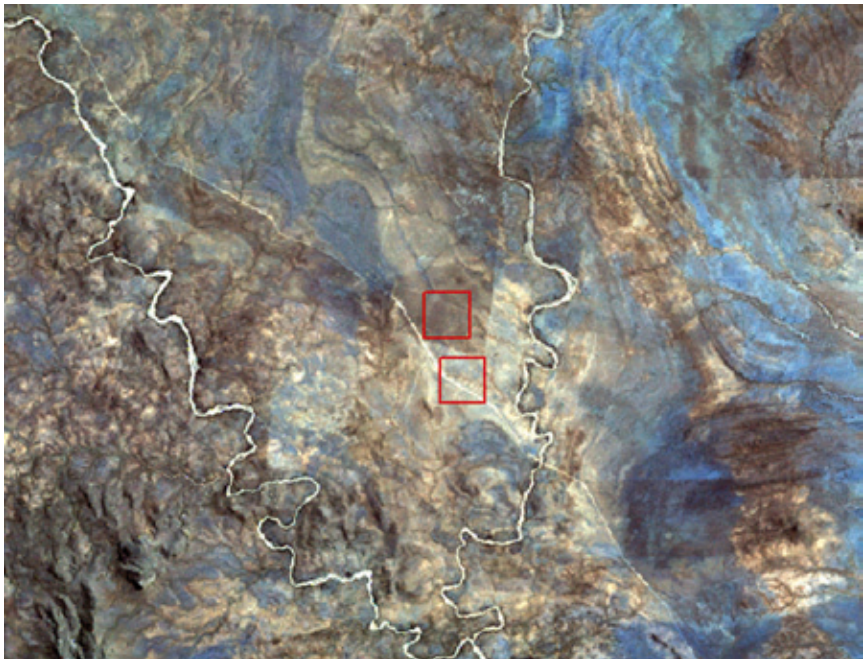

Fig. 40.1: Landsat Image of the Observatories S39 Narais (north) and S40 Duruchaus (south).

The Observatories Narais / Duruchaus (S39 / S40)—cultural aspects of the fence-line contrast

The satellite image shows a clear contrast between the farms Narais and Duruchaus. The reasons for this contrast are explained below.

Both Observatories are historically linked with the neighbouring farm Geelkop. Geelkop was part of Duruchaus, given by Hermanus van Wyk, the first Baster Kaptein, to his son Johannes in 1892. The Narais Observatory is situated on a former portion of Geelkop, purchased by S.A. Nack after several attempts in 1967, and most likely used exclusively by him since 1977. The Nack family is able to trace its descent from the first owner of Narais, five generations back. The first portion of 1,711 ha of the farm Duruchaus

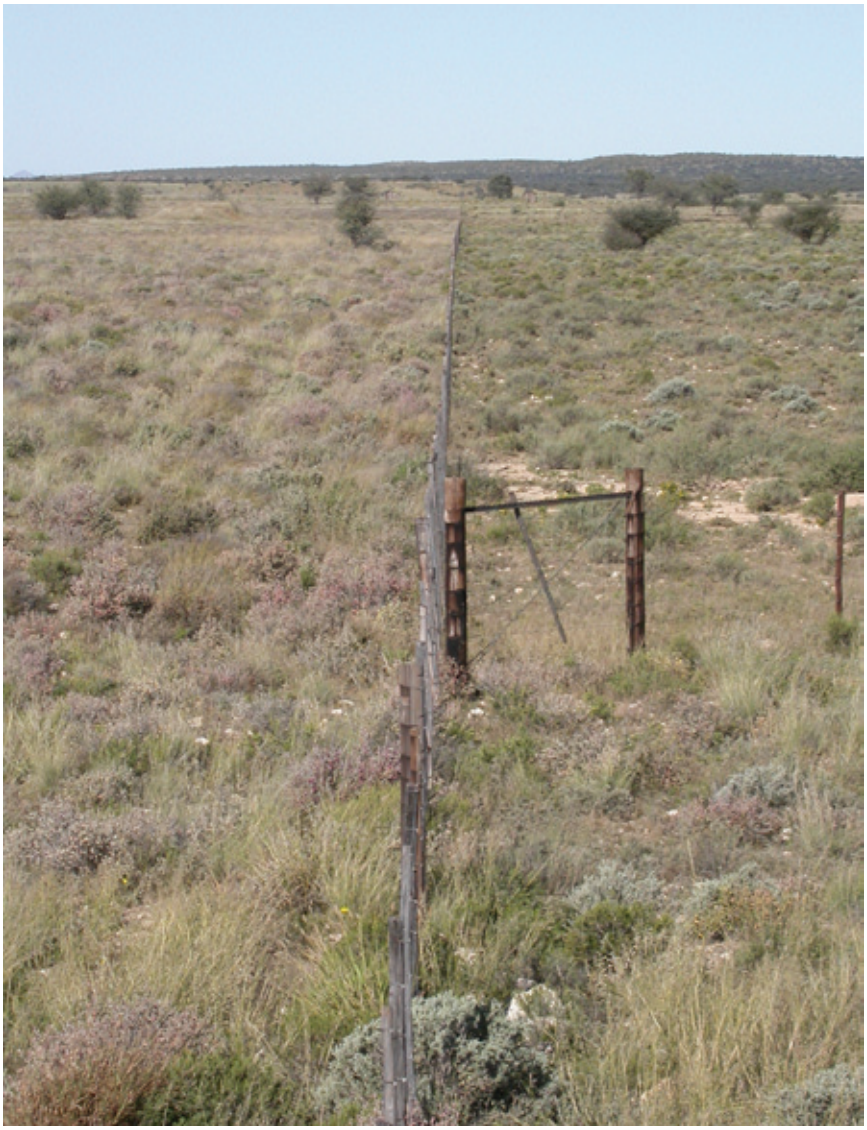

Photo 40.1: Fence-line contrast between S39 Narais (left) and S40 Duruchaus (right). Photo: D. Wesuls 2005.

was purchased in 1948 by Hans Olivier from descendants of the original owner. From 1951 onwards—after purchasing an additional 570 ha—the Olivier family had sole ownership and management of the farm.

The surveying process in this area started in 1937, and in 1943 the first farm maps of Duruchaus, Geelkop and Narais were drawn. The first fences were installed during the 1950s. At the end of the 19th century the history of the three farms starts each with a single owner. The farms became heavily subdivided during the first half of the 20th century, and developed into 3 different types of farms (representing 3 different stages) during the second half of the 20th century (see farm typology in Chapter IV.3):

- the estate farm with multiple owners (Geelkop),
- the medium sized partially consolidated farm, run part-time by a married couple/single owner (Duruchaus),
- and the big consolidated farm (2004/2010), run full-time by a single owner (Narais).

The development of the fence-line contrast

The history of the Observatory farms Narais (S39) and Duruchaus (S40) reflects that there was competition between farmers to purchase pieces and shares of the neighbouring farms, especially Geelkop, from the 1960s onwards. With a view to increase farm sizes, both owners were attempting to accumulate new farm portions and at a later stage to incorporate these portions into their own farms, in a process called consolidation. This competition, which lasted more than two decades, was won by the Narais owner, as a result of two advantages: his economic performance (amongst others, his immediate family was very small); and his closer kinship relation to Geelkop. This led to Narais being twice the size of Duruchaus.

Until the peak of a drought in 1980/81 there was no visible contrast between the two farms. Both were 'degraded' due to overstocking, as the owners tried to maximise their output, relying both on cattle, sheep and goats. A reorientation of the management style on Narais came after 1981/82 as a result of the drought, which had brought heavy losses. The Narais owner initially changed the stocking rate to 20 ha/LSU and farmed exclusively with cattle and goats, knowing that these animals do not compete with each other for natural resources.

The Narais owner, who farmed full-time, already had 8,000 ha at his disposal in 1981 and could afford to adapt his management strategy. The Duruchaus owner who only had 3,500 ha in 1983 and little more than 4,000 ha from 1987 onwards was not able to adapt. Additionally, the Duruchaus owner decided to share the farm management with his son, G. Olivier during the mid-1980s. Due to the sons' large family size and associated costs, it was not possible to change the farm management system, as it was too expensive. Instead, the Olivier family obtained additional income from the husband's job, and farmed part-time until 2005, where after they started farming full-time. They continued to stock cattle, sheep, and goats, quite often at the stocking limits.

Responsible authors: C. Limpricht & C. Naumann

Perceptions and measurements: the assessment of pasture states in a semi-arid area of Namibia (S40.01)

[D. Wesuls & H. Lang]

How farmers perceive the state of their pastures is an important component of their management decisions and affects natural resources in arid and semi-arid regions. In an explorative study conducted on the Observatory farm Duruchaus (S40), the adjacent farm Geelkop, and two other farm pairs in the Rehoboth farm area of central Namibia, we addressed the question whether the judgments of commercial farmers on pasture conditions are consistent with a botanical assessment of these pastures based on measurements. The perceptions were inferred from the comparative statements of farmers on the pasture quality of adjacent farm pairs. For the botanical assessment, biomass and plant species frequency counts of the same pastures were used. The results of the statistical analysis show a large agreement between perceived and measured pasture states of corresponding farm pairs. Thus, dimensions of pasture quality perceived by the farmers agreed with the measured pasture quality variables. We also discuss the problems of designing more elaborate studies of this type.

Wesuls, D., Lang, H. (2010): Perceptions and measurements: the assessment of pasture states in a semi-arid area of Namibia. – Human Ecology **38**: 305–312.

Influence of soil features on soil lichen diversity in the summer-rainfall biomes

► *See* **S03.02**

Plant diversity patterns at different spatial scales in semi-arid savannas of central Namibia

► *See* **S39.01**

Modelling of species and trait responses curves depending on grazing

► *See* **S39.02**

Connecting spectral indices, constrained ordination, and fuzzy classification as an innovative approach for mapping vegetation types

► *See* **S39.03**

No matter where and when: plant trait response to livestock grazing across habitats and years in semi-arid African savannas

► *See* **S39.04**

Further studies

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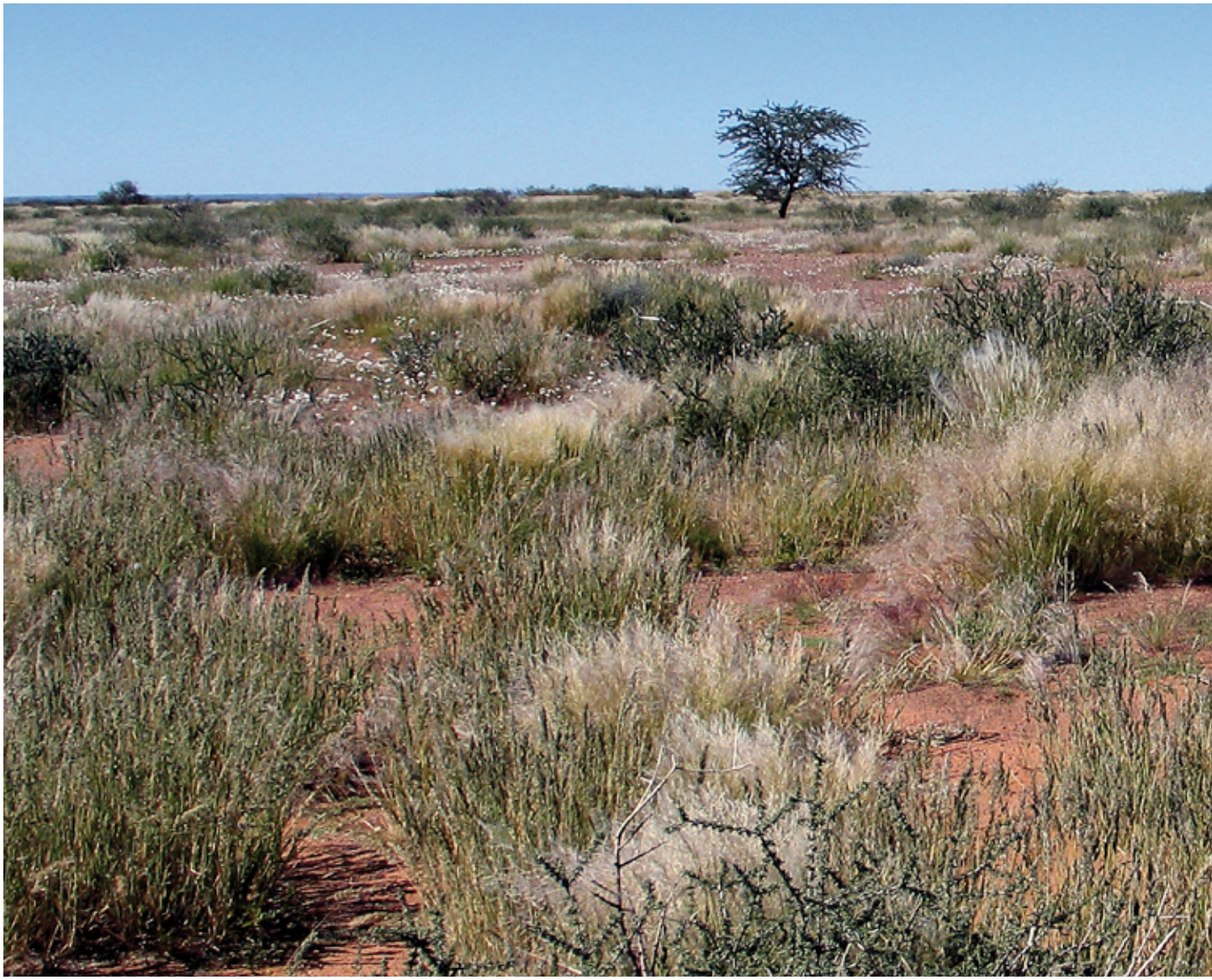
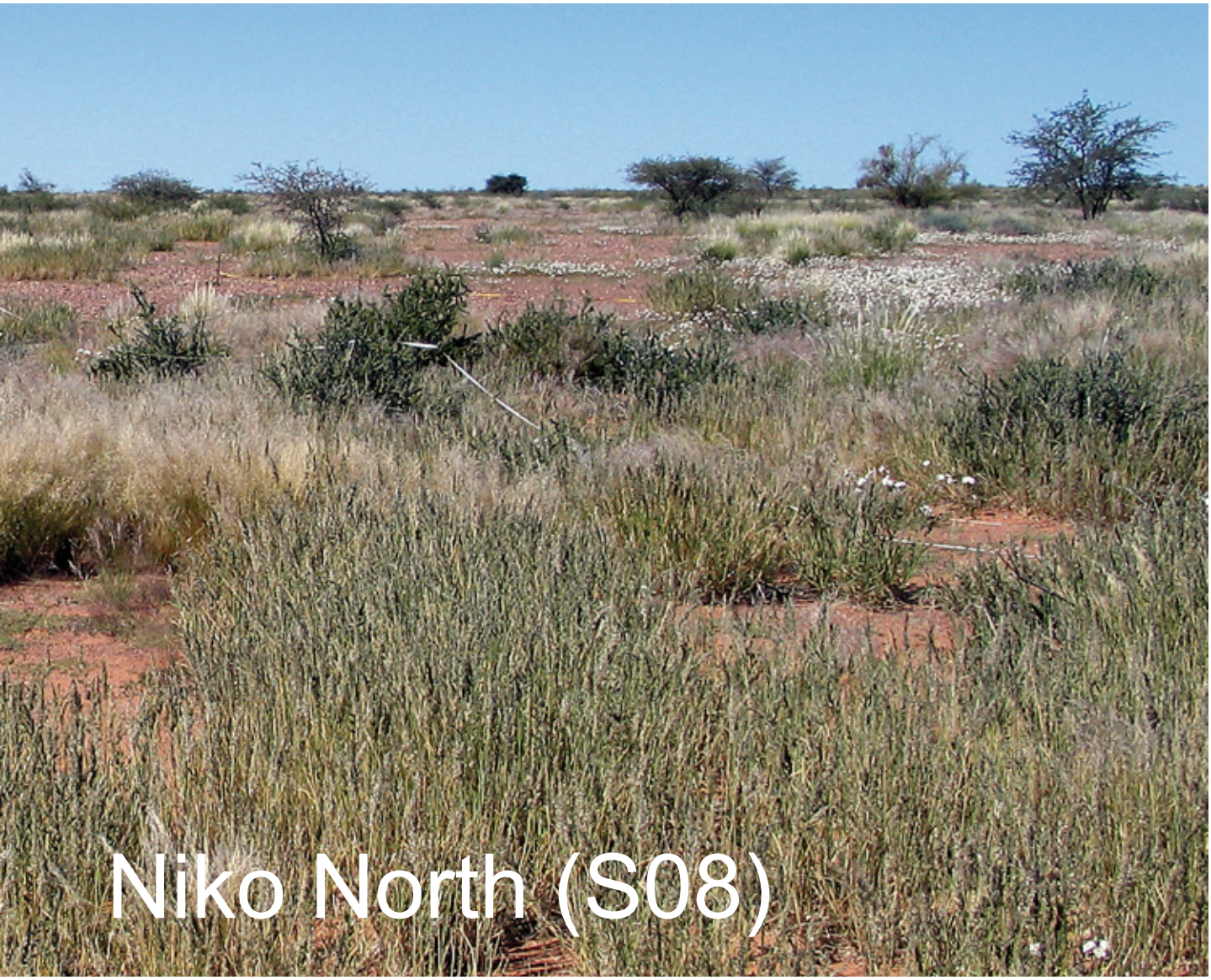


General data

Number	Name	Alternative name(s)
S08	Niko North	Niko grazing
Implementation	**Country**	**Province/ region**
2001	Namibia	Hardap
District/ constituency	**Locality**	**Farm name**
Mariental	near Gibeon	Niko 377
Latitude	**Longitude**	**Altitude**
25.342506 S	17.839093 E	1070 m a.s.l.
Rainfall season	**Biome**	**WWF Ecoregion**
Summer	Nama Karoo	AT1316 Namibian savanna woodlands
Agro-Ecological Zone	**Relative intensity of land use**	**Tenure**
CPL4-9	Medium	Communal
Type and history of landuse	**Land owner**	
Farming with goats	Government of Namibia	



Niko North (S08)

Alluvial plain with open shrubland formed by *Rhigozum trichotomum* in the foreground, annual grass patches and extended bare patches, the latter often with a crusted soil surface. Photo: N. Dreber.

The BIOTA Observatory Niko North (S08) is situated in the Gibeon area on the communal farmlands of Niko North about 80 km south of Mariental. The climate is semi-arid with high spatio-temporal variability of rainfall. The vegetation is an open dwarf-tall shrubland typical of the Nama Karoo. Trees are scattered and are concentrated along the washes and ephemeral river beds dissecting the stony plains.

This small farming area of about 2800 ha is divided into three camps, which are grazed in a rotational manner depending on rangeland condition. The management is centrally organised in order to maintain rangeland productivity and improve livestock production. The community received help in the past by taking part in programs for sustainable rangeland use such as the Sustainable Animal and Range Development Program (SARDEP) initiated by the Ministry of Agriculture, Water and Rural Development (MAWRD) with support from the Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ). They have also received help from the Desert Research Foundation of Namibia (DRFN), which implemented Namibia's UNCCD national action program. These special features contributed to the decision to include this Observatory in the BIOTA project. Besides Niko North, a second BIOTA Observatory (Niko South/S09) was established at another camp on the farm. The sustainability of the applied management strategies and consequent impacts on the

natural resources at Niko North are assessed through vegetation monitoring.

Responsible authors: N. Dreber & D.H. Haarmeyer

Remote sensing and landscape

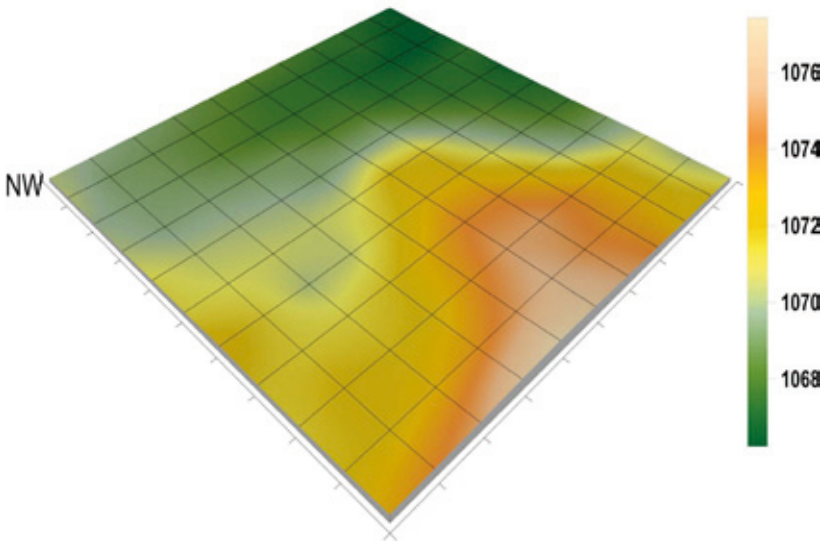
Geomorphology	Geological units	Lithological units
Stony and accumulation areas	Main Karoo Basin in Karoo Supergroup	Sandstones and shales
Mean EVI	**EVI absolute range**	**Mean leaf area index**
0.110 (0.082–0.168)	0.075 (2003)–0.233 (2009)	0.36

Grid map of Observatory

	0	1	2	3	4	5	6	7	8	9
0	88	83	56	94	67	92	27	45	21	50
1	43	73	84	8	38	4	22	60	2	87
2	19	58	46	5	80	55	53	24	76	29
3	54	33	41	28	10	15	36	31	96	98
4	85	11	99	32	49	61	74	65	86	63
5	100	69	75	59	78	52	91	39	34	90
6	18	77	14	17	81	42	82	26	93	1
7	66	44	37	47	57	25	95	30	62	48
8	72	89	40	13	79	51	16	9	64	7
9	12	35	3	70	20	71	23	6	97	68

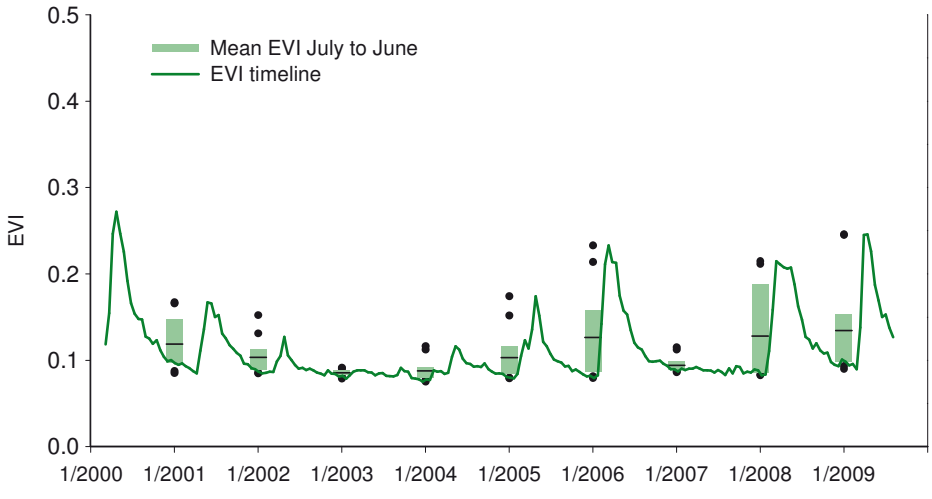
1 Low open shrubland on stony plain
2 Low open shrubland on accumulation area
3 Low open shrubland on slope
4 Low open shrubland with intersection of rivier

Elevation model of Observatory



MODIS time series

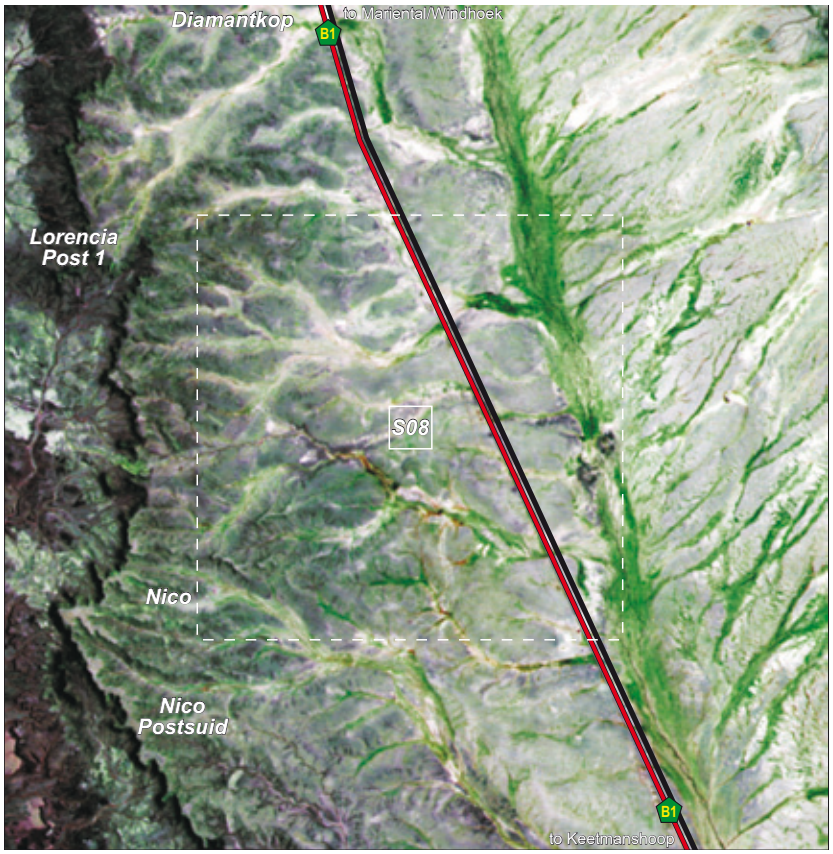
Temporal patterns of annual vegetation cover, and phenology



Landsat image

The northern Observatory at the Farm Niko is located in the Gibeon area, on a shallow slope between the higher Kalkrand Plateau in the east and the Schwarzkalk System in the west.

The sparse vegetation cover is an open dwarf-shrub savanna on stony plains typical of the Nama Karoo, which shows as blue-grey and dark grey to white colours reflecting the different types of geology. Green colours indicate denser herbaceous and grassy vegetation cover along riverbeds. Scattered trees and other woody vegetation can be identified by brown to red colours along washes and ephemeral rivers. The woody vegetation along the rivers is very sparse at Niko North.



Scene177/78, acquisition date: 15 February 2007

Responsible authors: M. Keil & T. Labitzky

Climate

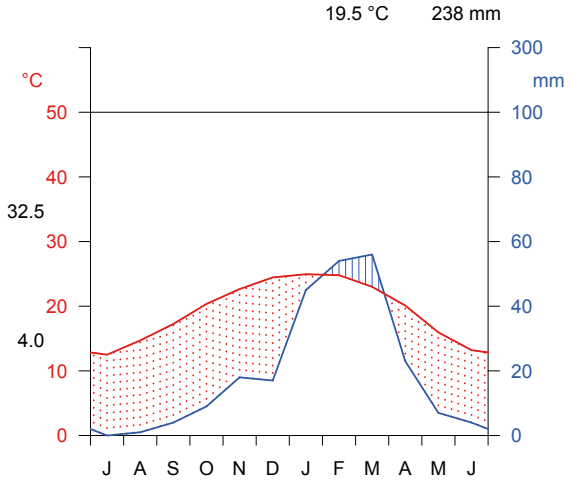
Modelled data

Mean temperature	Mean annual temperature range	Mean diurnal temperature range
19.5 (4.0–32.5) °C	12.1 °C	16.3 °C
Mean annual precipitation	**Precipitation seasonality**	**Percentage winter precipitation**
238 mm	99%	16% (strong summer)
Climate type	**Length of dry season**	**Aridity index (De Martonne)**
BWh	10 months	8.1 (dry)

Only interpolated data from the WorldClim dataset is available for this Observatory. The climate at the Observatory is characterised by arid to semi-arid conditions. Rainfall shows a pronounced seasonality with the major portion of rain falling during the summer season, peaking in March. The mean annual rainfall is 238 mm, which corresponds with the average rainfall recorded along the entire transect and within the Nama Karoo section of the transect. Near-surface air temperature shows a moderate seasonal cycle. The mean annual temperature is 19.5°C, which corresponds with the average for this biome.

Climate diagrams

Modelled data (WorldClim)



Responsible authors: K. Berger, A. Haensler & J. Luther-Mosebach

Lichens

Sampling period(s)	Hectare plots sampled	Cover
2001, 2004	10 (R1−R10)	0%
Total species richness	Species richness on soil [1 km²]	Species richness on rock [1 km²]
4	0	4 (100%)
Species richness on plants [1 km²]	Species richness on soil [1000 cm²]	
n.a.	0	

This Observatory hosts only a few saxicolous lichens, mainly growing on small quartz pebbles, while terricolous species are absent. Epiphytic lichens are rare and have not been investigated in further detail. The alkaline soils present at this Observatory are potentially suitable substrates for lichens, but climatic conditions are unfavourable for lichen growth (low precipitation, high temperature and low air humidity). Landuse, especially livestock grazing, probably also has a negative impact on the occurrence of soil-inhabiting lichens. Terricolous lichens are absent in the investigated hectare plots.

List of Taxa

Terricolous (on soil):

No records

Saxicolous (on rock):

Acarospora sp.
Peccania sp.
Peltula coriacea
Peltula inversa

Epiphytic (on plants):

No records

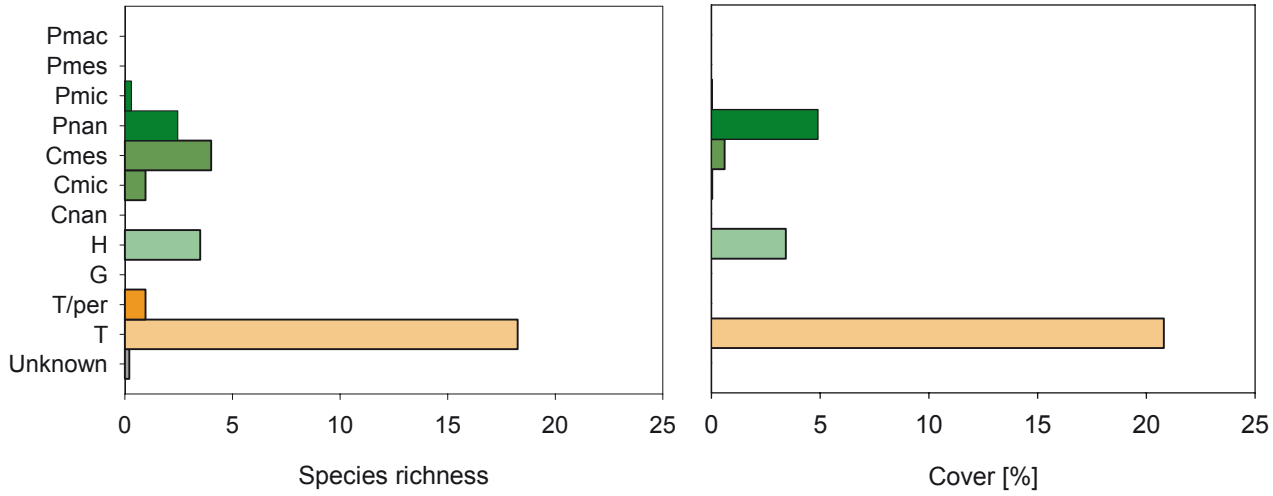
Peltula coriacea. Photo: M. Schultz, L. Zedda & G. Rambold.

Responsible authors: L. Zedda & G. Rambold

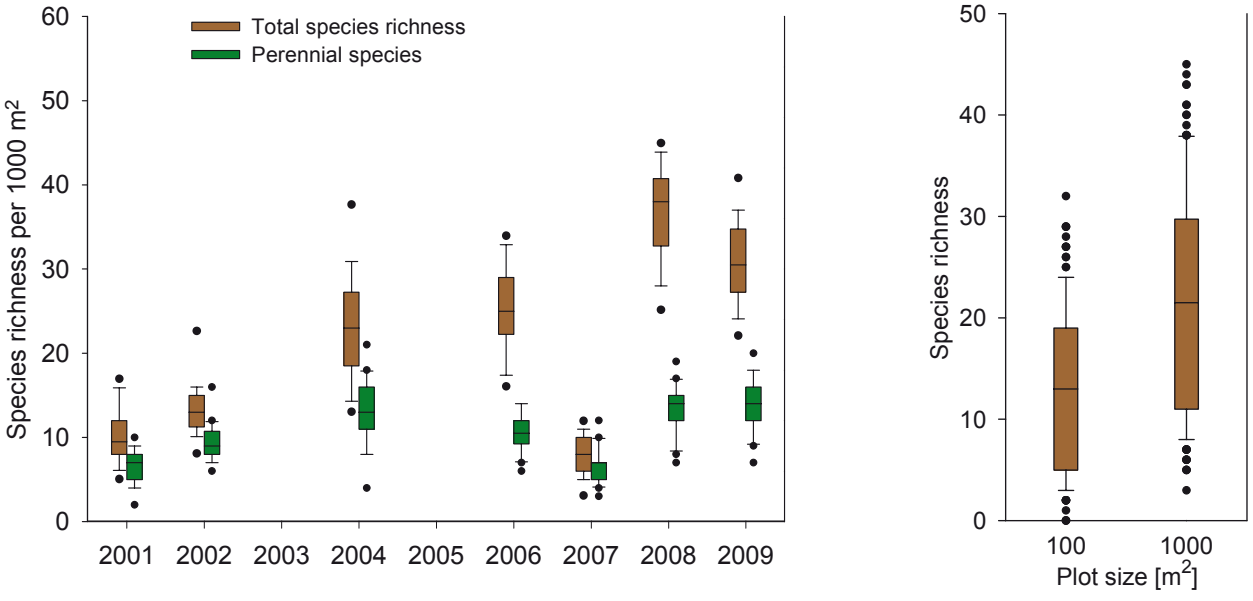
Vascular plants

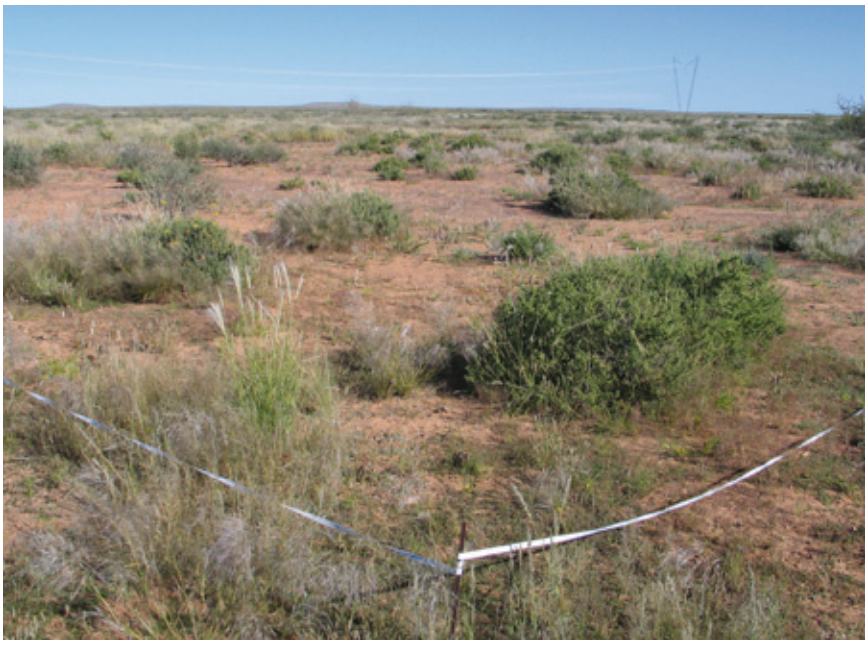
Sampling period(s)	Hectare plots sampled	Biome
2001, 2002, 2004, 2006–2009	20 (R1–R20)	Nama Karoo
Vegetation unit (level 1)	**Vegetation unit (level 2)**	**Identification rate**
Dwarf Shrub Savanna	n.a.	71% – 91% – 91%
Cumulative family richness	**Dominant families (cover)**	**Dominant families (richness)**
34	Poaceae, Bignoniaceae, Fabaceae	Poaceae, Asteraceae, Fabaceae
Cumulative species richness (1 km²)	**Species richness (1000 m²)**	**Species richness (100 m²)**
166 – 102	21.1 (3–45)	12.8 (0–32)
***z*-value**	**Species richness change per year (1000 m²)**	**Evenness (1000 m²)**
0.219 (0.051–0.778)	0.67	0.554 (0.043–0.875)
Evenness (100 m²)	**Simpson (1000 m²)**	**Simpson (100 m²)**
0.605 (0.021–0.936)	0.660 (0.015–0.938)	0.625 (0.000–0.893)

Life forms



Species richness





Unit 1, April 2008. Photo: N. Dreber.

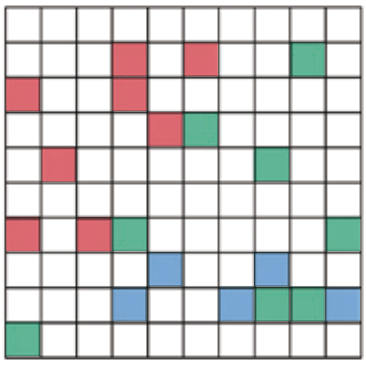
Unit 2, April 2009. Photo: N. Dreber.

Unit 3, April 2008. Photo: N. Dreber.

The vegetation of the BIOTA Observatory Niko North consists of open, grassy shrublands typical of the Nama Karoo. Overall, two habitat types can be distinguished, which are floristically well separated. Alluvial plains with much bare ground and low stone cover dominate the western parts of the Observatory. In contrast, stony plains dominate the eastern and south-eastern parts of the Observatory, and slope slightly towards the east. Trees (mainly *Acacia* spp., *Boscia foetida*, and *Parkinsonia africana*) are rare and are scattered throughout the Observatory. Localised, dense stands of shrubby vegetation occur, which are either associated with small gully structures or are due to clonal patches of the vegetatively-spreading shrub *Rhigozum trichotomum* (Driedoring). Three vegetation units can be distinguished, of which one is representative of the alluvial plains, and the remaining two occur on the stony plains. The β-diversity, measured as z-value at larger scales (1 ha to 1 km²), is amongst the highest along the BIOTA transect.

The *Salsola* spp.-*Xerocladia viridiramis* community (unit 1) is characteristic of the alluvial plains. This habitat type has silty-loamy textured soils mainly covered by fine material, which tend to form patches of abiotic crusts. A small-scale mosaic of extended bare patches and open dwarf shrublands is not further floristically differentiated. Patches of annual grasses, some as tall as waist-height, occur locally in good rainfall years. Most of them are pioneer grasses such as *Eragrostis annulata* (Ringwindhalmgras), *E. porosa* (Blousoetgras), *Schmidtia kalahariensis* (Kalaharisuurgras), and *Stipagrostis hirtigluma* (Bloutwa), indicating rangeland deterioration. In some places, water infiltration rates are low resulting in temporarily moist habitat conditions. Denser stands of the annual pioneer grass *Chloris virgata* (Klossiegras) grow in these areas. The common species of the halophytic genus *Salsola* (Ganna) indicate saline and/or alkaline habitat conditions, which might explain the high proportion of species unique to this vegetation unit. These conditions, and the frequently occurring soil crusts, might also be responsible for the high cover of

Map of vegetation units



bare ground due to unsuitable conditions for plant establishment and growth. The salt-tolerant, prostrate annual *Zygophyllum simplex* forms dense carpets after good rains. However, this species also frequently occurs in disturbed places. Similarly, the toxic *Geigeria ornativa* (Vermeerbos) is widespread, and indicates degradation due to overgrazing when it is abundant.

Vegetation unit 2 (*Geigeria alata-Eragrostis nindensis* community) and unit 3 (*Aptosimum spinescens-Limeum myosotis*) are typical of the stony plains. This habitat is densely covered by stones (up to 20 cm longest dimension) and varying amounts of quartz pebbles. Soil texture is sandy-loamy and abiotic crusts are

Classification table (2008)

Column		Cover	All	1	2	3
Number of relevés			**20**	**8**	***5***	**7**
Mean cover [%]			34.0	34.8	36.7	31.0
Mean species richness (1000 m²)			36.8	38.5	38.4	33.7
Unit 1: Salsola spp.-Xerocladia viridiramis community						
Cmes	Salsola spp.	0.87	45	100	20	.
Cmes	Geigeria pectidea	0.12	30	75	.	.
Cmic	Limeum argute-carinatum	0.17	45	88	.	29
H	Geigeria ornativa	0.21	45	88	20	14
T	Zygophyllum simplex	2.14	20	50	.	.
Cmic	Zygophyllum tenue	0.19	20	50	.	.
Cmes	Xerocladia viridiramis	0.63	30	63	.	14
Hper	Chascanum sp. 14343	0.01	30	63	.	14
T	Hermbstaedtia schaeferi	0.17	15	38	.	.
H	Cullen tomentosum	0.02	15	38	.	.
Cmes	Barleria rigida	0.02	15	38	.	.
Pnan	Acacia nebrownii	0.34	15	38	.	.
Unit 2: Geigeria alata-Eragrostis nindensis community						
T	Geigeria alata	0.01	25	.	100	.
H	Geigeria acaulis	0.22	35	25	100	.
T	Anticharis senegalensis	0.02	35	.	100	29
T	Tribulus pterophorus	0.18	25	.	80	14
T	Eragrostis nindensis	2.21	45	13	100	43
T	Gisekia africana	0.69	45	13	100	43
Pnan	Catophractes alexandri	0.56	35	13	80	29
Unit 3: Aptosimum spinescens-Limeum myosotis community						
Cmic	Limeum myosotis	0.02	60	.	.	43
Cnan	Aptosimum spinescens	0.04	15	25	60	100

Gisekia africana. Photo: N. Dreber.

Limeum myosotis. Photo: N. Dreber.

Classification table (continued)

Column		Cover	All	1	2	3
Number of relevés			**20**	**8**	***5***	**7**
T	Schmidtia kalahariensis	9.97	100	100	100	100
Pnan	Rhigozum trichotomum	4.00	100	100	100	100
T	Eragrostis porosa	2.61	100	100	100	100
T	Lotononis platycarpa	0.19	100	100	100	100
H	Indigofera charlieriana	0.15	100	100	100	100
T	Aristida adscensionis	1.44	95	88	100	100
T	Enneapogon desvauxii	0.56	95	88	100	100
T	Tribulus cristatus	0.31	95	88	100	100
H	Triraphis purpurea	0.09	95	100	100	86
T	Sesamum triphyllum	0.01	95	100	100	86
T	Trianthema parvifolia	1.71	90	75	100	100
T	Indigastrum argyroides	0.69	90	75	100	100
T	Tragus berteronianus	0.05	90	88	100	86
H	Stipagrostis hirtigluma	1.91	85	75	100	86
H	Stipagrostis uniplumis	1.51	85	63	100	100
H	Indigofera alternans	3.70	75	88	60	71
T	Enneapogon cenchroides	0.37	75	75	80	71
T	Cleome angustifolia	0.26	75	88	20	100
H	Dicoma capensis	0.06	75	38	100	100
Cmes	Blepharis obmitrata	0.04	75	63	100	71
Pnan	Calicorema capitata	0.45	70	38	100	86
T	Hermannia modesta	0.03	70	38	100	86
T	Monsonia umbellata	1.02	65	25	80	100
H	Stipagrostis hochstetteriana	0.33	65	75	20	86
H	Chloris virgata	0.32	65	88	40	57
T	Eragrostis annulata	0.31	65	88	20	71
T	Stipagrostis anomala	0.35	50	50	20	71
Cmes	Ptycholobium biflorum	0.04	45	63	40	29
Cmes	Aptosimum tragacanthoides	0.02	45	13	80	57
T	Tephrosia dregeana	0.02	45	50	40	43
T	Boerhavia repens	2.00	40	63	20	29
T	Entoplocamia aristulata	0.10	40	63	40	14
H	Ondetia linearis	0.08	40	50	80	.
G	Cucumis africanus	0.03	40	38	40	43
T	Limeum rhombifolium	0.05	35	63	.	29
Cmes	Phaeoptilum spinosum	0.72	30	13	60	29
T	Kohautia caespitosa ssp. brachyloba	0.01	30	13	20	57
H	Stipagrostis obtusa	0.32	25	25	.	43
T	Chascanum garipense	0.05	25	.	60	29
T	Chamaesyce glanduligera	0.03	25	25	20	29
Hper	Amaranthus praetermissus	0.02	20	25	20	14
T	Euphorbia inaequilatera	0.01	20	38	20	.
Cmes	Lycium bosciifolium	0.35	15	13	.	29
Pmic	Boscia foetida	0.15	15	.	20	29
Cmic	Limeum aethiopicum	0.04	15	25	20	.
H	Aristida congesta	0.01	15	25	20	.
T	Melinis repens	0.01	15	13	20	14
T	Mollugo cerviana	0.01	15	25	20	.

common in spaces between the stones. Shrubs such as *Calicorema capitata*, *Catophractes alexandri* (Gabbabos), and *Phaeoptilum spinosum* (Brosdoring) are more common within this habitat than in unit 1. It is unclear which environmental parameters determine the separation between vegetation unit 2 and unit 3. However, differences in soil properties are most likely responsible for the floristic separation of the communities, as no visual differences in habitat characteristics can be identified.

Community unit 2 possesses the most diagnostic species. Most are therophytes, except for example the perennial climax grass *E. nindensis* (Agtdaepluimgras), which preferentially grows in stony habitats including areas of quartzite. The shrub *C. alexandri* often occurs on shallow soils, and its diagnostic value for this community therefore might indicate an underlying gradient of soil depth within the rocky plains. This might be supported by the occurrence of the small perennial grass *Oropetium capense* (Haasgras), which is absent from vegetation unit 3 and is often observed growing on shallow soils. Both communities possess a high diversity of grasses, although some species are more frequently found in unit 3. These include less valuable grazing grasses such as *E. annulata* and *S. anomala* (Oumansbaard) and highly valuable grasses such as the perennials *S. hochstetteriana* (Gemsbokstertgras) and *S. obtusa* (Kortbeenboesmangras). Another difference between unit 2 and unit 3 is the occurrence of the toxic herb *Ondetia linearis* in unit 2.

Responsible authors: N. Dreber & J. Luther-Mosebach

Vertebrates

Total species richness	Reptile species richness	Bird species richness
11	n.a.	11
Large mammal species richness	Small mammal species richness	
n.a.	n.a.	

Birds

Passeriformes	**Perching birds**
Emberiza impetuani	Larklike Bunting
Mirafra apiata	Clapper Lark
Mirafra sabota	Sabota Lark (incl. Bradfield's)
Pteroclidiformes	**Sandgrouse**
Pterocles namaqua	Namaqua Sandgrouse

Namaqua Sandgrouse (*Pterocles namaqua*). Photo: J. Deckert.

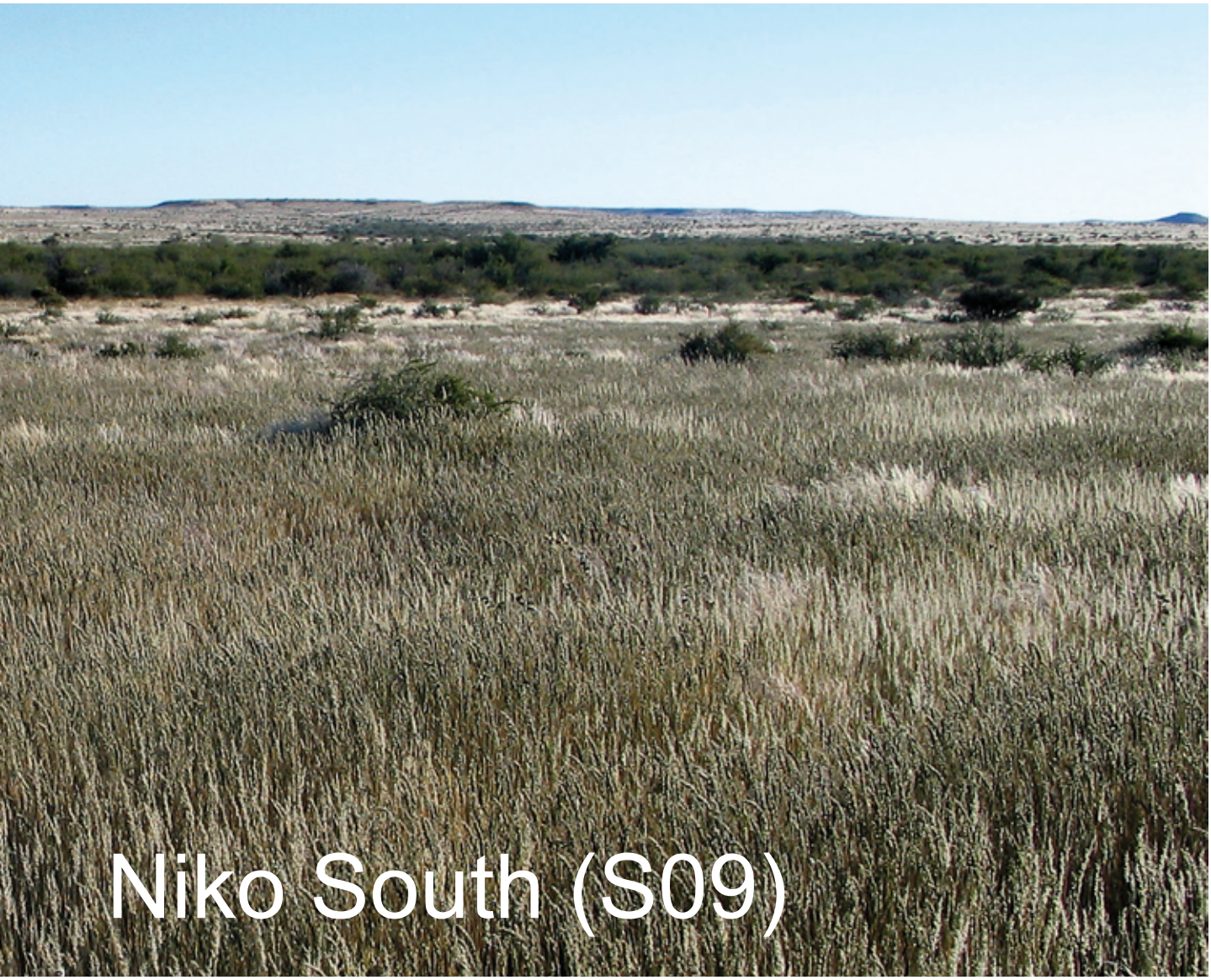
Responsible authors: J. Deckert, A. Hoffmann & A. Mills

Diversity measures in comparative rangeland studies: application and advantages of SADs and diversity profiles

► *See* **S04.07**

General data

Number	Name	Alternative name(s)
S09	Niko South	Niko reserve
Implementation	**Country**	**Province/ region**
2001	Namibia	Hardap
District/ constituency	**Locality**	**Farm name**
Mariental	near Gibeon	Niko 377
Latitude	**Longitude**	**Altitude**
25.333413 S	17.848966 E	1076 m a.s.l.
Rainfall season	**Biome**	**WWF Ecoregion**
Summer	Nama Karoo	AT1316 Namibian savanna woodlands
Agro-Ecological Zone	**Relative intensity of land use**	**Tenure**
CPL4-9	Medium	Communal
Type and history of landuse	**Land owner**	
Farming with goats	Government of Namibia	



Niko South (S09)

Annual grassland dominated by *Schmidtia kalahariensis* in front of an ephemeral riverbed with extended floodplains crossing the Observatory in the south-west. Photo: N. Dreber.

The BIOTA Observatory Niko South (S09) is situated in the Gibeon area on the communal farmlands of Niko about 80 km south of Mariental. The climate is semi-arid with high spatio-temporal variability of rainfall. The vegetation is an open dwarf-tall shrubland typical of the Nama Karoo. Trees are scattered and are concentrated along the washes and ephemeral river beds dissecting the stony plains.

This small farming area of about 2800 ha is divided into three camps, which are grazed in a rotational manner depending on rangeland condition. The management is centrally organised in order to maintain rangeland productivity and improve livestock production. The community received help in the past by taking part in programs for sustainable rangeland use such as the Sustainable Animal and Range Development Program (SARDEP) initiated by the Ministry of Agriculture, Water and Rural Development (MAWRD) with support from the Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ). They have also received help from the Desert Research Foundation of Namibia (DRFN), which implemented Namibia's UNCCD national action program. These special features contributed to the decision to include this Observatory in the BIOTA project. Besides Niko South, a second BIOTA Observatory (Niko North/S08) was established at another camp on the farm. The sustainability of the applied management strategies and consequent impacts on the

natural resources at Niko South are assessed through vegetation monitoring.

Responsible authors: N. Dreber & D.H. Haarmeyer

Remote sensing and landscape

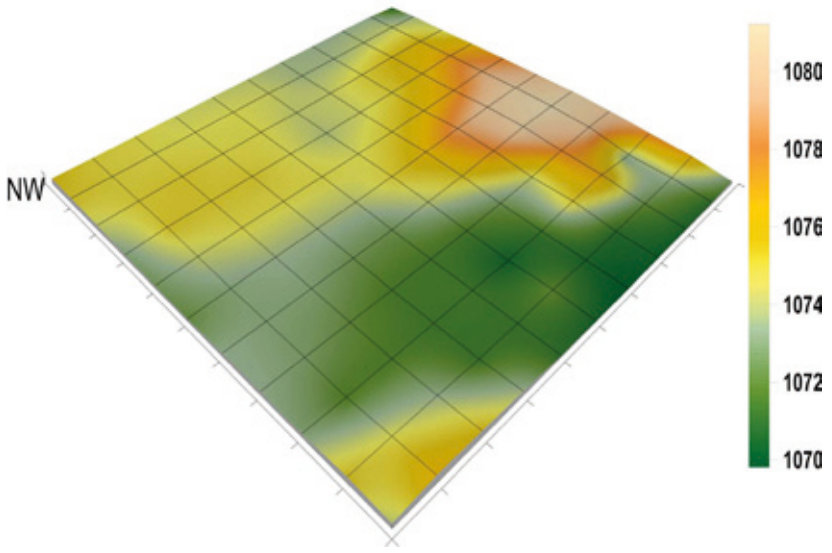
Geomorphology	Geological units	Lithological units
Stony to sandy areas, rivier	Main Karoo Basin in Karoo Supergroup	Sandstones and shales
Mean EVI	**EVI absolute range**	**Mean leaf area index**
0.111 (0.086–0.174)	0.076 (2003)–0.265 (2006)	0.39

Grid map of Observatory

	0	1	2	3	4	5	6	7	8	9
0	54	24	40	67	1	16	80	91	19	56
1	72	95	28	49	31	33	34	51	62	88
2	84	78	100	26	98	41	43	94	99	27
3	71	85	37	11	75	46	69	7	68	90
4	66	2	77	81	23	13	82	8	65	96
5	57	70	30	12	74	22	55	15	97	4
6	73	47	29	10	79	17	5	64	59	93
7	76	83	32	50	18	36	45	92	52	20
8	35	21	89	53	39	44	6	87	58	9
9	48	61	38	86	25	3	60	63	14	42

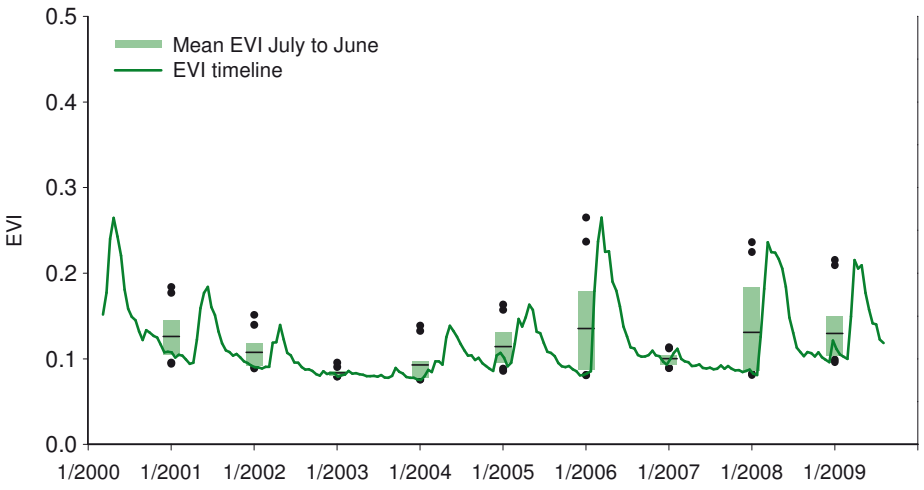
1 Low open shrubland on stony plain
2 Low open shrubland on accumulation area
3 Low open shrubland on slope
4 Low open shrubland with intersection of rivier

Elevation model of Observatory



MODIS time series

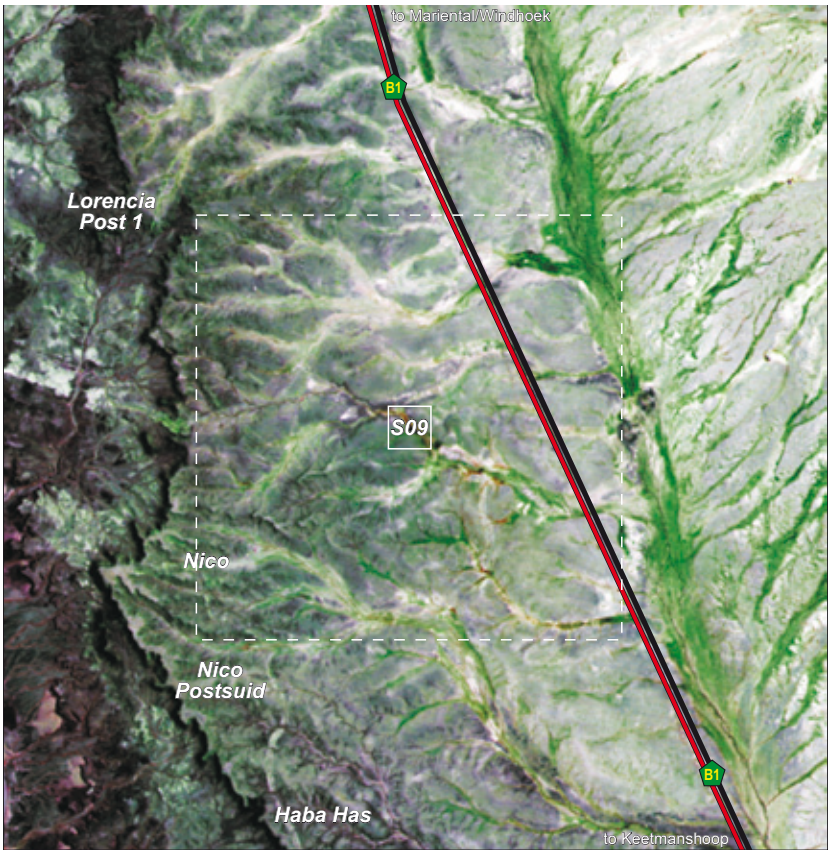
Temporal patterns of vegetation cover, and phenology



Landsat image

The southern Observatory at the farm Niko is located in the Gibeon area, on a shallow slope between the higher Kalkrand Plateau in the east and the Schwarzkalk System in the west.

The vegetation cover is an open dwarf shrub savanna on the stony plains typical of the Nama Karoo. Blue-grey and dark grey to white colours reflect the different types of geology, and green colours indicate higher herbaceous and grassland vegetation along the riverbeds. Scattered trees and other woody vegetation can be identified by brown to red colours along washes and ephemeral rivers. The woody vegetation along the rivers is denser on the Niko South Observatory, compared to the very sparse woody vegetation at Niko North (S08).



Scene177/78, acquisition date: 15 February 2007

Responsible authors: M. Keil & T. Labitzky

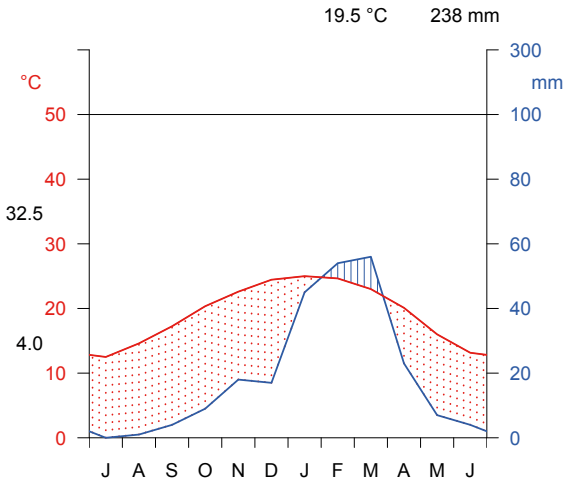
Climate

Modelled data		
Mean temperature	Mean annual temperature range	Mean diurnal temperature range
19.5 (4.0–32.5) °C	12.3 °C	16.3 °C
Mean annual precipitation	Precipitation seasonality	Percentage winter precipitation
238 mm	99%	16% (strong summer)
Climate type	Length of dry season	Aridity index (De Martonne)
BWh	10 months	8.1 (dry)

Only interpolated data from the WorldClim dataset is available for this Observatory. The climate at the Observatory is characterised by arid to semi-arid conditions. Rainfall shows a pronounced seasonality with the major portion of rain falling during the summer season, peaking in March. The mean annual rainfall is 238 mm, which corresponds with the average rainfall recorded along the entire transect and within the Nama Karoo section of the transect. Near-surface air temperature shows a moderate seasonal cycle. The mean annual temperature is 19.5°C, which corresponds with the average for this biome.

Climate diagrams

Modelled data (WorldClim)



Responsible authors: K. Berger, A. Haensler & J. Luther-Mosebach

Lichens

Sampling period(s)	Hectare plots sampled	Cover
2001, 2004	10 (R1−R10)	0%
Total species richness	**Species richness on soil [1 km²]**	**Species richness on rock [1 km²]**
4	0	4 (100%)
Species richness on plants [1 km²]	**Species richness on soil [1000 cm²]**	
n.a.	0	

This Observatory hosts only a few saxicolous lichens on small quartz pebbles and on stones, while terricolous lichens are absent. Epiphytic taxa are rare because of the lack of proper substrates and have not been investigated in further detail. The limited number of lichens occurring at the Observatory is related to unfavourable climatic conditions, as in the neighbouring Observatory S08 (Niko North). Landuse, especially livestock grazing, has probably also had a negative impact on the occurrence of soil-inhabiting lichens. Terricolous lichens are absent on all investigated hectare plots.

List of Taxa

Terricolous (on soil):

No records

Saxicolous (on rock):

Acarospora sp.
Buellia sp.
Peltula inversa
Verrucaria sp.

Epiphytic (on plants):

No records

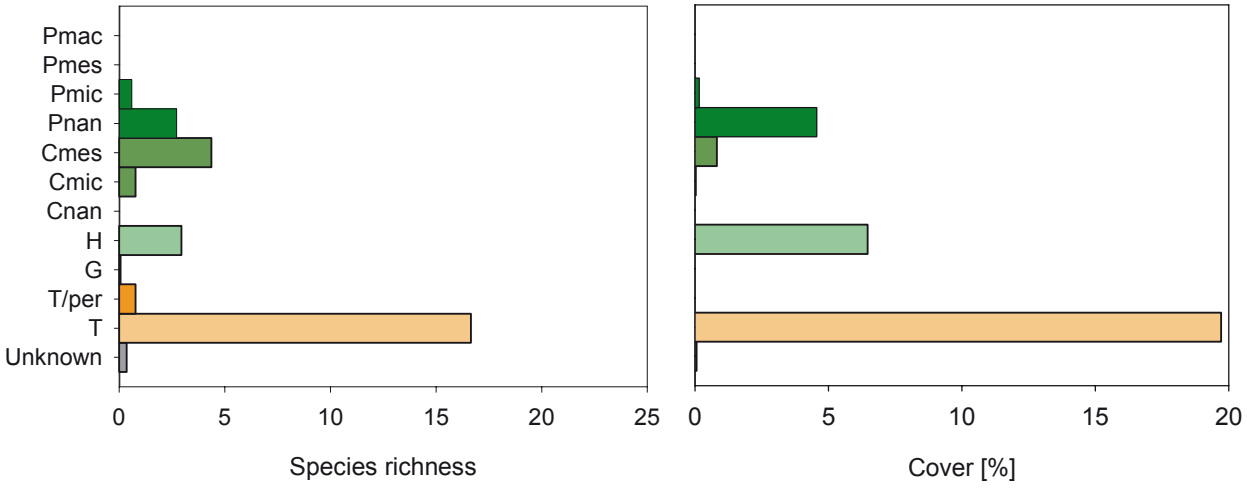
Peltula inversa. Photo: L. Zedda & G. Rambold.

Responsible authors: L. Zedda & G. Rambold

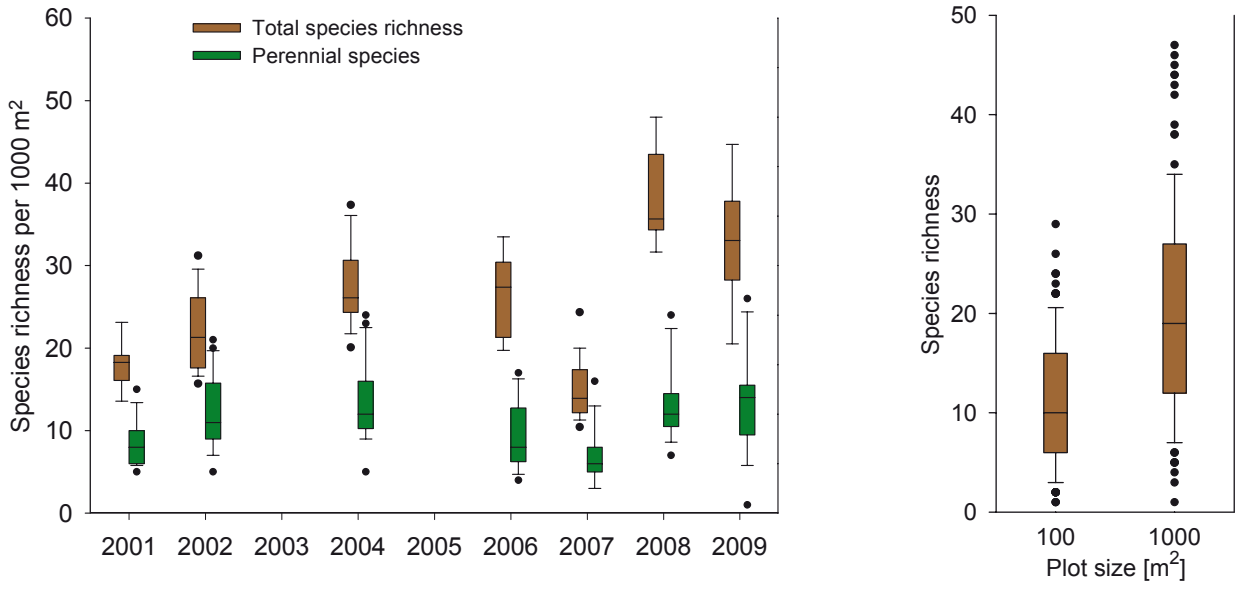
Vascular plants

Sampling period(s)	Hectare plots sampled	Biome
2001, 2002, 2004, 2006–2009	20 (R1–R20)	Nama Karoo
Vegetation unit (level 1)	**Vegetation unit (level 2)**	**Identification rate**
Dwarf Shrub Savanna	n.a.	73% – 94% – 96%
Cumulative family richness	**Dominant families (cover)**	**Dominant families (richness)**
41	Poaceae, Fabaceae, Bignoniaceae	Poaceae, Fabaceae, Asteraceae
Cumulative species richness (1 km²)	**Species richness (1000 m²)**	**Species richness (100 m²)**
204 – 115	20.3 (1–47)	11.0 (1–29)
z-value	**Species richness change per year (1000 m²)**	**Evenness (1000 m²)**
0.267 (0.000–0.778)	1.33	0.612 (0.043–0.934)
Evenness (100 m²)	**Simpson (1000 m²)**	**Simpson (100 m²)**
0.628 (0.045–0.961)	0.705 (0.000–0.938)	0.627 (0.000–0.896)

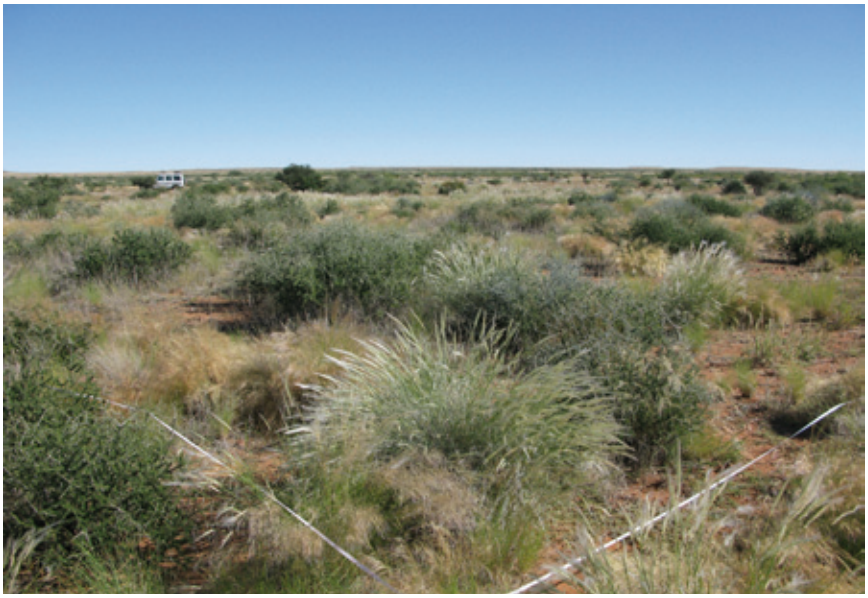
Life forms



Species richness



Unit 2, April 2009. Photo: N. Dreber.



Unit 3, April 2009. Photo: N. Dreber.

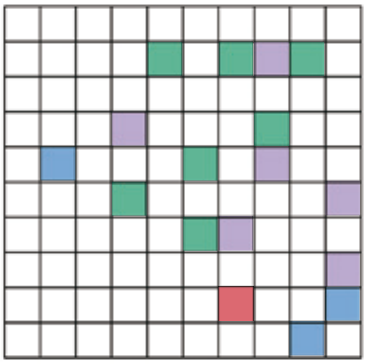
Unit 4, April 2009. Photo: N. Dreber.

Unit 1, April 2006. Photo: N. Dreber.

The vegetation at BIOTA Observatory Niko South consists of open, grassy shrublands typical of the Nama Karoo. The most common habitat type on the Observatory is plains covered by stones, rocks and quartz pebbles. This habitat slopes gently towards the south-west down to an ephemeral riverbed with extended floodplains. Accordingly, there is a transition from open shrublands into riverine thickets interspersed by pan-like patches densely vegetated with grasses. While trees are abundant in the riverine structures, they are scattered within the plains and on gentle slopes (e.g. *Commiphora pyracanthoides* and *Parkinsonia africana*). Four vegetation units can be distinguished on the Observatory, of which two are characteristic of the stony plains and gentle slopes, one is characteristic of the transition zone from grassy shrublands to the riverbed, and the last is characteristic of the riverine habitat. The β-diversity at this Observatory, measured as z-value at larger scales (1 ha to 1 km^2), is amongst the highest along the entire BIOTA transect.

The *Setaria pumila-Acacia nebrownii* community (unit 1) grows on the floodplains along the riverbed. It is one of the most species rich vegetation units occur-

Map of vegetation units



ring on the Observatory. The vegetation unit possesses a high diversity of grasses, forbs and woody vegetation, of which deep rooting species have access to ground water. The most prominent shrub/small tree of this unit is the thorny *A. nebrownii* (Slapdoring or Waterdoring), which forms locally impenetrable thickets. Another characteristic tree is *Ziziphus mucronata* (Blinkblaar-Wag-'n-Bietjie), which is used for medicinal purposes, handcrafting, and as fodder for game and livestock. Grass patches are dominated by *Chloris virgata* (Klossiegras), *Eragrostis rotifer* (Vleipluimgras), *S. pumila*, and *Urochloa brachyura*, which are of low-average grazing value. Inside the thickets, the annual grass *Setaria verticillata* (Klitsgras) is the most dominant species of the herbaceous layer. One of the most abundant forbs is the red flowering *Indigofera hochstetteri*, which together with the annuals *Hibiscus trionum* and *Corchorus schimperi,* form dense herbaceous vegetation between the waist-high grasses.

The *Indigofera pechuelii-Catophractes alexandri* vegetation unit 2 is representative of the transition between the stony plains and the riverine habitats. However, it has more species in common with vegetation units 3 and 4 than with vegetation unit 1, which is most likely due to the prevailing xeric habitat conditions. This unit is the most species rich occurring on the Observatory, and is characterised by a diverse mixture of taller shrubs/trees, dwarf shrubs and grasses. The most prominent shrub is *C. alexandri* (Gabbabos), with

Classification table (2008)

Column		Cover	All	*1*	2	3	4
Number of relevés			**17**	***1***	**3**	**7**	**6**
Mean cover [%]			36.9	*104.2*	50.2	29.3	27.9
Mean species richness (1000 m²)			36.0	*37.0*	48.3	31.6	34.8
Inclination [°]			2.1	*1.0*	4.3	1.6	1.7
Fine material [%]			46.4	*0.0*	55.0	52.5	42.5
Gravel [%]			26.6	*0.0*	17.7	33.4	27.5
Stones 2-6 cm [%]			11.1	*0.0*	12.0	6.5	17.8
Stones 6-20 cm [%]			8.7	*0.0*	12.3	7.2	10.2
Stones 20-60 cm [%]			1.3	*0.0*	3.0	0.1	2.0
Blocks [%]			0.0	*0.0*	0.0	0.0	0.0
Rock outcrops [%]			0.0	*0.0*	0.0	0.0	0.0
Unit 1: Setaria pumila-Acacia nebrownii community							
Pnan	Ehretia sp. 122943	1.00	6	*100*	.	.	.
Hper	Cullen tomentosum	0.30	6	*100*	.	.	.
T	Felicia sp. 122945	0.30	6	*100*	.	.	.
H	Eragrostis rotifer	5.00	6	*100*	.	.	.
T	Corchorus tridens	0.50	6	*100*	.	.	.
Hper	Achyranthes aspera	0.50	6	*100*	.	.	.
n.a.	Bidens bipinnata	0.30	6	*100*	.	.	.
T	Corchorus schimperi	1.00	6	*100*	.	.	.
G	Androcymbium roseum	0.20	6	*100*	.	.	.
H	Acalypha segetalis	0.30	6	*100*	.	.	.
T	Setaria pumila	20.00	6	*100*	.	.	.
Pnan	Grewia flava	0.30	6	*100*	.	.	.
T	Zehneria marlothii	1.00	6	*100*	.	.	.
T	Urochloa brachyura	5.00	6	*100*	.	.	.
T	Setaria verticillata	10.00	6	*100*	.	.	.
T	Hibiscus trionum	0.50	6	*100*	.	.	.
H	Panicum lanipes	0.50	6	*100*	.	.	.
Cmes	Lycium bosciifolium	2.00	6	*100*	.	.	.
T	Indigofera hochstetteri	2.00	6	*100*	.	.	.
H	Cenchrus ciliaris	0.50	6	*100*	.	.	.
n.a.	Monechma sp. 122949	0.50	6	*100*	.	.	.
T	Brachiaria eruciformis	0.50	6	*100*	.	.	.
T	Melinis repens	0.04	18	*100*	.	14	17
Pmic	Ziziphus mucronata	0.85	29	*100*	33	0	0
Hper	Geigeria pectidea	0.14	35	*100*	33	14	17
Pnan	Acacia nebrownii	5.24	35	*100*	67	0	0
Cmes	Asparagus sp.	0.05	41	*100*	67	14	33
H	Chloris virgata	2.01	35	*100*	67	14	33
Unit 2: Indigofera pechuelii-Catophractes alexandri community							
Cmes	Sericocoma heterochiton	0.01	18	.	100	.	.
Cmic	Leucosphaera bainesii	0.06	18	.	100	.	.
Hper	Chascanum garipense	0.05	24	.	100	.	17
Cmes	Aptosimum tragacanthoides	0.17	29	.	100	14	17
Cmes	Indigofera pechuelii	0.43	12	.	67	.	.
Pmic	Boscia foetida	0.54	35	.	100	43	.
Pnan	Catophractes alexandri	3.76	35	.	100	29	17
Unit 3: Indigofera alternans-Rhigozum trichotomum community							
Hper	Indigofera alternans	0.73	47	.	.	100	17
Unit 4: Geigeria alata-Eragrostis nindensis community							
T	Geigeria alata	0.20	41	.	33	.	100
Hper/T	Anticharis senegalensis	0.01	59	.	67	29	100
T	Tribulus pterophorus	0.41	41	.	67	.	83

continued on next page

Classification table (continued)

Classification table (continued)

Column		Cover	All	*1*	2	3	4
Number of relevés			17	*1*	3	7	6
Most frequent companions							
T	Aristida adscensionis	1.89	94	*100*	67	100	100
T	Enneapogon desvauxii	0.99	94	.	100	100	100
T	Indigofera charlieriana	0.66	94	*100*	100	100	83
T	Lotononis platycarpa	0.58	94	.	100	100	100
T	Tribulus cristatus	0.44	94	.	100	100	100
Cmes	Calicorema capitata	0.44	94	.	100	100	100
T	Eragrostis porosa	0.21	94	*100*	100	100	83
Hper	Dicoma capensis	0.11	94	.	100	100	100
Cmes	Blepharis obmitrata	0.09	94	.	100	100	100
H	Stipagrostis uniplumis	2.65	94	.	100	100	100
T	Schmidtia kalahariensis	9.27	88	.	67	100	100
T	Trianthema parvifolia	2.61	88	.	100	86	100
Pnan	Rhigozum trichotomum	1.99	88	.	67	100	100
T	Indigastrum argyroides	0.71	88	.	100	100	83
H	Stipagrostis hirtigluma	3.39	82	.	67	100	83
T	Tragus berteronianus	0.04	82	.	100	100	67
Hper	Monsonia umbellata	0.53	76	.	67	86	83
T	Sesamum triphyllum	0.02	76	.	33	86	100
Pnan	Phaeoptilum spinosum	0.36	71	*100*	100	71	50
Cmes	Hermannia modesta	0.07	71	.	67	86	67
T	Eragrostis nindensis	1.47	65	.	67	57	83
T	Gisekia africana	0.15	65	.	67	57	83
T	Entoplocamia aristulata	0.08	65	.	67	57	83
Cmes	Ptycholobium biflorum	0.06	65	.	100	57	67
T	Enneapogon cenchroides	0.56	59	.	67	71	50
T/Hper	Ondetia linearis	0.16	59	.	67	43	83
T	Triraphis purpurea	0.01	53	.	67	43	67
T/H	Stipagrostis anomala	1.35	47	.	67	43	50
Cmic	Aptosimum spinescens	0.02	47	.	67	43	50
Hper	Cleome angustifolia	0.15	41	.	100	29	33
T	Chamaesyce glanduligera	0.11	41	.	100	29	33
T/Hper	Tephrosia dregeana	0.07	41	.	100	29	33
T	Eragrostis annulata	0.02	41	.	33	57	33
H	Chloris virgata	2.01	35	*100*	67	14	33
Cmes	Asparagus spp.	0.05	35	*100*	67	14	33
H	Stipagrostis hochstetteriana	0.29	29	.	.	43	33
T	Mollugo cerviana	0.01	29	.	67	29	17
T	Geigeria acaulis	0.22	24	.	33	.	50
Hper	Geigeria pectidea	0.14	24	*100*	33	14	17
Hper	Cucumis africanus	0.03	24	.	33	14	33
Pnan	Acacia nebrownii	5.24	18	*100*	67	.	.
Pnan	Cryptolepis decidua	0.30	18	.	67	.	17
T/Hper	Indigofera auricoma	0.10	18	.	67	.	17
n.a.	Talinum sp. 14304	0.04	18	.	33	14	17
Pnan	Commiphora pyracanthoides	0.04	18	.	67	14	.
T	Boerhavia repens	0.03	18	.	33	29	.
T/Hper	Kohautia caespitosa ssp. brachyloba	0.01	18	.	.	29	17
Pmic	Ziziphus mucronata	0.85	12	*100*	33	.	.
Pmic	Acacia mellifera ssp. detinens	0.36	12	.	33	.	17
H	Oropetium capense	0.08	12	.	.	.	33
Cmes	Barleria rigida	0.04	12	.	33	.	17
T	Dactyliandra welwitschii	0.04	12	.	.	29	.
T	Limeum rhombifolium	0.01	12	.	.	14	17
Hper	Striga gesnerioides	0.01	12	.	33	14	.

Phaeoptilum spinosum (Brosdoring), *Acacia mellifera* (Swarthaak) and *A. nebrownii* also being common. The dwarf-shrubs *Indigofera pechuelii*, *Leucosphaera bainesii* (Wolbos), and *Sericocoma heterochiton* are unique to this community. In good rainfall years, the herbaceous layer is dominated by annual pioneer grasses such as *Enneapogon cenchroides* (Eenjarige Negenaaldgras), *Schmidtia kalahariensis* (Kalaharisuurgras), and *Stipagrostis hirtigluma* (Bloutwa), which indicate a certain degree of habitat disturbance. The high fodder supply in this community, even during dry years, and its location near the similarly diverse riverine habitat may result in frequent livestock pressure, which favours the high abundance of these grasses.

The two communities characteristic of the stony habitats are hardly separable and similar to those found in the respective habitat types on the adjacent Observatory Niko (S08). Generally, the small tree *Boscia foetida* (Stinkbos) and shrubs such as *Calicorema capitata*, *C. alexandri*, and *Rhigozum trichotomum* (Driedoring) are widespread, and the latter two form locally dense stands. Vegetation unit 4 is identical to the *Geigeria alata-Eragrostis nindensis* community of Observatory Niko North (S08). This unit is typical of the plains and gentle slopes, which are densely covered by stones (up to 20 cm longest dimension) and varying amounts of quartz pebbles. For a detailed description of this community refer to Observatory Niko (S08). The *Indigofera alternans-Rhigozum trichotomum* vegetation unit 3 occurs in habitats with mostly moderate stone cover and sandy-loamy patches, which are sparsely vegetated. The prostrate annual *Indigofera alternans* forms locally dense carpets on the ground, which is less frequently observed in unit 4. However, the most striking visual difference to unit 4 is the characteristic matrix of stands of *R. trichotomum* and grasses dominated by *S. kalahariensis*. The therophytic *Limeum myosotis* occurs at some plots within this vegetation unit 3, highlighting the relation of this unit to vegetation unit 3 on Observatory Niko North (S08).

Responsible authors: N. Dreber & J. Luther-Mosebach

Vertebrates

Total species richness	Reptile species richness	Bird species richness
7	n.a.	7
Large mammal species richness	Small mammal species richness	
n.a.	n.a.	

Birds

Passeriformes	**Perching birds**
Certhilauda curvirostris	Cape Long-billed Lark
Parisoma subcaeruleum	Chestnut-vented Tit-Babbler
Telophorus zeylonus	Bokmakierie
Prinia flavicans	Black-chested Prinia
Sporopipes squamifrons	Scaly-fronted Weaver
Pteroclidiformes	**Sandgrouse**
Pterocles namaqua	Namaqua Sandgrouse
Piciformes	**Woodpeckers and relatives**
Tricholaema leucomelas	Acacia Pied Barbet

Responsible authors: J. Deckert, A. Hoffmann & A. Mills

Diversity measures in comparative rangeland studies: application and advantages of SADs and diversity profiles

► *See* **S04.07**

General data

Number	Name	Alternative name(s)
S10	Gellap Ost	Gellap Ost Research Station
Implementation	**Country**	**Province/ region**
2001	Namibia	Karas
District/ constituency	**Locality**	**Farm name**
Keetmanshoop	Keetmanshoop	Gellap Ost 3
Latitude	**Longitude**	**Altitude**
26.401195 S	18.004842 E	1099 m a.s.l.
Rainfall season	**Biome**	**WWF Ecoregion**
Summer	Nama Karoo	AT1316 Namibian savanna woodlands
Agro-Ecological Zone	**Relative intensity of land use**	**Tenure**
CPL7	Medium	State
Type and history of landuse	**Land owner**	
Farming with sheep, cattle and horses	MAWF	

Gellap Ost (S10)

Hilly landscape on the Gellap Ost Observatory. Photo: N. Dreber.

The BIOTA Observatory Gellap Ost (S10) is situated on the government research station Gellap Ost, which is one of the oldest research farms in Namibia and specialises in small stock breeding and farming extension programs. The 13,734 ha farm is located about 15 km north-west of Keetmanshoop, the capital of the southern Karas region. This arid part of the Nama Karoo Biome is dominated by slightly undulating plains dissected by washes, prominent dolerite hills and dykes, and cone-shaped shale 'inselbergs'. The vegetation consists of grassland, dwarf shrubland and shrub savannas. Due to the low and spatiotemporally variable rainfall, the mean seasonal biomass production of the area is low as in the western desert regions, which restricts pastoral activities to mainly small stock farming.

This BIOTA Observatory has been established in a 261 ha camp bordering the communal area of Nabaos, directly adjacent to the BIOTA Observatory Nabaos (S11). The difference in land tenure and grazing regime between Gellap Ost and Nabaos is manifested in a fence-line contrast, which allows the study of contrasting land use impacts on the biotic and abiotic environment. Therefore, the monitoring program provides important information about ecosystem dynamics, resistance, and resilience. Due to low stocking rates and sustainable grazing management, the rangelands of Gellap Ost are in good condition in terms of biodiversity, productivity and ecosystem

functioning. Thus, Gellap Ost is regarded a reference site or benchmark for research on land degradation at the adjacent Nabaos Observatory.

Responsible authors: N. Dreber & D.H. Haarmeyer

Remote sensing and landscape

Geomorphology	Geological units	Lithological units
Plains, slopes, outcrops, accumulation area, rivier	Main Karoo Basin in Karoo Supergroup	Sandstones and shales
Mean EVI	**EVI absolute range**	**Mean leaf area index**
0.067 (0.040–0.134)	0.031 (2003)–0.164 (2009)	0.37

Grid map of Observatory

	0	1	2	3	4	5	6	7	8	9
0	95	33	93	36	43	2	62	52	92	10
1	96	98	61	5	27	37	32	19	42	8
2	53	14	71	88	63	50	81	24	13	57
3	56	48	40	100	74	30	68	69	66	90
4	67	29	76	17	45	99	9	75	87	3
5	72	22	60	97	91	64	82	55	31	85
6	12	46	7	18	79	58	6	59	21	73
7	38	54	15	16	70	78	35	84	49	34
8	11	80	20	83	47	94	39	65	26	77
9	44	28	1	23	51	25	89	86	41	4

1 Grass-dominated open shrubland on footslopes
2 Low shrubland on rocky slopes
3 Grass-dominated open shrubland on rocky slopes
4 Grass-dominated open shrubland on accumulation area
5 Grass- and thornbush-dominated shrubland on footslopes
6 Grass- and thornbush-dominated shrubland on rocky outcrops

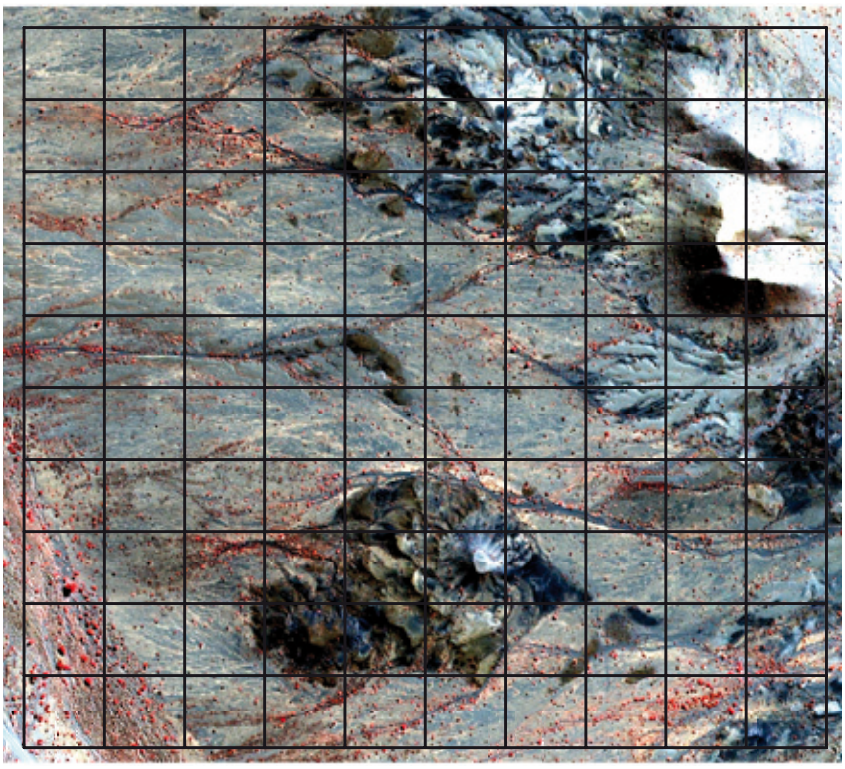
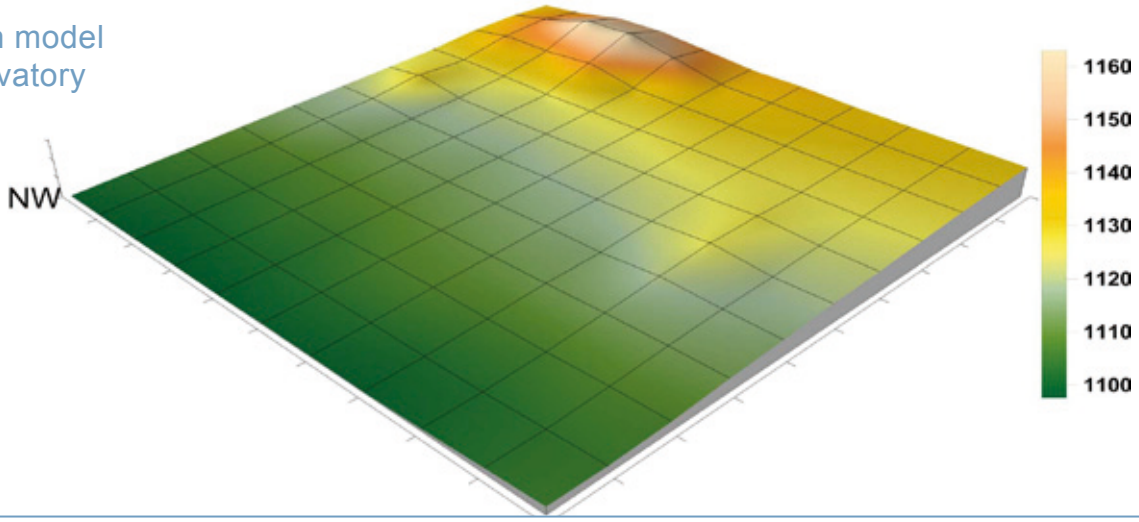


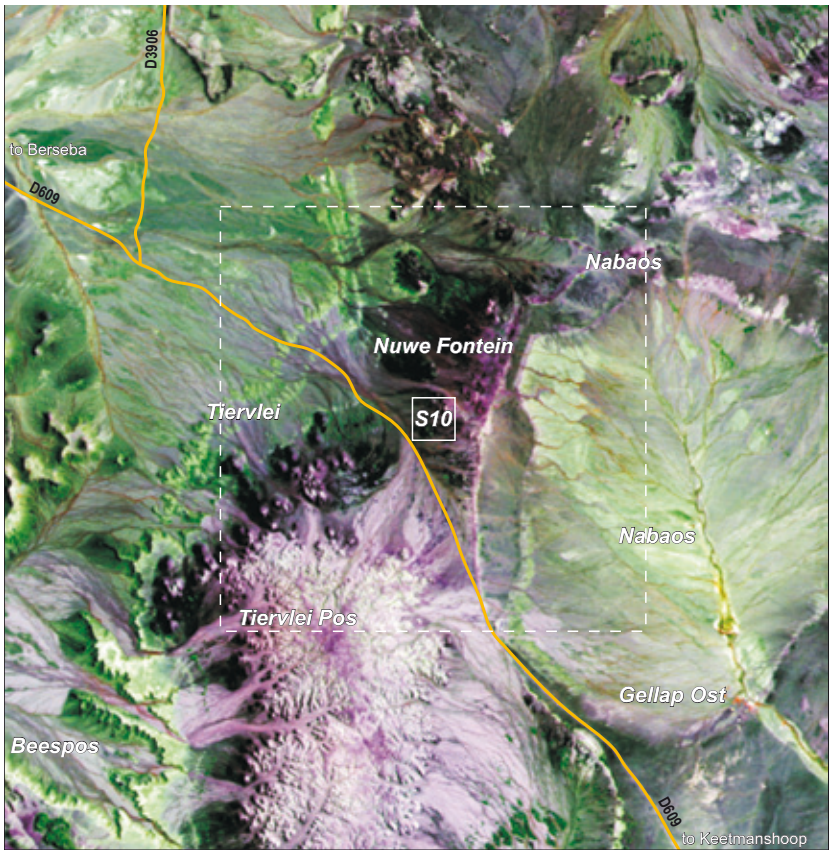
Image: QuickBird, 21 August 2004

Elevation model of Observatory



Landsat image

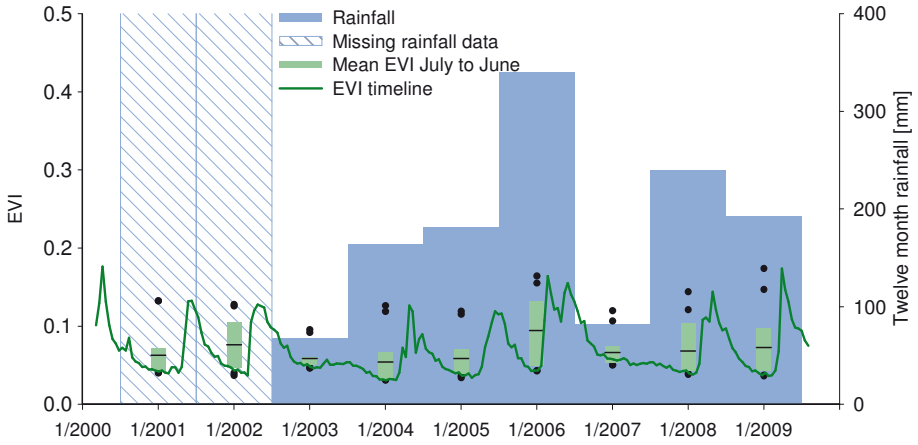
The landscape northwest of Keetmanshoop consists of fan-shaped erosion plains and persisting, deeply eroded crests. Dense cover of shrubs and trees is mainly concentrated along aquifers and riverbeds (red lines). The herbaceous vegetation in the northwest part of the Observatory, which consists mainly of perennial grasses and herbaceous vegetation, shows up in green colours. Blue colours indicate open or sparsely vegetated areas in the rocky southern parts of the Observatory. White patches indicate areas of pure rock in the dissected south-western mountains and bare, eroded slopes at the eastern edge of the image. The vegetation on the Observatory Gellap Ost appears denser than at the neighbouring Observatory Nabaos.



Scene: 177/78, acquisition date: 15 February 2007

MODIS time series

Temporal patterns of annual rainfall, vegetation cover, and phenology



Responsible authors: M. Keil & T. Labitzky

Climate

Data from BIOTA weather station

Location	Recorded period	Mean temperature
Gellap Ost (S10)	2001–2009	22.6 (0.4–41.5) °C
Mean solar radiation	**Mean wind speed**	**Mean annual precipitation**
589 (358–842) MJ·m^{-2}·month^{-1}	3.2 (9.3) m·s^{-1}	183 (90–320) mm
Mean annual potential evapotranspiration	**Interannual precipitation variability**	**Mean relative humidity**
1804 mm	173%	35% (23–56%)
Aridity index (UNEP)		
0.10 (arid)		

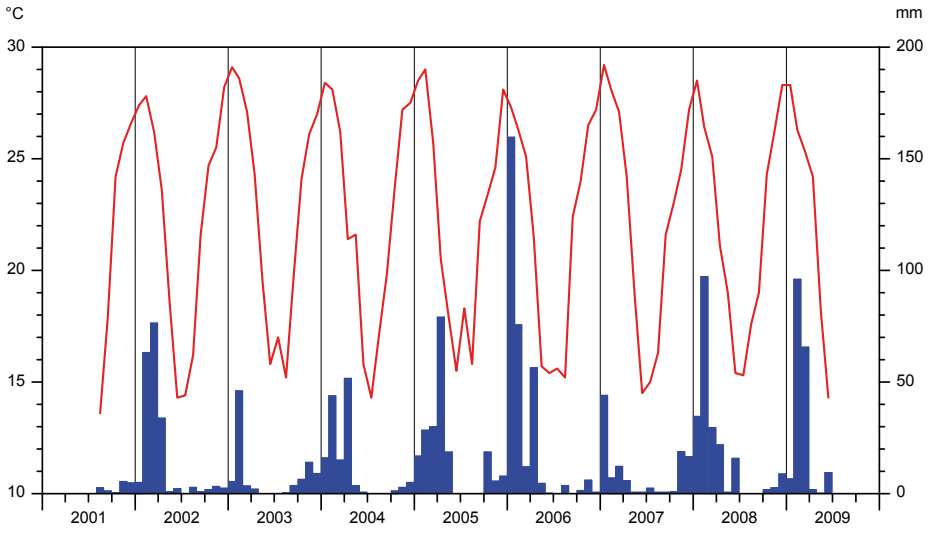
Modelled data

Mean temperature	Mean annual temperature range	Mean diurnal temperature range
20.5 (5.6–34.5) °C	12.9 °C	16.2 °C
Mean annual precipitation	**Precipitation seasonality**	**Percentage winter precipitation**
153 mm	106%	14% (strong summer)
Climate type	**Length of dry season**	**Aridity index (De Martonne)**
BWh	12 months	5.0 (dry)

The climate at the Observatory is characterised by arid to semi-arid conditions. Rainfall shows a moderate seasonality with the major portion of rain falling during the summer season, peaking in February. The mean annual rainfall over the observation period was 183 mm, which is drier than the average rainfall recorded along the entire transect but about the average within the Nama Karoo section of the transect. However, substantial interannual variability is evident. The observed near-surface air temperatures show a moderate seasonal cycle. The mean annual temperature is 22.6°C and is therefore slightly warmer than the mean temperature of all Observatories, and of the Observatories within the Nama Karoo. Compared to the interpolated long-term data taken from the WorldClim dataset, a noticeably warmer mean annual temperature was observed at the station. Furthermore, the station records of temperature extremes deviate substantially from the WorldClim data, showing warmer maximum and minimum temperatures. For precipitation, mean annual rainfall is remarkably higher at the BIOTA weather station compared to the WorldClim data.

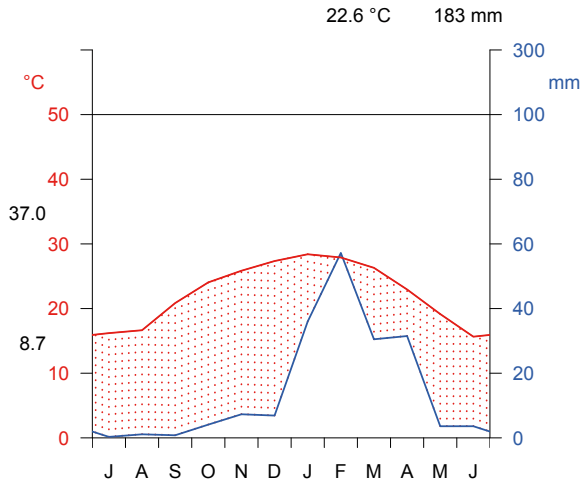
The observed near-surface winds at the Observatory are mainly constituted of southerly flows during spring and summer. During the autumn and winter seasons, the circulation changes to flows from northerly and north-easterly directions, but a south-easterly flow component is also noticeable. Mean wind speed recorded in the evenings shows a pronounced annual cycle, peaking in mid-summer. Winds observed during the mornings and early afternoons stay fairly constant throughout the year, with higher wind speeds in the early afternoon, reaching about 13 km/h.

Time series: rainfall and temperature

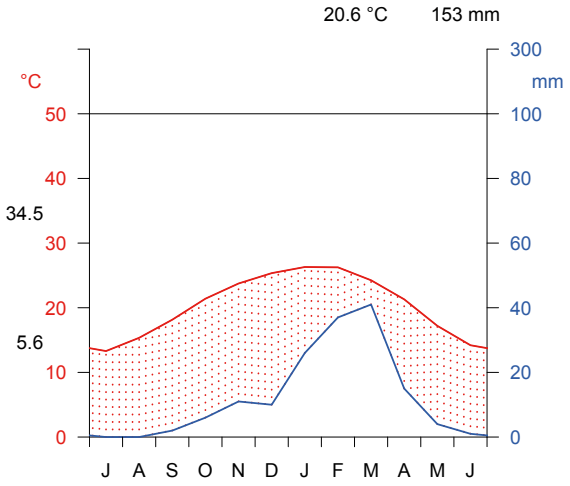


Climate diagrams

Recorded data (BIOTA)

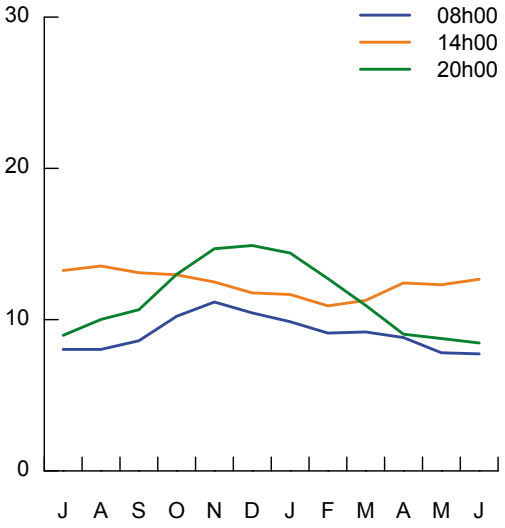


Modelled data (WorldClim)

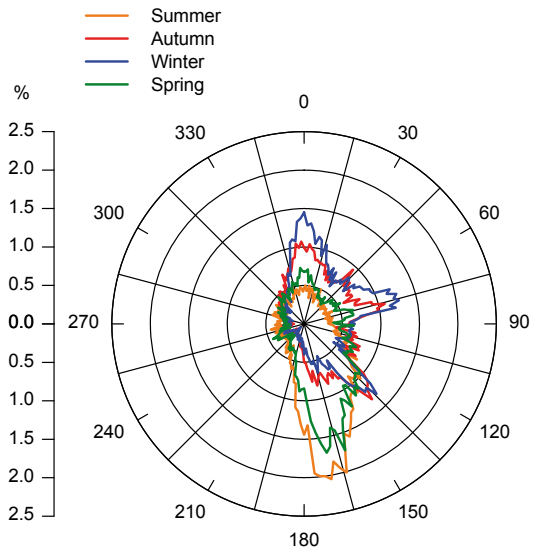


Wind diagrams

Speed



Directions



Responsible authors: K. Berger, A. Haensler & J. Luther-Mosebach

Soils

Year of sampling	Hectare plots sampled	SOTER unit
2001	25 (R1–25)	NA68
Soilscape	**Dominant soil group(s)**	**Reference group richness**
n.a.	Regosol	4
Soil unit richness	**Soil unit evenness**	**Soil ecotype richness**
9	0.596	8
Parametric space	**pH**	**Electrical conductivity**
3.28	6.8 (5.8–8.7)	23 (2–790) $\mu S \cdot cm^{-1}$
Organic carbon		
0.20% (0.06–0.43%)		

The dominant soil reference groups found on the Observatory are Regosols and Cambisols, but also some Leptosols and one Fluvisol and Arenosol occur. The predominance of Regosols (about 55%) is a sign for the low influence of soil forming processes in the study area.

The most important driving factors for the soil properties and the classification are the type and age of substrate, the depth of the profiles and the content of coarse rock fragments. The Observatory covers plains and washes with shale outcrops. The soil parent materials are shale (partly shattered and with thin calcareous layers) and colluvial materials (sand to loam) of different but not old ages. Only in few vertical rock fissures, reddish and clay-rich material that has been developed under wetter climate conditions has been found, indicating that nearly all of the former paleosoils have been eroded. Initial soil development presumably took place under moister conditions when most of the Cambisol material developed. This phase must have been followed by massive transports of soil materials. Most likely, the loamy parent material in the plains is a result of this process. This phase was followed by a more arid climate with physical weathering as the dominant process and subsequently mass transports, which again translocated soil material into the plains where it covers, to some extent, the loamy phases. These mass transports and erosion processes are the most important soil forming processes to date as soils are still vulnerable to water and wind erosion. Therefore, the reduction of plant cover by overgrazing but also by natural droughts strongly enhances the risk of soil erosion.

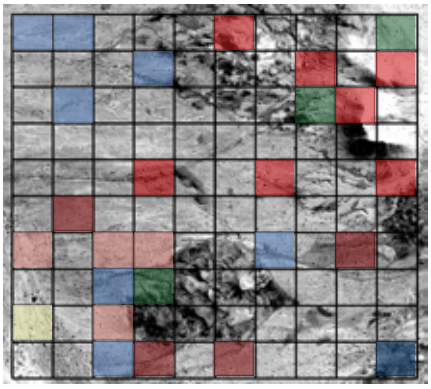
Rocky outcrops and slopes are dominated by shallow Leptosols and Epileptic Regosols, whereas plains and washes are characterised by weakly developed Regosols. Partly stronger developed Cambisols occur on ridges with loamy parent material in the plains. Cambisols have developed in situ at the base and footslope of outcrops. These Cambisols are associated with Epileptic Regosols. The Fluvisol is situated in the southwest corner of the Observatory in the broad dry river structure. A typical catena from an outcrop in the east to the dry river in the west would show the following sequence: Leptosols > in situ developed Epileptic Regosols > in situ developed Cambisols > deep Regosols and Cambisols > Fluvisol. Within this sequence, the size of the physically weathered shale particles reduces from fine gravel to coarse sand.

A common feature of all soil units is the development of a 'desert pavement' on the soil surface, which consists of fine to coarse gravel. This indicates a continuous influence of wind erosion of the silty substrates. In the loamier substrates often a vesicular layer is found in the first centimetre of the topsoil. These features in many cases led to the use of the qualifier 'Aridic'.

The variability of soil properties and thus the Observatory's main differentiating ecological factor is defined by soil physical properties, mainly texture and the available rooting space, i.e. content of coarse rock fragments and depth to bedrock. The variability of the soil's chemical properties is low to moderate. Remarkably low is the vertical difference in the profiles. In the case of organic carbon this is due to the dominance of background carbon contents in the parent material which overrides the organic carbon contents by in situ humus accumulation.

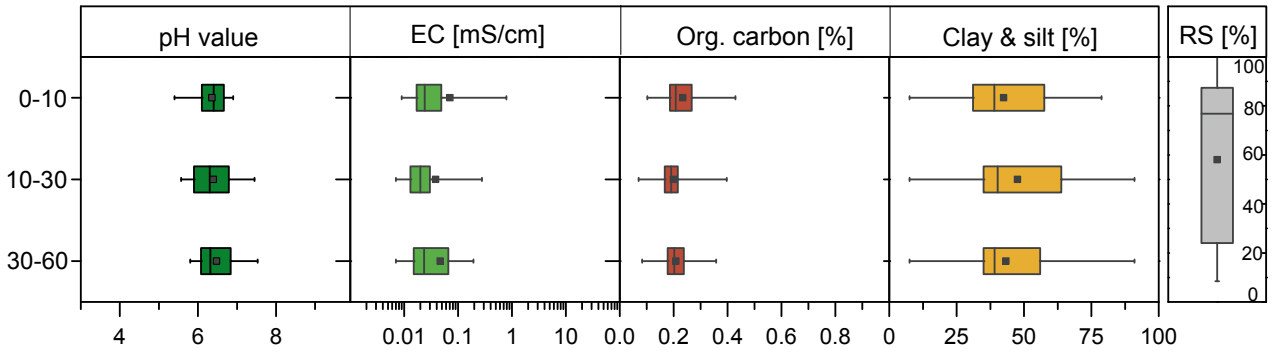
The sandy and silty fraction is dominant, only few samples of the Cambisols have more than 30% clay in the fine earth. Within the sand fraction the analysed samples can be described as coarse sands.

Map of soil profiles

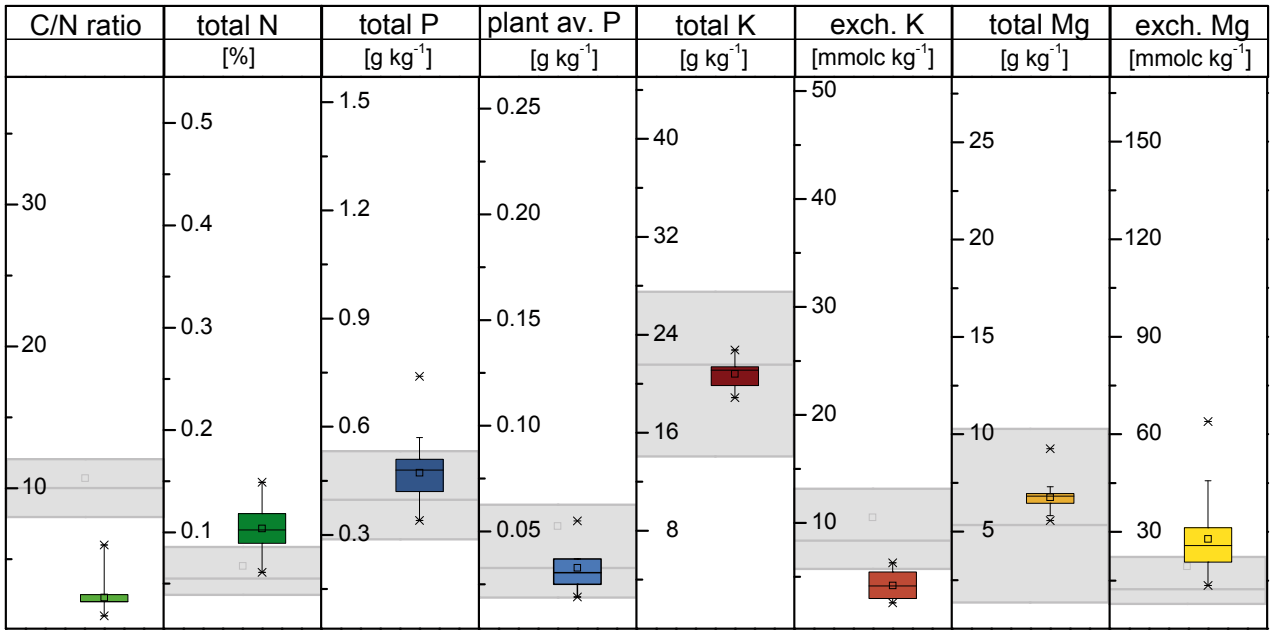


Haplic Regosol
Epileptic Regosol
Colluvic Regosol
Haplic Cambisol
Epileptic Cambisol
Haplic Fluvisol
Haplic Leptosol

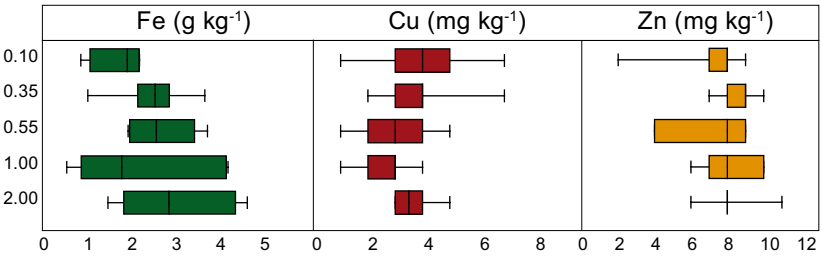
Soil characteristics



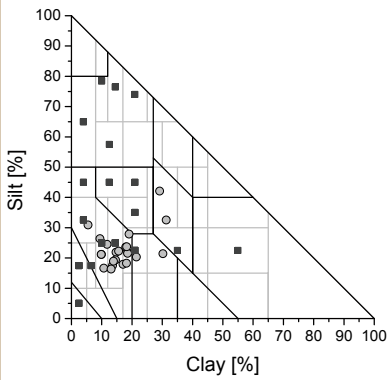
Soil nutrients



Soil micronutrients



Soil texture triangle



The silt proportion tends to be washed off from the topmost soil layer in deeper horizons, leaving the surface particles black and loose. Further typical features of the soils are the relatively low electrical conductivity, high carbon and nitrogen contents of the parent material and the lack of microbiotic crusts. The low electrical conductivity indicates a regular deep drainage of the soils, which does not allow the accumulation of soluble salts. The trend of higher values in loamier soils strengthens this theory as these textures are not drained as intensively as sandy soils. The relatively high content of organic carbon (up to 0.8%) and nitrogen (up to 0.15%) of the shale lead to untypical C/N ratios between 1 and 4

in the soils, though nitrogen seems to be relatively stable in the parent material. Total content of nutrients are in general in a medium range, especially phosphorus.

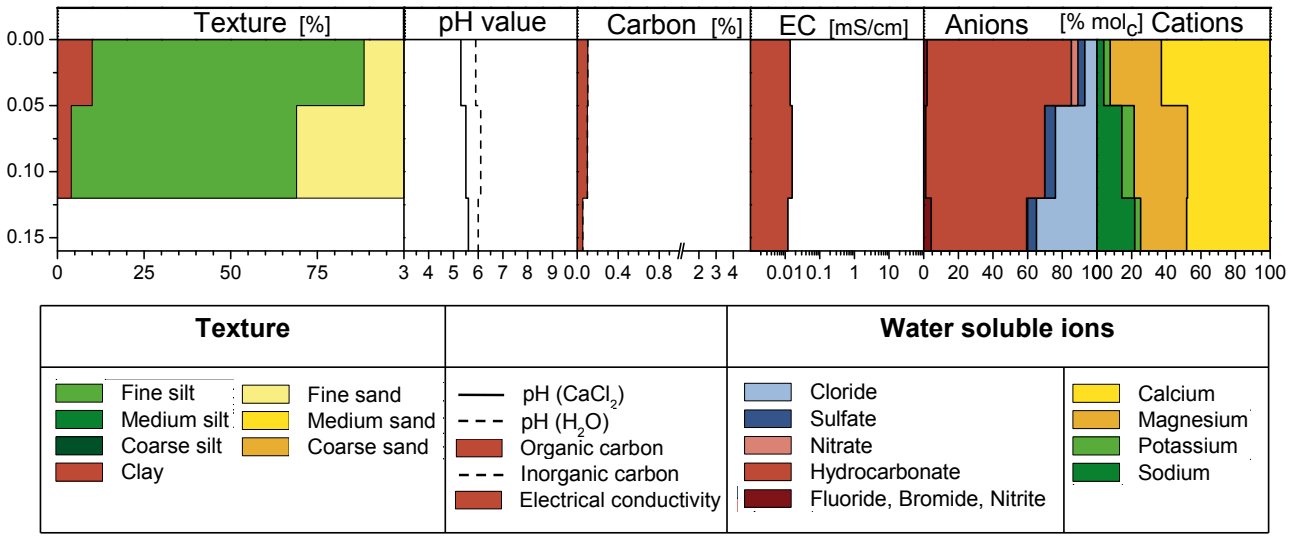
A further feature is the dark grey colour of the shale that raises soil temperature significantly under high radiation compared to lighter substrates. Higher temperatures might be an advantage in the formation of vesicular layers, which are most likely a result of water vapour creating micro-bubbles when the topsoil is wet (Volk & Geyer 1970, Miller 1971).

Reference profile (H09)

A typical example of shallow soils developed on shale derived substrates of the rocky outcrops and surrounding slopes is the **Haplic Leptosol (Eutric, Aridic).** Typically, the bedrock starts within 25 cm below the soil surface, and the substrates have a high content of coarse rock fragments. The soil surface and the first horizon have a loose single-grain to subangular blocky structure, densely covered with gravel and with relatively high bulk density (1.6 g cm^{-3}). The content of rock fragments increases from 5% in the topsoil to nearly 100% in the transition to the bedrock.

The texture of the fine earth is dominated by silt and sand and has some specific properties which are the result of shale as soil parent material. The physical weathering led to a variety of grain sizes, which all consist of the same material and thus elemental composition. This is different to soils of other origin where particles of different size fractions can also be differentiated by their chemical compounds, with sands mostly consisting of quartzes. Moreover, the particles have a relatively low resistance against pressure, which causes a continuous breakdown of material when pounding during the finger test. The resulting texture therefore ranges from silty sand to silt, depending on the method. As the sand particles and coarser gravel are porous, and thus able to store water, it is recommended to be careful when interpreting water supply based on soil texture.

Soil reaction is slightly to moderately acid, and the organic carbon reaches



only 0.1% in the fine earth, which is not atypical for an arid environment. However, careful considerations should be taken into account when interpreting the organic carbon content as the shale already bears considerable amounts of organic carbon and nitrogen. The electrical conductivity is very low with 10–15 µS cm^{-1} across the entire profile.

Total element content shows no significant changes with profile depth and is dominated by iron and potassium (11 and 12 g kg^{-1} respectively). The content of water soluble ions is very low with 3–5 $mmol_c$ kg^{-1}. The cation exchange capacity is 110 $mmol_c$ kg^{-1} in the topsoil and 60 $mmol_c$ kg^{-1} in the second horizon, which has lower silt and clay content.

Responsible authors: U. Wisch, A. Petersen, A. Gröngröft & D. Mager

Lichens

Sampling period(s)	Hectare plots sampled	Cover
2001, 2004	10 (R1−R10)	0%
Total species richness	Species richness on soil [1 km²]	Species richness on rock [1 km²]
0	0	0
Species richness on plants [1 km²]	Species richness on soil [1000 cm²]	
0	0	

No lichens occur at this Observatory. The climate of this site is not suitable for lichen growth because of extremely high temperatures, low precipitation, and very low air humidity. In addition, high soil acidity prevents soil lichens from growing. Pebble and gravel cover is high in some hectare plots, which prevents the occurrence of terricolous lichens.

Responsible authors: L. Zedda & G. Rambold

Vascular plants

Sampling period(s)	Hectare plots sampled	Biome
2001–2009	20 (R1–R20)	Nama Karoo
Vegetation unit (level 1)	Vegetation unit (level 2)	Identification rate
Dwarf Shrub Savanna	n.a.	71% – 95% – 97%
Cumulative family richness	Dominant families (cover)	Dominant families (richness)
43	Poaceae, Bignoniaceae, Fabaceae	Poaceae, Fabaceae, Asteraceae
Cumulative species richness (1 km²)	Species richness (1000 m²)	Species richness (100 m²)
264 – 120	26.4 (5–49)	12.6 (0–45)
z-value	Species richness change per year (1000 m²)	Evenness (1000 m²)
0.319 (0.000–0.921)	1.00	0.557 (0.058–0.898)
Evenness (100 m²)	Simpson (1000 m²)	Simpson (100 m²)
0.614 (0.025–0.909)	0.669 (0.037–0.945)	0.637 (0.000–0.918)

The vegetation at the BIOTA Observatory Gellap Ost (S10) consists of grassy shrublands and open dwarf shrublands, as well as thickets along drainage lines and riverine structures. From southeast to northwest, sparsely vegetated slopes and rocky outcrops grade into slightly undulating plains, which are in places dissected by washes ending up in an ephemeral river bed (rivier). This catena of broad habitat types has a characteristic sequence of the main soil units, with shallow Leptosols dominating slopes and outcrops, deep Regosols and Cambisols on the plains, and a unique Fluvisol in the river bed. Within this sequence, soil texture, content of coarse fragments and soil depth are assumed to be the most important factors influencing plant growth conditions on the Observatory as they determine the water supply available to plants (Petersen 2008). Indeed, outcrops and slopes, plains, and the river bed are floristically well-separated habitats. Three vegetation units can be distinguished on the Observatory, each representative of one of these three habitats. The high β-diversity at the Observatory is reflected in high z-values, which are amongst the highest along the entire BIOTA transect, at all scales.

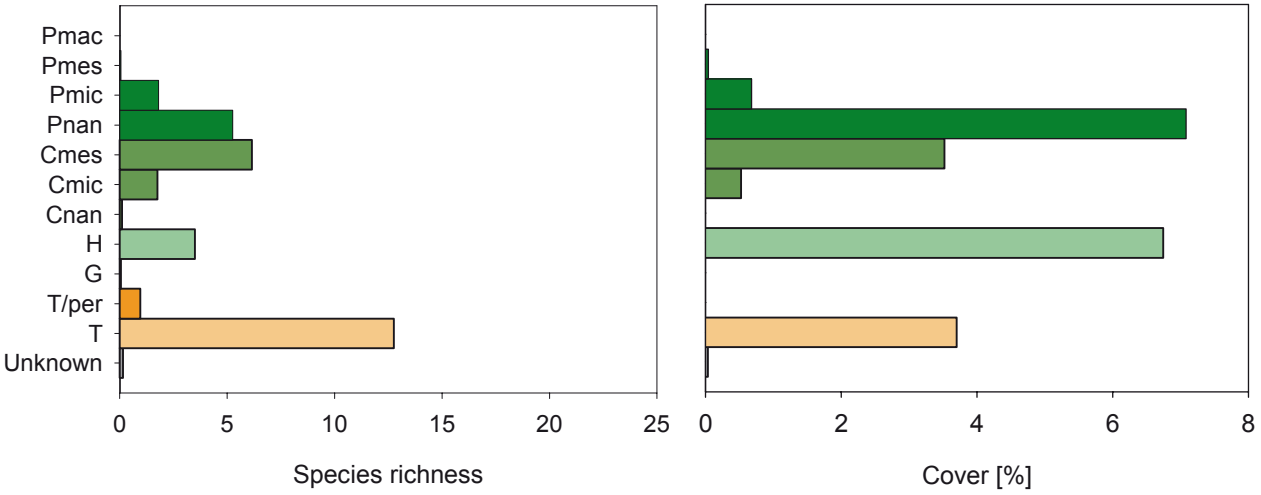
The *Hibiscus elliottiae-Panicum arbusculum* community (unit 1) is typically found on slopes and around rocky outcrops. These habitats are densely covered by gravel and stones, and are characterised mostly by shallow soils (Leptosols) with a high content of coarse fragments and a low proportion of fine material. This unit forms a diverse dwarf shrubland with very low plant cover, which reflects the low water supply due to increased surface run-off and the restricted rooting space available in these habitats. It possesses a diverse dwarf shrub flora, of which some are spiny and rather unpalatable, such as *Aptosimum spinescens* (Kankerbossie) and *Barleria rigida* (Skerpioendissel). Others, such as the 'Wolbos' (*Leucosphaera bainesii*), are palatable, and the abundance of this species is regarded as an indicator of good rangeland condition. Several valuable and perennial climax grasses are associated with this unit, although they rarely grow in dense stands. Examples are *Panicum arbusculum* (Struik panicum), which is an effective soil stabiliser, *Enneapogon scaber* (Klipgras), a low-growing grazing grass, and *Setaria appendiculata* (Berggras), with a high nutritional value. Shrubs are concentrated in areas with deeper soils around footslopes and along watercourses, although they are also scattered over the top- and mid-slopes. The most prominent species is the beautifully red flowering *Hibiscus elliottiae,* which has a wide distribution range in Namibia. *Cryptolepis decidua* (Bokhorinkie), a toxic shrub, which can cause poisoning in livestock, occurs less frequently. The annuals *Codon royenii* (Suikerkelk) and *Forsskaolea viridis* dominate the herbaceous vegetation on steep slopes.

The *Stipagrostis namaquensis-Ziziphus mucronata* community (unit 2) is characteristic of riverine habitats. This unit is represented by one plot only, which is located on the ephemeral river crossing the southwestern corner of the Observatory. Habitat conditions are favorable for plant growth on the deep soils rich in fine material occurring here. The ephemeral river occasionally contains water, and deep-rooted species have access to ground water. As a result, the vegetation is diverse and dense with a variety of tree species. An example is *Ziziphus mucronata* (Blinkblaar-Wag-'n-Bietjie), which is used for medicinal purposes and handcraft, and the leaves provide fodder for game and livestock. Another common tree is *Acacia erioloba* (Kameeldoring), with its wood and edible gum being widely used. The shrub-like perennial grass *S. namaquensis* (Steekwiet) is by far the most dominant species in this vegetation unit, and is valuable in many respects. For example, it is effective in reducing water erosion and trapping organic material, and the young plant parts are well-utilised by browsing animals. Similarly, the young plant parts of the common *Leucophrys mesocoma* (Withaargras) are also well-utilised. However, this grass seldom occurs in dense stands. This plant community has a high grazing value, as it contains a high proportion of palatable perennial plant species, which provide fodder to livestock for the entire year and also during dry years.

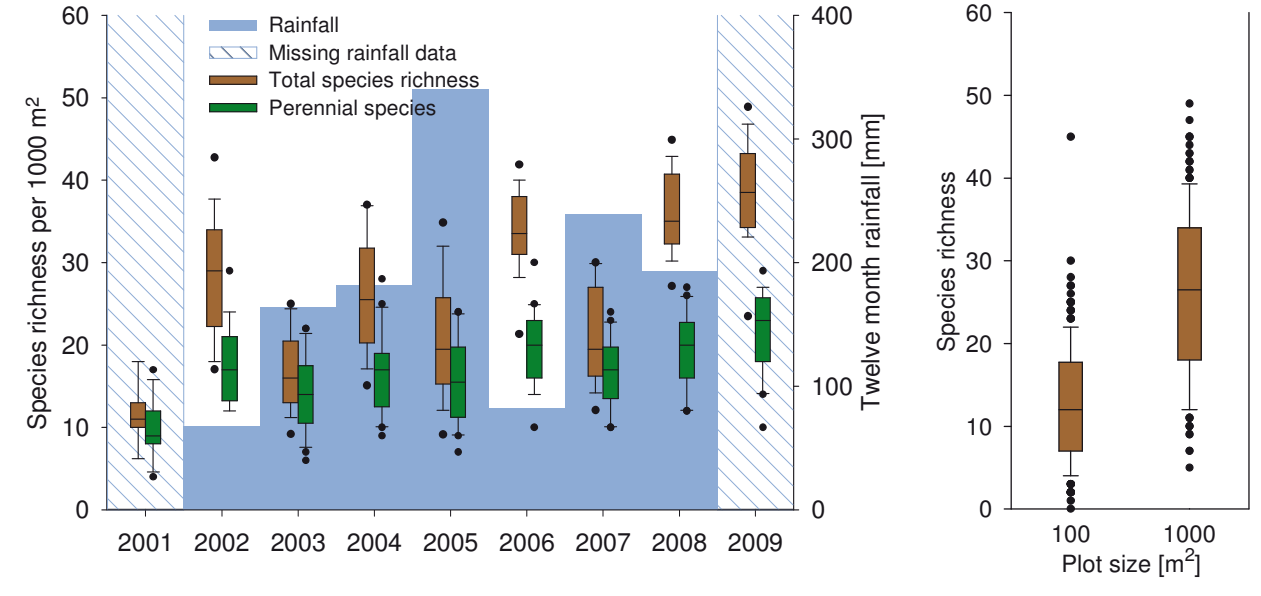
The *Phaeoptilum spinosum-Stipagrostis uniplumis* community (unit 3) occurs on the plains on deep, shale-derived soils. This vegetation type forms grassy shrub-

lands, which are less diverse than the other two vegetation types. The woody vegetation is dominated by the shrubby species such as *Boscia foetida* (Stinkbos), *Lycium* spp. (Wolwedoring), and *P. spinosum* (Brosdoring), with the latter providing palatable fruits. The shrub *Catophractes alexandri* (Gabbabos) forms dense localised stands usually on shallower soils. Trees such as *Maerua schinzii* (Kringboom), which is browsed by livestock, occur sporadically. The inter-shrub matrix is dominated by the perennial grass *Stipagrostis uniplumis* (Blinkhaarboesmangras) resulting in high grass cover-values within this vegetation unit. This abundant subclimax grass is one of the most important agricultural grasses in Namibia, as it is productive and palatable. Another common perennial grass of grazing value is *Stipagrostis hochstetteriana* (Gemsbokstertgras). The herbaceous layer of this vegetation type is rich in annual and biennial life-forms, of which the most abundant species belongs to the Fabaceae. A variety of shrubs and trees are concentrated along drainage lines dissecting the plains, such as the commonly occurring swarthaak (*Acacia mellifera*), which provides shade and fodder for game and livestock.

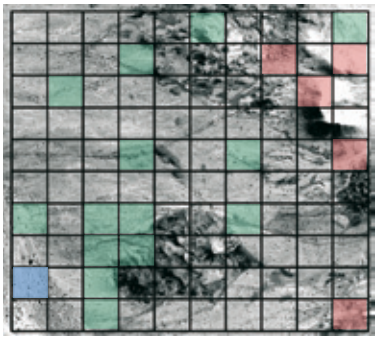
Life forms



Species richness



Map of vegetation units



Codon royenii. Photo: N. Dreber.

Barleria rigida. Photo: N. Dreber.

Cryptolepis decidua. Photo: N. Dreber.

Hibiscus elliottiae. Photo: N. Dreber.

Classification table (2009)*

Column		Cover	All	1	2	3
Number of relevés			**23**	**5**	***1***	**17**
Mean cover [%]			23.6	14.1	*42.3*	25.2
Mean species richness (1000 m²)			35.4	38.8	*43.0*	33.9
Inclination [°]			7.9	19.6	*1.0*	4.2
Mean soil depth [cm]			53	22	*100*	60
Mean soil pH			6.82	7.02	*7.00*	6.74
Mean electrical conductivity [µS·cm^{-1}]			52	55	*9*	54
Fine material			54.2	35.8	*80.0*	58.0
Gravel			38.1	41.5	*19.5*	38.2
Stones 2-6 cm			4.4	12.5	*0.5*	2.3
Stones 6-20 cm			1.3	3.5	*0.0*	0.7
Stones 20-60 cm			0.4	1.3	*0.0*	0.2
Blocks			2.5	2.0	*0.0*	3.0
Abiotic crust			2.7	2.3	*2.0*	2.8
Soft litter			0.7	0.2	*5.0*	0.6
Unit 1: Pegolettia oxyodonta-Hibiscus elliottiae community						
H	Pegolettia oxyodonta	0.17	13	60	.	.
H	Setaria appendiculata	0.18	9	40	.	.
T/Hper	Corbichonia decumbens	0.12	9	40	.	.
Hper	Limeum dinteri	0.17	35	60	.	29
Cmes	Indigofera pechuelii	0.18	43	100	*100*	24
Pnan	Hibiscus elliottiae	0.43	70	100	.	65
Pnan	Adenolobus garipensis	0.73	13	40	.	6
Cmes	Polygala leptophylla	0.30	4	20	.	.
Cmes	Cryptolepis decidua	0.05	4	20	.	.
n.a.	Aristida parvula	1.01	9	40	.	.
T	Tribulus pterophorus	0.40	87	100	*100*	82
Pmic	Boscia foetida	0.32	87	100	.	88
Cmes	Asparagus spp.	0.07	87	80	.	94
T/Hper	Phyllanthus maderaspatensis	0.04	9	40	.	.
Unit 2: Portulaca oleracea-Stipagrostis namaquensis community						
T	Portulaca oleracea	0.12	9	.	*100*	6
Cmes	Tapinanthus oleifolius	0.04	9	.	*100*	6
H	Stipagrostis namaquensis	35.00	4	.	*100*	.
Cmes	Monechma divaricatum	0.15	4	.	*100*	.
T	Hermannia modesta	0.02	30	40	*100*	24
n.a.	Jamesbrittenia glutinosa	0.02	26	20	*100*	24
Pmic	Ziziphus mucronata	0.50	4	.	*100*	.
Unit 3: Tripteris microcarpa-Belepharis omitrata community						
T	Tripteris microcarpa	0.13	48	.	*100*	59
Cmes	Phaeoptilum spinosum	1.26	91	80	.	100
T	Gisekia africana	0.52	74	40	*100*	82
Cmes	Blepharis obmitrata	3.38	83	40	*100*	94
Pnan	Montinia caryophyllacea	0.51	13	.	.	18
T	Lotononis platycarpa	1.18	91	60	*100*	100
Most frequent companions						
H	Stipagrostis uniplumis	5.89	100	100	*100*	100
T	Microcharis disjuncta	1.27	96	80	*100*	100
T	Mollugo cerviana	0.07	96	100	*100*	94
T	Tephrosia dregeana	0.49	91	80	*100*	94
Cmes	Ptycholobium biflorum	0.12	91	80	*100*	94
Pnan	Cadaba aphylla	0.33	87	80	*100*	88
T	Enneapogon cenchroides	0.30	83	80	*100*	82
T	Trianthema parvifolia	0.11	83	80	*100*	82
T	Chamaesyce glanduligera	0.03	83	60	.	94
H	Dicoma capensis	0.18	78	20	.	100

**classification is based on data also including relevés outside the Observatory*

Continued on next page

Unit 1. Photo: N. Dreber.

Unit 2. Photo: N. Dreber.

Pergularia daemia fruit before opening. Photo: N. Jürgens.

The seeds of *Pergularia daemia* are transported by wind. Photo: N. Jürgens.

Flower of the shrub *Catophractes alexandri*. Photo: N. Dreber.

Classification table (continued)

Column		Cover	All	1	2	3
Number of relevés			**23**	**5**	***1***	**17**
Hper	Amaranthus praetermissus	0.15	78	60	*100*	82
T	Schmidtia kalahariensis	0.10	78	60	*100*	82
H	Stipagrostis hochstetteriana	1.01	70	20	.	88
T	Sesamum triphyllum	0.02	70	20	.	88
T	Monsonia umbellata	0.31	61	60	.	65
Pnan	Catophractes alexandri	3.55	57	40	.	65
Cmic	Limeum argute-carinatum	0.47	57	.	*100*	71
Cmic	Leucosphaera bainesii	0.33	57	100	.	47
T	Aristida adscensionis	0.09	57	60	.	59
Cmic	Limeum aethiopicum	0.09	52	60	*100*	47
Pnan	Rhigozum trichotomum	0.91	48	80	.	41
Pmic	Acacia mellifera	0.59	48	60	.	47
Cnan	Aptosimum spinescens	0.40	48	60	.	47
Cmes	Sericocoma heterochiton	0.28	43	80	.	35
T	Melinis repens	0.12	43	20	*100*	47
T	Forsskaolea viridis	0.09	43	80	*100*	29
H	Stipagrostis hirtigluma	0.09	39	60	.	35
T/Hper	Kohautia caespitosa	0.03	39	.	*100*	47
Pnan	Acacia nebrownii	0.80	35	.	*100*	41
Cnan	Hermannia fruticulosa	0.23	35	60	.	29
T	Enneapogon desvauxii	0.17	35	100	.	18
Pnan	Calicorema capitata	0.34	30	20	.	35
Pmic	Maerua schinzii	0.15	30	60	*100*	18
T	Setaria verticillata	0.08	30	.	*100*	35
H	Panicum arbusculum	0.25	26	100	.	6
T	Kissenia capensis	0.03	26	20	.	29
H	Leucophrys mesocoma	2.43	22	40	*100*	12
H	Aristida engleri var. engleri	0.15	22	100	.	.
T	Enneapogon scaber	0.12	22	80	.	6
T	Codon royenii	0.06	22	40	*100*	12
Cmes	Barleria rigida	0.05	22	40	.	18
Pnan	Monechma genistifolium	0.86	17	20	.	18
Pnan	Salsola spp.	0.32	17	20	*100*	12
Cmes	Solanum dinteri	0.03	17	20	.	18
T/Hper	Indigofera auricoma	0.11	13	.	.	18
Cmes	Galenia africana	0.07	13	.	*100*	12
Cmes	Salsola spp.	0.07	13	40	.	6
Cnan	Wellstedia dinteri	0.04	13	20	.	12
Cmes	Peliostomum leucorrhizum	0.04	13	20	.	12
H	Pergularia daemia	0.04	13	.	*100*	12
G	Coccinia rehmannii	0.04	13	.	*100*	12
H	Stipagrostis ciliata	0.03	13	20	.	12
T	Tragus berteronianus	0.02	13	60	.	.
Cmes	Helichrysum candolleanum	0.01	13	.	.	18

Unit 3. Photo: N. Dreber.

Spatial patterns in vegetation. Photo: N. Dreber.

Responsible authors: N. Dreber & J. Luther-Mosebach

Millipedes

Sampling period(s)	Species richness
2003/X	1

Dorsal view of the penicillate millipede *Afraustaloxenodes coineaui* (from Nguyen Duy-Jaquemin 2003; with kind permission from African Invertebrates, Natal Museum).

A species of the recently described penicillate millipede genus Afraustaloxenodes was found on this Observatory. This millipede species from the family Polyxenidae is soft and very small, measuring only about 3 mm in length. Lateral, dorsal and posterior tufts (see Figure) are characteristic of this species. Only a few species of these minute millipedes are known from southern Africa. Penicillate millipedes are mainly encountered in rock cracks, decaying wood and under stones, where they feed on soft plant tissues such as algae and perhaps fungal hyphae.

Millipede species

Species	Family	Relative frequency	Feeding group
Afraustraloxenodes coineaui	Polyxenidae	n.a.	Plant tissue, fungal hyphae

Shrubs and stones provide slightly more humid and therefore more favourable microhabitats for arthropods such as the humidity-dependent millipede *Afraustaloxenodes coineaui*. Photo: K. Vohland.

Responsible author: K. Vohland

Termites

Taxon richness	Abundance index	Dominant (sub-) family
3	9	Hodotermitidae

The same three termite species were encountered at this Observatory as on the twin Observatory S11 (Nabaos). Besides the most frequent species *Hodotermes mossambicus* (for more details see Observatory S39/Narais) and *Psammotermes allocerus* (see Observatory S11/Nabaos), *Baucaliotermes hainesi* also occur here (see Photo). *B. hainesi* belongs to the subfamily Nasutitermitinae, in which the soldiers of all African species are characterised by a reduction of the mandibles. Instead, the head capsule has a pointed protrusion from which a sticky defensive fluid can be secreted. Like *H. mossambicus* (see Observatory S39/Narais), this species forages mainly on grass, but also on leaf litter, herbivore dung, and decaying wood. *B. hainesi* is endemic to southern Africa and occurs in the drier areas of southern Namibia and the Northern Cape Province of South Africa where it replaces *Trinervitermes*, which is abundant throughout southern Africa except in arid areas.

Baucaliotermes hainesi feeding on dry grass. Photos: C. Grohmann.

Baucaliotermes hainesi at the entrance hole of their nest.

List of taxa

Taxon	(Sub-)family	Frequency Index	Feeding substrate
Hodotermes mossambicus	Hodotermitidae	0.36	g
Baucaliotermes hainesi	Termitidae (Nasutitermitinae)	0.18	s, w, g, l, m
Psammotermes allocerus	Rhinotermitidae	0.18	w, d

Responsible authors: C. Grohmann & K.E. Linsenmair

True bugs

Sampling period(s)	Methods	Family richness
2001/IV, X; 2002/II, IV, V, VII, VIII, X; 2003/III, IV; 2008/IV, IX	Trapping (light, pitfall traps); beating of plants; hand collecting	23
Species richness	**Individuals sampled**	**Fisher's alpha diversity**
75	719	21.07

Most species at the Observatory Gellap Ost are phytophagous. About 27% of the collected species were only recorded as single specimen.

Nysius ericae was the most common true bug (23% of all collected specimens). It is very widespread and common in the Afrotropical and Palearctic regions. In Namibia, it occurs almost everywhere in arid environments. This species was also recorded at other Observatories, even from the desert Observatory S16 (Wlotzkasbaken).

Thaumastella namaquensis was subdominant in pitfall traps, accounting for 9% of all collected specimens. This species is endemic to the Nama Karoo biome. It is wingless and lives under stones, often on the slopes of rocky outcrops. It feeds on seeds and is adapted to dry habitats. It is only known from the locality of their original description near Vioolsdrift and from the Naukluft Mountains, where it occurs in similar habitats. A sister species occurs in the Northern Cape Province. Because of its highly adapted nature and reduced ability to migrate due to a winglessness, this species should be regarded as an indicator of environmental changes due to its highly adapted nature and reduced ability to migrate.

The most common species in pitfall traps was *Leptodemus irroratus*, which accounted for 37% of the sample. In contrast, only one specimen was captured around light traps.

Three new Heteroptera species were discovered at Gellap and were recently described. Two of them are the lace bugs (Tingidae) *Haedus foetidus* and *Haedus agalisticus*. *H. foetidus* is associated with the shrub *Boscia foetida* and *H. agalisticus* with *Boscia albitrunca*. The third species, *Goellneriana deckerti*, is an ambush bug (Phymatinae, Reduviidae). Phymatinae are very rare in Africa. They are predatory and usually hide amongst flowers, waiting for prey. It is the first record of this subfamily in Namibia. Only four species occur in South Africa and all are endemic. Two are endemics of the Western Cape. *Goellneriana deckerti* is most probably restricted to the Nama Karoo.

Species abundances

Light traps

Species	Family	*N*	%
Nysius ericae	Lygaeidae	160	50
Micronecta spec.	Micronectidae	28	9
Euthetus leucostictus	Alydidae	19	6
Sigara meridionalis	Corixidae	19	6
Macroscytus brunneus	Cydnidae	11	3
Dicranocephalus schmitzi	Stenocephalidae	8	2
Miridae spec.	Miridae	6	2
Edocla quadrimaculata	Reduviidae	6	2
Aethus lautipennis	Cydnidae	5	2
Camptocoris rostratus	Lygaeidae	5	2
Dieuches herero	Rhyparochromidae	5	2
Hyalochilus scudderi	Rhyparochromidae	5	2
Others (23)		44	13
Total		**321**	**100**

Pitfall traps

Species	Family	*N*	%
Leptodemus irroratus	Oxycarenidae	41	37
Eupododus orbicularis	Pentatomidae	24	22
Thaumastella namaquensis	Thaumastellidae	10	9
Liorhyssus hessei	Rhopalidae	8	7
Spilostethus pandurus elegans	Lygaeidae	5	5
Geocoris phaeopterus	Geocoridae	5	5
Nysius ericae	Lygaeidae	4	4
Haemobaphus concinnus	Lygaeidae	3	3
Micrometacanthus spec.	Berytidae	2	2
Others (8)		8	7
Total		**110**	**100**

Species richness in families

Family	*S*
Miridae	17
Pentatomidae	10
Reduviidae	6
Rhyparochromidae	6
Alydidae	4
Coreidae	4
Cydnidae	4
Lygaeidae	4
Tingidae	3
Berytidae	2
Naucoridae	2
Oxycarenidae	2
Anthocoridae	1
Corixidae	1
Enicocephalidae	1
Geocoridae	1
Micronectidae	1
Nabidae	1
Notonectidae	1
Pachygronthidae	1
Rhopalidae	1
Stenocephalidae	1
Thaumastellidae	1
Total	**75**

Thaumastella namaquensis. Photo: J. Deckert.

Responsible author: J. Deckert

Butterflies and moths

Sampling period(s)	Number of samples (moths)	Species richness (total)
2001/IV; 2002/IV; 2003/III	9	187
Species richness (butterflies)	**Species richness (all moths)**	**Species richness (Microlepidoptera)**
11	176	51
Species richness (Pyraloidea)	**Species richness (Macrolepidoptera)**	**Species richness (Noctuidae)**
35	29	61
Individuals sampled (moths)	**Fisher's alpha diversity (moths)**	
880	28.5	

Butterflies

All species encountered on the Observatory are common and widespread elements of the butterfly fauna of southern Africa. The only exception is Doubleday's Tip (*Colotis doubledayi flavulus*; see Photo). It has a more restricted distribution ranging from the valley of the Orange River in the south to Angola in the north. It is a rare species and occurs more abundantly only in few places in the Nama Karoo Biome of Namibia. The Observatory Gellap Ost is one such suitable place, supporting a large and stable population. In all years, the overwhelming majority of individuals were Brown-veined Whites (*Belenois aurota*). This is the most common and widespread species in Namibia. At the end of summer this species tends to migrate in large groups (Pringle et al. 1994). The large number of recorded specimens at the Observatory is in part due to such migrants. A typical feature of open savanna habitats is the syntopic occurrence of a number of *Colotis* species. The species recorded at the Gellap Ost Observatory belong to this species-guild-complex. The low number of individuals indicates the transitional nature of the vegetation at the Observatory from savanna to desert.

Transect analysis of butterflies

Sampling period: 06–09 March 2003. During this time, after a short rainy period, a reasonable number of specimens were on the wing.
Description of transect: Deviating from the standard, one transect of 1500 m which was divided into 3 sections of 500 m was investigated. It followed the path crossing the observatory towards the weather station (transect 1 and 2) and from there ran parallel to the Nabaos fence for the last 500 m (transect 3). **Species richness:** 9, **Number of individuals:** 372

Abundance

Species	*N*	Proportion
Belenois aurota	357	95.9%
Pinacopteryx eriphia	6	1.6%
Eurema brigitta	3	0.5%
Junonia hirta	2	0.5%
Colotis doubledayi	2	0.5%

Butterfly species and main food plants

Lycaenidae	
Chilades trochylus	Indigofera (Fabaceae), Heliotropium (Boraginaceae)
Nymphalidae	
Cynthia cardui	Carduus, Arctotheca, Arctotis, Gazania (Asteraceae), Malva (Malvaceae)
Junonia hierta cebrene	Barberia, Ruellia (Acanthaceae)
Danaus chrysippus aegyptius	Asclepias, Stapelia, Cynanchum (Asclepiadaceae)
Pieridae	
Eurema brigitta brigitta	Hypericum (Hypericaceae), Chamaecrista (Fabaceae)
Pinacopteryx eriphia eriphia	Maerua, Boscia (Capparaceae)
Belenois aurota aurota	Maerua, Boscia, Capparis (Capparaceae)
Colotis doubledayi flavulus	Maerua (Capparaceae)
Colotis eris eris	Boscia (Capparaceae)
Colotis evippe omphale	Maerua, Boscia, Cadaba (Capparaceae)
Colotis evenina evenina	Boscia, Capparis, (Capparaceae)

Moths

The woodlands in northern Namibia have the highest species diversity of moths in Namibia. The sample taken from the Observatory in March 2003 is an example of this high diversity, with the proportion of species represented by single individuals (singletons) being 47% (= 105 species). Leaf mining *Epicephala pyrrhogastra* (*Gracillariidae*) and *Deltophora typica* (Gelechiidae) are the most abundant Microlepidoptera species. The Pyraloidea are dominated by *Staudingeria* sp. (Pyralidae: Phycitinae) and *Achyra coelatalis* (Crambidae: Pyraustinae) (see Photo). Abundant macro-moths are *Palasea albimacula* (Lymantriidae) and *Antharmostes papilio* (Geometridae) (see Photo). The Noctuidae is the most species-rich family, with *Amyna punctum* and *Spodoptera exigua* being the most common species.

Male of *Colotis doubledayi flavulus*. Photo: W. Mey.

Female of *Hypotia dinteri*. Photo: W. Mey.

Taxonomic spectrum of moths

Collection period: 2001/IV, 2002/IV, 2003/III

Family	S	N
Nepticulidae	2	12
Tineidae	8	10
Yponomeutidae	1	1
Ethmiidae	1	1
Scythrididae	7	6
Oecophoridae	1	1
Cosmopterigidae	5	15
Gelechiidae	21	74
Pterophoridae	1	1
Tortricidae	4	21
Microlepidoptera	**51**	**142**
Pyralidae	25	143
Crambidae	10	99
Pyraloidea	**35**	**242**
Limacodidae	1	7
Cossidae	2	4
Metarbelidae	1	1
Lasiocampidae	2	15
Sphingidae	2	10
Geometridae	19	88
Arctiidae	1	2
Noctuidae	61	366
Nolidae	1	3
Macrolepidoptera	**90**	**496**
Total	**176**	**880**

Male of *Epicrosis nigrinella*. Photo: W. Mey.

Female of *Pseudozarba schencki*. Photo: W. Mey.

Responsible author: W. Mey

Vertebrates

Total species richness	Reptile species richness	Bird species richness
76	7	47
Large mammal species richness	Small mammal species richness	
13	9	

Cape fox (*Vulpes chama*). Photo: J. Deckert.

Namaqua micaelamys (*Micaelamys namaquensis*). Photo: A. Hoffmann.

Large mammals

Carnivora	**Carnivores**
Canis mesomelas	Black-backed jackal
Caracal caracal	Caracal
Cynictis penicillata	Yellow mongoose
Galerella sanguinea	Slender mongoose
Ictonyx striatus	Striped polecat
Otocyon megalotis	Bat-eared fox
Suricata suricatta	Meerkat
Vulpes chama	Cape fox
Artiodactyla	**Even-toed ungulates**
Raphicerus campestris	Steenbok
Sylvicapra grimmia	Bush duiker
Tragelaphus strepsiceros	Greater kudu
Tubulidentata	**Aardvarks**
Orycteropus afer	Aardvark

Small mammals

Macroscelidea	**Elephant shrews**
Elephantulus intufi	Bushveld elephant shrew
Rodentia	**Rodents**
Desmodillus auricularis	Cape short-tailed gerbil
Gerbilliscus leucogaster	Bushveld gerbil
Gerbillurus vallinus	Bushy-tailed hairy-footed gerbil
Micaelamys namaquensis	Namaqua micaelamys
Mus indutus	Desert pygmy mouse
Rhabdomys pumilio	Xeric four-striped grass rat
Saccostomus campestris	Southern African pouched mouse
Xerus inauris	South African ground squirrel

Reptiles

Squamata	**Lizards and snakes**
Aspidelaps lubricus	Cape coral snake
Aspidelaps scutatus	Shield-nose snake
Bitis arietans	Puff adder
Bitis caudalis	Horned adder
Naja nivea	Cape cobra
Pedioplanis namaquensis	Namaqua sand lizard
Testudines	**Tortoises and turtles**
Psammobates tentorius verroxii	Verrox's tent tortoise

Birds

Passeriformes	**Perching birds**	**Pteroclidiformes**	**Sandgrouse**
Acrocephalus baeticatus	African Reed-Warbler	Pterocles namaqua	Namaqua Sandgrouse
Anthoscopus minutus	Cape Penduline-Tit		
Calandrella cinerea	Red-capped Lark	**Coraciiformes**	**Kingfishers and relatives**
Cercomela familiaris	Familiar Chat	Upupa epops africana	African Hoopoe
Cercotrichas coryphaeus	Karoo Scrub-Robin		
Chersomanes albofasciata	Spike-heeled Lark	**Accipitriformes**	**Birds of prey**
Cinnyris fuscus	Dusky Sunbird	Elanus caeruleus	Black-winged Kite
Cisticola chiniana	Rattling Cisticola	Melierax canorus	Pale chanting Goshawk
Emberiza capensis	Cape Bunting	Melierax gabar	Gabar Goshawk
Emberiza impetuani	Larklike Bunting		Pale chanting Goshawk
Eremalauda starki	Stark's Lark		
Eremomela icteropygialis	Yellow-bellied Eremomela	**Falconiformes**	**Birds of prey**
Eremopterix australis	Black-eared Sparrow-Lark	Falco biarmicus	Lanner Falcon
Estrilda astrild	Common Waxbill	Falco pelegrinoides	Barbary Falcon
Lamprotornis nitens	Cape Glossy Starling	Hieraaetus pennatus	Booted Eagle
Melaenornis infuscatus	Chat-Flycatcher	Polihierax semitorquatus	African Pygmy Falcon
Oenanthe monticola	Mountain Wheatear	Falco tinnunculus	Common Kestrel
Parus cinerascens	Ashy Tit		
Passer melanurus	Cape Sparrow	**Columbiformes**	**Doves and pigeons**
Philetairus socius	Sociable Weaver	Columba guinea	Speckled Pigeon
Ploceus velatus	Southern masked Weaver	Streptopelia capicola	Ring-necked Dove
Prinia flavicans	Black-chested Prinia	Stigmatopelia senegalensis	Laughing Dove
Serinus flaviventris	Yellow Canary	Oena capensis	Namaqua Dove
Sporopipes squamifrons	Scaly-fronted Weaver		
Sylvietta rufescens	Long-billed Crombec		
Strigiformes	**Owls**		
Bubo africanus	Spotted Eagle Owl		
Bubo lacteus	Verreaux's Eagle Owl		
Tyto alba	Barn Owl		
Coliiformes	**Mousebirds**		
Colius colius	White-backed Mousebird		
Gruiformes	**Cranes, rails, coots, and allies**		
Afrotis afraoides	White-quilled Bustard		
Ardeotis kori	Kori Bustard		
Eupodotis rueppellii	Rueppell's Bustard		
Piciformes	**Woodpeckers and relatives**		
Lybius leucocephalus	White-headed Barbet		

White-quilled Bustard (*Afrotis afraoides*). Photo: J. Deckert.

African Pygmy Falcon (*Polihierax semitorquatus*). Photo: J. Deckert.

Responsible authors: J. Deckert, A. Hoffmann & A. Mills

The people

Study period	Size of study area	Population density
2005–2007	7500 km²	0.1–0.2 inhabitants per km²*
Mean age of farmers	**Education of farmers**	**Ethnicity of farm owners**
51 (23–68) years	Completion of secondary school at the least	Afrikaans, Baster, Nama (Orlam)
Ethnicity of farm workers	**Fertility**	**Main sources of income**
Nama, San, Kavango	Approx. 3 children per household	Farming, self employment, tourism, wage labour
Markets		
Local abattoirs, National Keetmanshoop Abattoir, RSA for goats, AGRA cooperative for Karakul skins		

**not including town of Keetmanshoop*

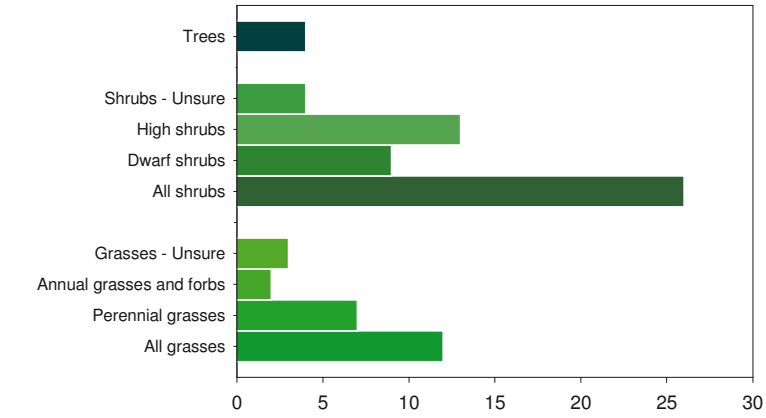


Fig. 10.1: Farmers' species knowledge. Number of plant species cited, in total for the group, classified into different plant types (trees, grasses, shrubs). "Unsure" indicates that the species was named in Afrikaans but not identified with its scientific name. n = 20.

The socio-cultural, economic and institutional background of the Gellap Ost research station: commercial ranching in southern Namibia

The Gellap Ost research station was developed on the model of the large commercial ranches of the region and uses the same management principles. These include the free ranging of animals in camps, the use of a rotational grazing system, and breeding activities primarily based on small stock, especially Karakul sheep skin (Aztrakan) production and Dorper sheep meat production.

Commercial farms of southern Namibia are family enterprises and the land is privately owned. Occasionally, farmers rent additional municipal farmland around the town of Keetmanshoop and Bethanie. Due to the common history of apartheid in Namibia and South-Africa, commercial farms are mostly owned by white Afrikaans farmers although this is changing slowly, with 15% of the free hold land having been transferred from white owners to previously disadvantaged Namibians (Werner and Kruger 2007). Farmers are organised into two main agricultural unions which organise training, forums and meetings to inform members about market evolution. Small stock production is the main economic activity in the area. Farm consumption is low (50 animals a year) and satisfies family and labourer needs, as well as donations. Meat is the main product and is sold primarily to Namibian abattoirs. Few animals are exported live to South Africa as sheep export is restricted to a quota of a seventh of the production (Schutz 2009). Karakul pelt (skins) production has decreased drastically since the 1980's but still takes place on a small scale. Gellap Ost Research Station plays a key role in the production of these pelts in Namibia.

Environmental knowledge of the farmers

When asked about the vegetation characteristics of rangelands in good and bad condition, 14 out of 20 farmers spontaneously named plant species by their Afrikaans names. The plants mentioned by the farmers corresponded to 20% of the total species diversity recorded at the Observatory. Interestingly, their knowledge of shrubs is most prominent (Fig. 10.1). As many as 21 shrub species were cited among the plants typical of 'good' rangeland, which highlights the importance of shrubs and browse biomass in the farming systems of southern Namibia.

Objectives, activities, and constraints on Gellap Ost

As a research station, Gellap Ost has a status, and particular objectives and financial constraints which markedly distinguish it from neighbouring ranches and determine its landuse strategy. Gellap

Ost research station is active in three domains. The first is the production of the world's top Karakul breeding stock. It is the main producer and supplier of high quality Karakul stud rams and ewes in Namibia, and probably worldwide, as Namibian skins are recognised internationally. Years of research and selection have led to very high quality stock distinguished from those produced in the Karakul sheep's country of origin, Uzbekistan (pers. comm. van der Merwe, manager of Gellap, 2006). Secondly, Gellap Ost is a training center for Karakul breeding and skin preparation. The station provides training to over 100 trainees per year in cooperation with the extension service of the Ministry of Agriculture, Water and Forestry (MAWF). Thirdly, research and development is conducted at Gellap Ost. Research and development projects are aimed at improving yields and income from farming in the communal areas. Examples are the provision of communal farmers with high quality Karakul rams, or the breeding of cross-bred sheep suitable for meat production under a communal management setting. Importantly, operational costs are not supported by the income of the research station: both costs and income of the research station flow through the MAWF. Therefore, management is not constrained by economic considerations, which allows Gellap Ost to operate with fewer constraints than commercial farms.

Responsible author: S.E. Domptail

Landuse

Observatory farm

Sampling period	Size of Observatory farm	Recommended stocking rate
2005–2007	137 km²	6 ha·SSU^{-1}
Actual stocking rate	**Number of camps**	**Number of farm workers**
18 ha·SSU^{-1} (average 1993–2006)	160	14*
Number of boreholes		
9		

** Including assistants for research and breeding programs, training, cleaning and gardening*

Study area

Size of study area	Size of commercial farmland	Number of farms on commercial land (total)
7500 km²	3750 km²	Approx. 40
Number of farms surveyed	**Density of farms**	**Mean number of camps per farm**
22	0.01 farms·km^{-2}	22 (4–63)
Mean farm size	**Mean camp size**	**Mean number of farm workers per farm**
100 km² (26–253 km²)	450 ha (300–600 ha)	3 (1–7)
Mean farm family working units	**Mean farm working units**	**Mean number of boreholes per farm**
1.5 (0.4–8.0)	4.0 (1.9–9.0)	7 (2–19)
Mean borehole depth	**Main farming activities**	**Agricultural products**
47 (12–100) m	Breeding (19), livestock speculation (3)	Mutton, goat meat, Karakul pelts

Farm infrastructure and productivity on Gellap Ost and the commercial farms in the area

Commercial farms in the study area are large and their size varies considerably. Farms are characterised by a low ratio of labour over capital assets. Gellap Ost, like all commercial farms of the region, employs a rotational grazing strategy, a form of farm management involving the rotation of several small flocks between paddocks. Infrastructure costs for the implementation and maintenance of such systems are extremely high. Specific costs which are associated with a rotational grazing management system include:

- Camp fencing (hundreds of kilometres for a 10,000 ha farm)
- Water provisioning for each camp, via many kilometres of pipeline
- Replacement and maintenance of water extraction pumps
- Labour for weekly surveillance and maintenance of infrastructure (20–80% of the labour time depending on the farm)
- Fuel costs for transport around the farm to carry out surveillance and for water extraction
- Construction and maintenance of roads to access each camp

Productivity varies from farm to farm, and depends mainly on weaning rates and

Photo 10.1. Karakul lambs. Gellap Ost Research Station.
Photo: S.E. Domptail 2005.

Photo 10.2. Damara sheep. Omatjene Research Station.
Photo: S.E. Domptail 2007.

livestock loss due to predation, which is one of the main limiting factors of production. Gross margins generated per ewe are an indicator of the productivity of the farms in the study area.

Calculations have shown that biomass production is dependent on the species composition and cover (particularly of shrubs vs. grasses) of the vegetation in rangelands. Therefore, productivity at the farm level is also dependent on the level of land degradation (Fig. 10.2).

Management strategies in time and space

The Gellap Ost herd is mainly constituted of Karakul, but there are also Friesian cows for milk production, Dorper sheep for stud production, Damara sheep, Gellaper sheep (cross breed between Dorper and Damara) and Boergoats for meat. In this way, both browsers and grazers are mixed to maintain some equilibrium between the feeding patterns of the stock and the vegetation of the dwarf shrub savanna (Falk 2008). The farm employs a strategy of low stocking rates combined with the breeding and production of high quality animals and products.

Great effort is directed towards sustainable management of the veld (rangeland) (pers. comm., van der Merwe, 2005). Grazing management is based on both quantitative and qualitative indicators. A detailed evaluation of the available biomass in each camp, carried out at the end of the rainy season in April, determines the stocking rates applied in that year. Furthermore, indicator plants are used to make informed decisions about the timing of the rotation of flocks on the farm. An example of such an indicator plant is the woolbos (Leucosphera bainsii), a highly palatable dwarf shrub which is sensitive to grazing. However, Gellap Ost has experienced degradation in some camps due to droughts and management errors. These camps are the focus of regeneration experiments, including ridge ploughing, bush planting and the application of very low stocking rates.

Tab. 10.1. Definition of six rangeland condition states based on vegetation composition (Popp et al. 2009b).

Ecological state	Grass cover [%]	Shrub cover [%]
S 1	30–100	40–100
S 2	0–29	40–100
S 3	50–100	0–39
S 4	10–49	0–39
S 5	0–9	10–49
S 6	0–9	0–9

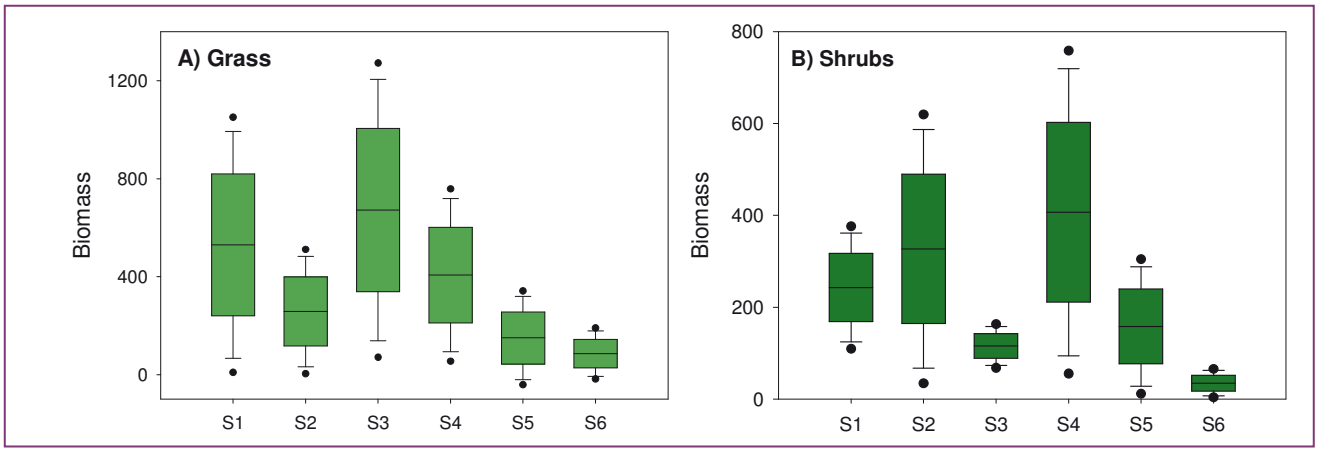


Fig. 10.2: Projections of biomass production depending on the ecological state of rangelands (Popp, own data of 2006). Total biomass production (grasses and palatable shrubs) given in kg ·year-1·ha-1 and calculated using the TOPMAN vegetation model (Popp et al. 2009a). A) Grass biomass; B) Shrub and dwarf shrub biomass.

Photo 10.4: Gellaper Breed: cross breed between Dorper and Damara sheep. Gellap Ost Research Station. Photo: S.E. Domptail 2007.

Photo 10.5. Boergoats. Farm Schlangkopf. Photo: S.E. Domptail 2005.

Stocking rates, carrying capacity and major events on the Observatory Gellap Ost

The camp on Gellap Ost where the BIOTA Observatory is located is largely understocked, on average only up to a third of the total recommended stocking rate. Stocking rates have been fairly low and very variable from 1993 to 2006 (Fig. 10.3). Interestingly, the stocking rates at this camp do not follow rainfall. On the contrary, the camp appears to be mostly used as a reserve camp when rainfall is low. This may be related to its location on the farm and the presence of high shrub biomass in the camp. These characteristics may explain why the camp is grazed mainly in the wet season, and it allows the vegetation of grassier or strategically more important camps to grow or the camps to regenerate with the rains. In addition, livestock are able to benefit from the fresh shrub biomass in the late rainy season in this camp. Thus, stocking rates vary strongly within each year and from year to year.

Photo 10.6: Cattle at water point. Farm Amonkopf. Photo: S.E. Domptail 2005.

Tab. 10.2. Productivity data for small stock breeds in the study area. * Average for the sampled farmers. ** Price data 2001–2006 Meat Board Namibia. *** Data for weaning rate and losses from Omajene and Gellap Ost Research station.

	Dorper sheep	Karakul sheep	Damara sheep***	Boergoats (goats)
Diet	Grazer	Grazer	Browser	Browser
Lamb price [NAD]	325 ± 53	329 ± 81	219 ± 21	334 ± 78
Weaning rate* [lambs · ewe^{-1} · y^{-1}]	1.34	1.17	1.77	1.63
Annual losses of lambs	8.0%	9.0%	3.5%	10.0%
Labour* [hours · SSU^{-1}]	1.53	2.71	1.22	2.3
Gross margin per ewe [NAD per head]**	260	159	n.a.	244

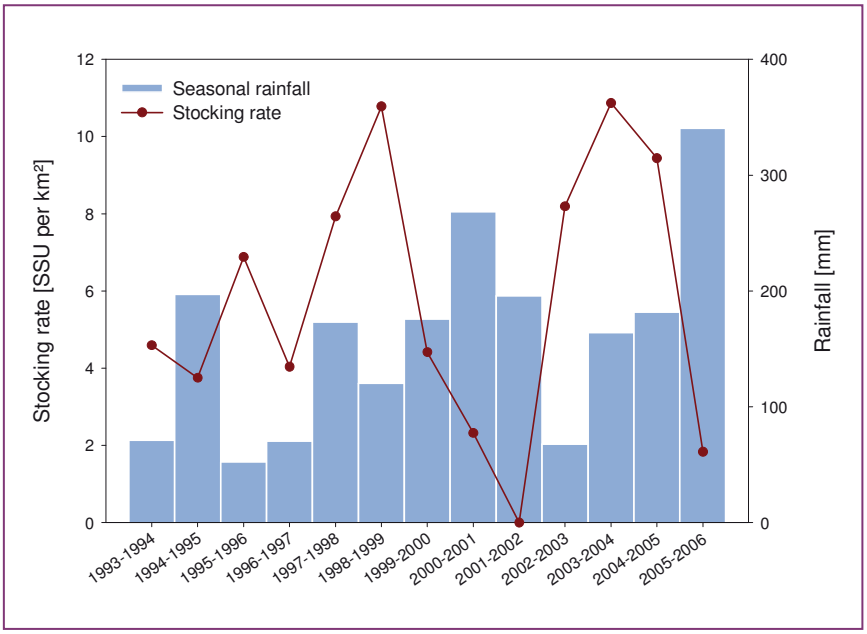


Fig. 10.3: Seasonal stocking rates and rainfall on camp B1 from 1993 to 2006 (Observatory Gellap Ost). The season extends from one dry season to the next dry season i.e from April 1st to March 31st in the following year. Sources: rainfall data 1993–2000 and stocking rates: Gellap Ost research station; rainfall data 2001–2006: BIOTA Africa http://www.biota-africa.org

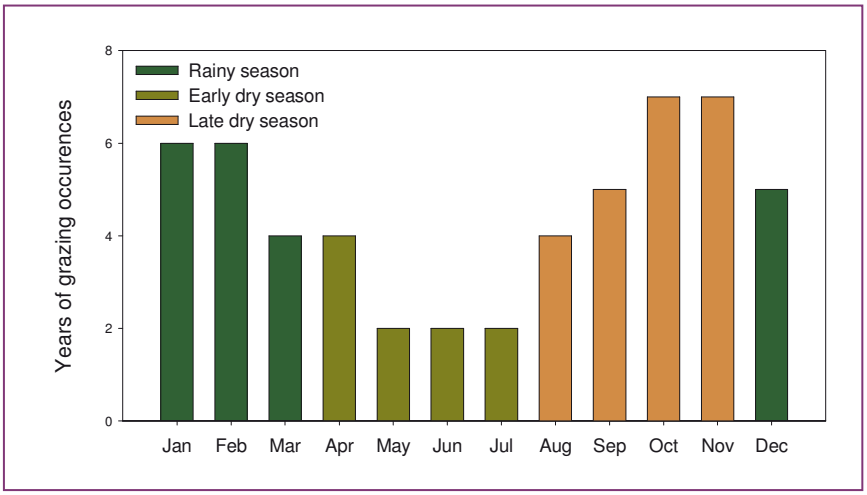


Fig. 10.4: Seasonal grazing patterns on camp B1 observed over 13 years from 1993 to 2005. Data from Gellap Ost research station.

Photo 10.3. Dorper sheep. Warmbakkies farm. Photo: S.E. Domptail 2006.

Responsible author: S.E. Domptail

Site-specific studies

Evaluating methods for soil seed bank quantification in arid grazing lands of Namibia (S10.01)

[N. Dreber]

Soil seed bank (SSB) analysis is an effective tool to assess rangeland condition as well as regeneration and restoration potential. However, the choice of the sampling design and seed quantification method influences the results. Thus, different approaches should be tested for their efficacy, particularly in little studied regions. This study addressed this issue for arid Nama Karoo rangelands in southern Namibia. SSBs were sampled in April 2006 on this Observatory and the adjacent Observatory S11 (Nabaos). Species composition and seed densities in under-canopy and open-matrix samples from two soil depths were contrasted. In addition, the effects of cold-, heat-, and no stratification of samples prior the application of the germination method were compared.

The floristic similarity between SSB and standing vegetation was generally low. Nearly 90% of the germinated seeds were located in the top 4 cm of the soil, with under-canopy samples containing more species and seeds than open-matrix samples. Sample stratification had no effect on either diversity or number of seeds germinated.

Pre-treatment of samples prior to germination did not influence the results significantly and thus is not recommended in terms of cost efficacy. By contrast, the strong spatial variability of SSBs in this ecosystem showed a strong spatial variation in readily germinable seeds. Accordingly, the precise sampling design is crucial for the adequate assessment of arid Nama Karoo SSBs and the comparison of results from different studies.

Dreber, N. (in press): How best to quantify soil seed banks in arid rangelands of the Nama Karoo? – Environmental Monitoring and Assessment. DOI: 10.1007/s10661-010-1425-4.

Spatio-temporal seed bank dynamics in a degraded vs. non-degraded rangeland in southern Namibia (S10.02)

[N. Dreber]

Southern Namibian rangelands experience frequent droughts, which together with severe grazing can transform ecosystems substantially. The resulting variation in resources such as seeds plays an important role in degradation processes of arid ecosystems. However, less is known on how characteristics of soil seed banks (SSBs) vary with climate, livestock pressure, and habitat condition in Namibia. This issue was studied in 2007–2008 on this Observatory as a benchmark for the degraded Observatory S11 (Nabaos). The effect of grazing intensity and rainfall on spatial patterns in SSB density and richness was analysed over distinct microsites, and the influence of diaspore size on seed dispersion evaluated.

High grazing intensity favoured small-seeded annuals, leading to increased seed

densities and species richness of this life form across microsites. Despite degradation, SSB structure and spatial patterning were similar to that found under sustainable grazing. Overall, seed distribution was dictated by the small-scale heterogeneity of the physical environment, and interacted with diaspore size. Besides shrubs, even small physical barriers like stones were highly effective in seed retention. These patterns were maintained over time, although readily germinable seeds accumulated from 2007 to 2008.

The results indicate that the degraded rangeland still is functional in terms of seed entrapment and accumulation. Temporal patterns provide evidence for prevailing persistent seed banks, which are affected by both condition and sequence of preceding rainfall seasons.

Dreber, N., Esler, K.J. (subm.): Spatio-temporal variation in soil seed banks under contrasting grazing regimes following low and high seasonal rainfall in arid Namibia. – Journal of Arid Environments.

Floristic similarity of soil seed banks over microsites and grazing intensities in arid Namibia (S10.03)

[N. Dreber]

Soil seed banks (SSB) are important components of vegetation dynamics, resistance, and resilience. Assessing their composition can help to evaluate if degraded vegetation still is capable of natural regeneration or restoration is needed for rangeland improvement. Safe sites are effective in trapping seeds, and therefore may be crucial in providing a diverse seed pool for post-disturbance vegetation.

This issue was studied in 2008 at this Observatory as a benchmark and potential seed source for the adjacent Observatory S11 severely impacted by grazing. Species composition and community structure of the SSBs and standing vegetation were compared, and floristic similarities between safe sites and between the two Observatories analysed. Irrespective of rangeland condition, aboveground and belowground species composition was of moderate similarity with species diversity and the abundance patterns of the most dominant species being similar. The SSBs were highly dissimilar between the Observatories, both for the pooled data and for each of the three safe-site types. Moreover, under intense grazing, there was a shift towards a dominance of prostrate forbs, while seeds of perennial grasses were lacking.

The results suggest that the condition of established vegetation can serve as an indicator of SSB condition, and vice versa. It was shown that long-term severe goat grazing in arid Namibia can alter SSBs to a state where adequate seed material for site improvement is lost from the system, and active restoration is inevitable.

Classification of the Nama Karoo vegetation in south-central Namibia (S10.04)

[J. Dorendorf, N. Dreber & J. Dengler]

Vegetation is the most important resource in the farmlands of Namibia, but still there is insufficient knowledge about plant communities, their site conditions, and their distribution in space. Further, the assessment of vegetation types, their composition, and associated habitat characteristics is an important tool for conservation and land management. This study aims at providing a first detailed classification of arid Nama Karoo vegetation in the northern Keetmanshoop region. Additionally, it compares two different plot sizes of relevés (100 m² and 1000 m²) to determine which size is better suitable for classification of arid Nama Karoo vegetation. The study area encompassed about 1800 km², including this Observatory and the adjacent Observatory S11 (Nabaos).

Vegetation relevés of nested plots were conducted in summer 2008 and 2009 at locations determined with a stratified-random approach based on satellite images. The vegetation was then classified with modified TWINSPAN. A set of environmental variables were recorded for each plot and tested for differences between vegetation units.

The 1000-m² scale allowed a slightly better discrimination of distinct vegetation units than the smaller scale. Within the area, 19 basic vegetation units equivalent to associations were distinguished. They could be grouped into six alliances, three orders, and two classes, each representative for a certain habitat type. The main driving factors separating plant communities were soil depth, pH value, and lime content.

The classification with its link to habitat characteristics provides an overview of the diversity of vegetation types and plant lists, which allows farmers and extension offices to identify standardised vegetation types, which in turn can improve communication and management decisions.

Dorendorf, J.U. (2010): Hierarchical classification of Nama-Karoo vegetation in the Keetmanshoop area, south-central Namibia. – Diplom thesis in Biology. Hamburg: University of Hamburg.

Dorendorf, J.U., Dreber, N., Dengler, J. (2010): A classification of Nama Karoo vegetation in southern Namibia – first results. – Poster at the 9th international Meeting on Vegetation Databases, 24–26 February 2010 in Hamburg. http://www.botanik.uni-greifswald.de/fileadmin/workshop/2010/Post_Symposium/contrib/Poster_17.pdf.

Land use strategies of ranchers in southern Namibian Nama Karoo and environmental sustainability (S10.05)

[S.E. Domptail]

Ranching is the dominant land use in southern Namibia. Because land use strategies impact on the ecological state of rangeland resources, they play an important role for their conservation. Land use strategies of ranchers in the surroundings of the city of Keetmanshoop were investigated. About 30 farmers were interviewed in 2005 and 2006. Data on production parameters, farming systems, and strategies preferred by farmers to cope with the great rainfall and ensuing biomass inter-annual variability characterising the study area were gathered. After a first qualitative analysis, a bio-economic model was developed and used to simulate land use strategies.

A first result is that strategies used are very diverse with regard to how they

shape the system's dynamics. Also farmers appear to have various objectives besides income generation including rangeland conservation. Model simulations showed that objectives, uncertainty of rainfall and especially expectations of future unknown rainfall play an important role in directing land use strategies in terms of stocking intensity and herd composition and management. Finally, in the context of a normative analysis, the effect on strategies of a reward scheme for rangeland conservation designed on the basis of the actual land tax scheme was simulated. The scheme revealed a valuable tool to positively influence on-farm conservation.

Domptail, S.E. (in prep.): Towards rangeland conservation strategies. Case study and bio-economic modeling of farms in southern Namibia. PhD thesis. Gießen: University of Gießen.

Domptail, S.E., Popp, A., Nuppenau, E.A. (2009): A trade-off analysis between rangeland health and income generation in southern Namibia. – In: Kontoleon, A., Pascual, U., Smale, M. (eds.): Agrobiodiversity, conservation and economic development: 204–232. Abington: Routledge.

Domptail, S.E., Nuppenau, E.A., Popp, A. (in press): Land tax: towards a multifunctional institutional tool for land reform and rangeland conservation. – International Journal of Environmental Policy and Decision Making.

Reptiles on Gellap Ost (S10.06)

[A. Hoffmann & J. Deckert]

Photo SSS10.1: Verrox's Tent Tortoise (*Psammobates tentorius verroxii*). Photo: A. Hoffmann.

Encounters with snakes were rare, but except of two individuals others were identified: one Puff Adder (*Bitis arietans*), one Horned Adder (*Bites caudalis*) and one Cape Coral Snake (*Aspidelaps lubricus*) or Shield-nose Snake (*A. scutatus*).

Photo SSS10.2: Bushveld Gerbil (*Gerbilliscus leucogaster*), the most abundant rodent. Photo: S. Bengsch.

On the main road close to the Observatory, another Puff Adder and a large aggressive Cape Cobra (*Naja nivea*) of about 1.5 m length were observed. Among these species, the puff adder has a wide distribution in Africa, the others occur only in southern Africa. Lizards were rarely seen on Gellap Ost comparing to the proximate Observatory S11 (Nabaos), where lizards were rather common. One Verrox's Tent Tortoise (*Psammobates tentorius verroxii*, Photo SSS10.1) was observed on the Observatory, a taxon that is known to occur throughout the Karoo and southern Namibia.

Birds on Gellap Ost (S10.07)

[J. Deckert & A. Hoffmann]

On the Observatory, 47 bird species were observed. All species are known to be resident bird species that remain in their area throughout the year, except the African Reed-warbler (*Acrocephalus baeticatus*), which is a non-breeding migrant. None of these species is endangered, but they are all assigned to the IUCN Red List category "least concern". This is mainly due to the large range of distribution of these species in Africa, at least in southern Africa (Angola, Botswana, Namibia, and South Africa). However, the population size of these species has not been quantified in general. At local focus the trends in population density over years may differ from the general appearance. Day active predators as falcon species, Black-winged Kite (*Elanus caeruleus*), and pale Chanting Goshawk (*Melierax canorus*), and night active owl species were regionally significant. The African Pygmy Falcon (*Polihierax semitorquatus*) was associated with the Sociable Weaver's colony (*Philetairus socius*) at the south boundary of the observatory. The Sociable Weaver colony had their nest in a large *Acacia erioloba*. The birds were using the Observatory as foraging ground. From time to time, three species of bustards were also observed using the area of the Observatory. Altogether, four lark species were found in the Observatory, species which are characteristic of open landscapes.

Small mammals on Gellap Ost and Nabaos (S10.08)

[A. Hoffmann & U. Zeller]

Ten small mammal species belonging to three orders were recorded during a long-term field study between 2001 and 2003. Species diversity, abundance and survival were found to be much higher than in the overgrazed proximate Observatory S11 (Nabaos). The Bushveld Gerbil (*Gerbilliscus leucogaster*; Photo SSS10.2) was the most dominant species, which is known to occur in a wide range of savannas and open woodlands of southern Africa. This gerbil occurs also in drier areas like the Nama Karoo where it is assumed to depend on an adequate ground vegetation layer not only because of food availability and cover, but also due to dew water availability. Because this species was not found in the overgrazed area of Nabaos, it could be seen as

an indicator for an undisturbed grassland habitat. The Bushy-tailed Hairy-footed Gerbil (*Gerbillurus vallinus*), which is a xeric-adapted species, was subdominant on Gellap Ost, but was found to have a shorter survival rate respectively a shorter length of stay than in the degraded area of Nabaos (S11), where it could find its preferred desert-like habitat. The relatively high number of carnivorous species and bird predators can be seen as indicator for the high abundance and species diversity of small mammals on Gellap Ost. Owl pellets of the Spotted Eagle Owl (*Bubo africanus*) as well as skulls of *Crocidura* sp. (Soricidae, Eulipotyphla) were found. However, it could not be ascertained where these shrews exactly had been hunted.

► *See also* **Article III.5.8.**

Large mammals on Gellap Ost (S10.09)

[A. Hoffmann & U. Zeller]

Twelve larger mammal species belonging to three orders were recorded on the Observatory and its immediate surroundings. None of these is endangered, but they are assigned to the IUCN redlist category "least concern". The steenbok (*Raphicerus campestris*) was the most observed large mammal species in this Observatory. The Greater Kudu (*Tragelaphus strepsiceros*; Photo SSS10.3), which also occurs widely in southern Africa, but actually prefers woodland savannas with adequate cover and food, was recorded only twice in large groups of nine to eleven animals. According to farmers of this area, the Black-Backed Jackal (*Canis mesomelas*; only identified by its voice) and the Caracal (*Caracal caracal*) were more present than we have noticed, and are seen as pest in farming because they prey also on sheep and goats. The strictly nocturnal Striped Polecat (*Ictonyx striatus*) was only found as a road-kill on the main road close to the Observatory, but is in fact a common carnivore and preys on rodents, insects, and other small animals. Merely tracks and a used burrow indicated the presence of an Aardvark (*Orycteropus afer*) on the Observatory. This species, which feeds only on termites and ants is indeed widespread south of the Sahara, but occurs in low densities.

Analysis of Nama Karoo soils using Landsat satellite data (S10.10)

[A. Gröngröft & L. Grotehusmann]

This study was focused on the relation of remote sensing data and soil characteristics on five farms within the area of Keetmanshoop, comprising the Observatories S10 and S11. Soil investigations included extensive profile description, classification according to the World Reference Base (WRB), sampling, and laboratory analysis. A cluster analysis allowed for a plausible grouping of the soils according to the parent materials (dolerite, metamorphic rocks). Soil colour and satellite imagery values were strongly correlated, but the relationships between satellite data and elemental composition were week for most elements. Based on data of six Landsat-TM5 channels, a map showing the topsoil concentrations of potassium has been developed and its predictability evaluated.

Grotehusmann, L. (2006): Analyse der Böden und ihrer Eigenschaften in Bezug auf Fernerkundungsdaten im südlichen Namibia (Raum Keetmanshoop). – Diplom thesis in Soil Science. Hamburg: University of Hamburg.

Photo SSS10.3:Greater Kudu (*Tragelaphus strepsiceros*). Photo: J. Deckert.

Further studies

Buß, H.-J. (2006): Land use options of Namibian farms – optimal management strategies proposed by bioeconomic models. – Agrarökonomische Studien **26**: 1–201. Kiel: Wissenschaftsverlag Vauk.

Domptail, S.E., Popp, A., Nuppenau, E.A. (2009): A trade-off analysis between rangeland health and income generation in southern Namibia. – In: Kontoleon, A, Pascual, U, Smale, M. (eds): Agrobiodiversity, conservation and economic development: 204–232. Oxon Abington: Routledge.

Herpel, N. (2008): The scale-dependent variability of topsoil properties reflecting ecosystem patchiness in drylands of southern Africa. – Hamburger Bodenkundliche Arbeiten **62**: 1–299. http://www.sub.uni-hamburg.de/opus/volltexte/2008/3831/.

Hoffmann, A., and Zeller, U. (2005): Influence of variations in land use intensity on species diversity and abundance of small mammals in the Nama Karoo, Namibia. – Belgian Journal of Zoology **135** (supplement): 91–96

Popp, A. (2007): An integrated modelling approach for sustainable management of semi-arid and arid rangelands. – PhD thesis in Ecology. Potsdam: University of Potsdam.

Popp, A., Blaum, N., Jeltsch, F. (2009): Eco-hydrological feedback mechanisms in arid rangelands: simulating the impacts of topography and landuse. – Basic and Applied Ecology **10**: 319–329.

Popp, A., Domptail, S., Blaum, N., Jeltsch, F. (2009): Landuse experience does not qualify for adaptation to climate change. – Ecological Modelling **220**: 694–702.

Popp, A., Vogel, M., Blaum, N., Jeltsch, F. (2009): Scaling up eco-hydrological processes - the role of source-sink systems in water limited landscapes. – Journal of Geophysical Research – Biogeosciences **114**: 1–10.

General data

Number	Name	Alternative name(s)
S11	Nabaos	n.a.
Implementation	**Country**	**Province/ region**
2001	Namibia	Karas
District/ constituency	**Locality**	**Farm name**
Keetmanshoop	Keetmanshoop	Nabaos 7
Latitude	**Longitude**	**Altitude**
26.390643 S	17.995478 E	1045 m a.s.l.
Rainfall season	**Biome**	**WWF Ecoregion**
Summer	Nama Karoo	AT1316 Namibian savanna woodlands
Agro-Ecological Zone	**Relative intensity of land use**	**Tenure**
CPL7	High	Communal
Type and history of landuse	**Land owner**	
Farming with goats, sheep and donkeys	Government of Namibia	

Nabaos (S11)

Open dwarf shrub landscape of the Nabaos Observatory. Photo: N. Dreber.

The BIOTA Observatory Nabaos (S11) is named after its location on the communal land of Nabaos, which belongs to the most southern settlements of Namaland. Nabaos is situated about 25 km north of Keetmanshoop, the capital of the southern Karas region, and directly borders the Gellap Ost research station (BIOTA Observatory S10). This arid part of the Nama Karoo Biome is dominated by slightly undulating plains dissected by washes, prominent dolerite hills and dykes, and cone-shaped shale 'inselbergs'. The area receives little rainfall with a high inter-annual variability, resulting in low mean seasonal biomass production. Land degradation is widespread in this communal area due to inappropriate governance structures and poor management of natural resources. As a result, vegetation consists mainly of open shrublands lacking valuable plants such as perennial grasses. Soil erosion and the spread of bare ground are signs of ongoing environmental deterioration and ecosystem dysfunction.

This BIOTA Observatory was established to analyse the long-term consequences of overgrazing on the biotic and abiotic environment. Using the fence-line contrast approach, rangeland degradation can be assessed in comparison to the adjacent non-degraded BIOTA Observatory Gellap Ost (S10). Together with the monitoring program, the gathered data provide important information on ecosystem dynamics, resistance, and resilience. Embedded in a local socio-

economic framework, the Observatory data further aids in deriving recommendations towards sustainable resource management.

Responsible authors: N. Dreber & D.H. Haarmeyer

Remote sensing and landscape

Geomorphology	Geological units	Lithological units
Plains, slopes	Main Karoo Basin in Karoo Supergroup	Sandstones and shales
Mean EVI	**EVI absolute range**	**Mean leaf area index**
0.055 (0.034–0.109)	0.026 (2004)–0.163 (2009)	0.31

Grid map of Observatory

	0	1	2	3	4	5	6	7	8	9
0	70	12	77	81	28	58	34	52	16	10
1	60	6	27	73	56	22	36	14	61	9
2	92	83	37	19	30	18	99	41	25	63
3	15	2	40	48	43	57	84	3	51	31
4	50	86	90	54	33	8	23	76	39	46
5	93	100	26	5	24	94	38	11	45	4
6	87	49	29	82	79	64	98	53	71	66
7	97	21	74	55	32	88	96	7	78	20
8	85	44	91	72	80	67	47	42	89	13
9	95	65	35	59	1	75	62	17	69	68

1 Overgrazed shrubland on footslopes
2 Low open shrubland on rocky slopes
3 Overgrazed shrubland on eroded footslopes
4 Low open shrubland on rocky slopes
5 Low open shrubland on strongly eroded footslopes

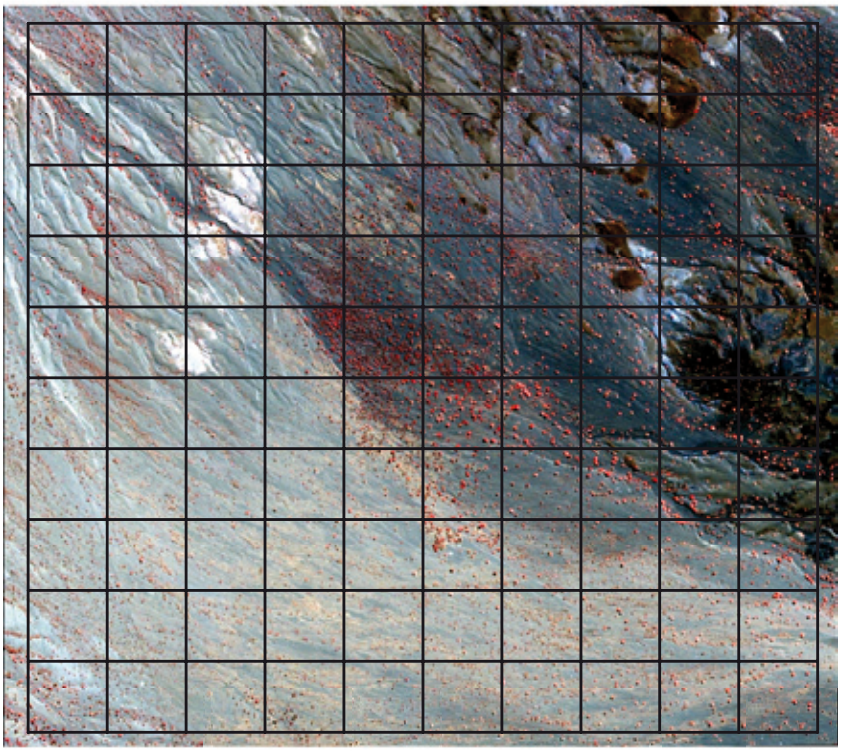
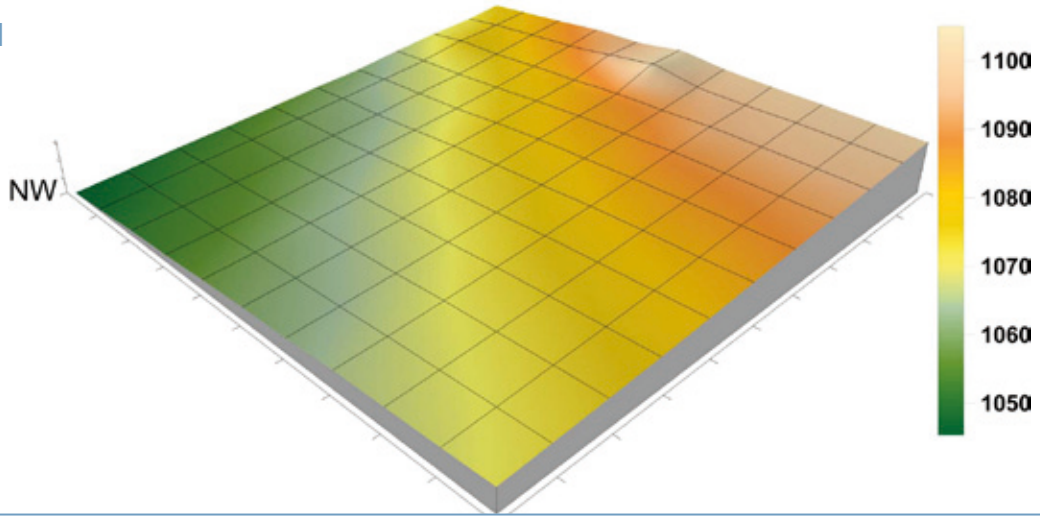


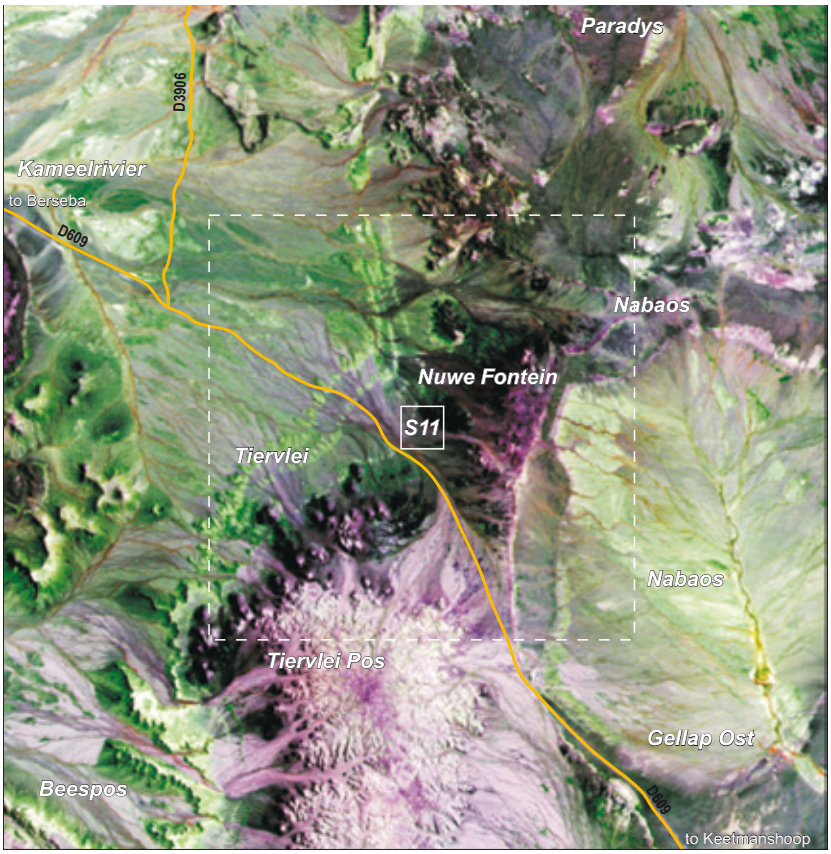
Image: QuickBird, 21 August 2004

Elevation model of Observatory



Landsat image

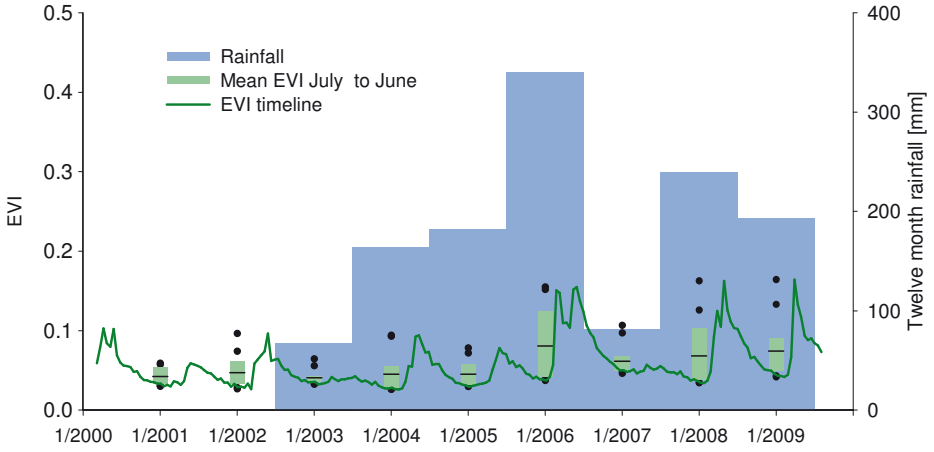
Fan-shaped erosion plains and persisting, deeply eroded crests characterise the landscape northwest of Keetmanshoop. Denser woody vegetation, including shrubs and trees, mainly grows along aquifers and riverbeds (red lines). Green colours indicate non-woody vegetation in the northwestern part of the Observatory, consisting mainly of grasses and herbaceous species. Blue colours indicate open or very sparsely vegetated areas in the rocky southern parts, while white colours correspond to rocky and bare parts in the dissected south-western mountains, and to bare and eroded slopes at the eastern edge of the image. The vegetation on the Observatory Nabaos is less dense than at Gellap Ost.



Scene: 177/78, acquisition date: 15 February 2007

MODIS time series

Temporal patterns of annual rainfall, vegetation cover, and phenology



Responsible authors: M. Keil & T. Labitzky

Climate

Data from BIOTA weather station

Location	Recorded period	Mean temperature
Gellap Ost (S10)	2001–2009	22.6 (0.4–41.5) °C
Mean solar radiation	**Mean wind speed**	**Mean annual precipitation**
589 (358–842) MJ·m^{-2}·month^{-1}	3.2 (9.3) m·s^{-1}	183 (90–320) mm
Mean annual potential evapotranspiration	**Interannual precipitation variability**	**Mean relative humidity**
1804 mm	173%	35% (23–56%)
Aridity index (UNEP)		
0.10 (arid)		

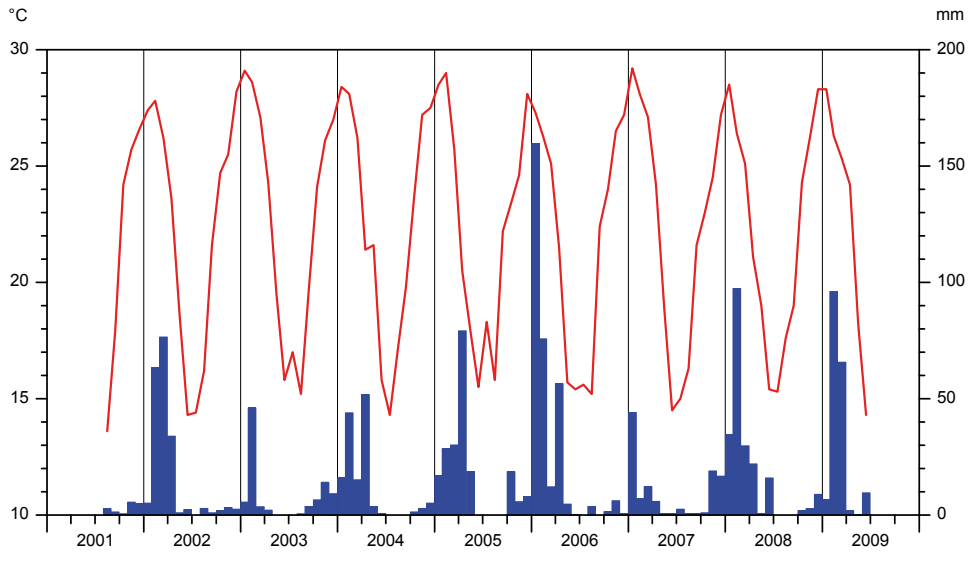
Modelled data

Mean temperature	Mean annual temperature range	Mean diurnal temperature range
20.8 (5.7–34.6) °C	12.9 °C	16.2 °C
Mean annual precipitation	**Precipitation seasonality**	**Percentage winter precipitation**
146 mm	103%	14% (strong summer)
Climate type	**Length of dry season**	**Aridity index (De Martonne)**
BWh	12 months	4.7 (dry)

The climate at the Observatory is characterised by arid to semi-arid conditions. Rainfall shows a moderate seasonality with the major portion of rain falling during the summer season, peaking in February. The mean annual rainfall over the observation period was 183 mm, which is drier than the average rainfall recorded along the entire transect but corresponds approximately with the average of the Observatories within the Nama Karoo. However, substantial interannual variability is evident. The observed near-surface air temperatures show a moderate seasonal cycle. The mean annual temperature is 22.6°C and is therefore slightly warmer than the mean temperature of all Observatories, and of the Observatories within the Nama Karoo. Compared to the interpolated long-term data taken from the WorldClim dataset, a noticeably warmer mean annual temperature was observed at the BIOTA weather station. Furthermore, the station records of temperature extremes deviate substantially from the interpolated data, showing warmer maximum and minimum temperatures. For precipitation, annual mean rainfall is markedly higher at the BIOTA weather station than the WorldClim data.

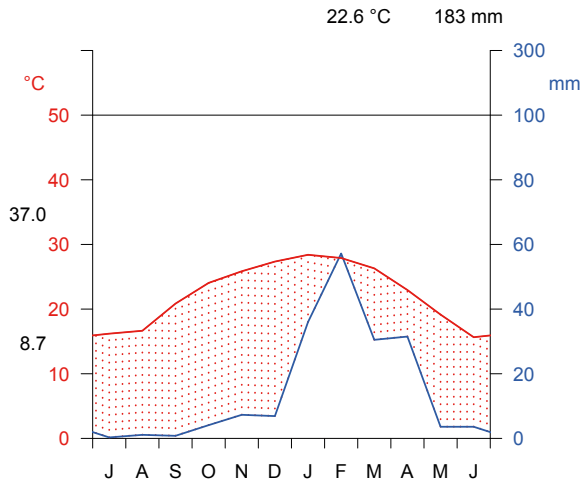
The observed near-surface winds at the Observatory are mainly constituted of southerly flows during spring and summer. During the autumn and winter seasons, the circulation changes to flows from northerly and north-easterly directions, but a south-easterly flow component is also noticeable. Mean wind speed recorded in the evenings shows a pronounced annual cycle peaking in mid-summer. Winds observed during the mornings and early afternoons stay fairly constant throughout the year, with higher wind speeds in the early afternoons, reaching about 13 km/h.

Time series: rainfall and temperature

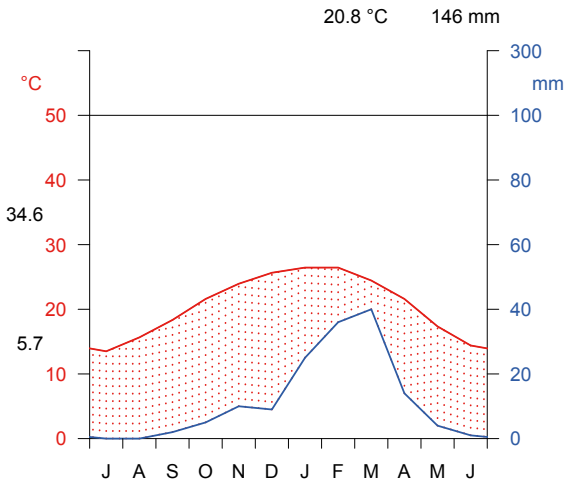


Climate diagrams

Recorded data (BIOTA)

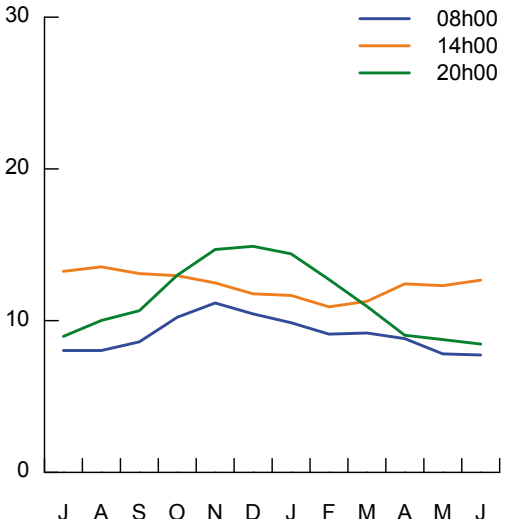


Modelled data (WorldClim)

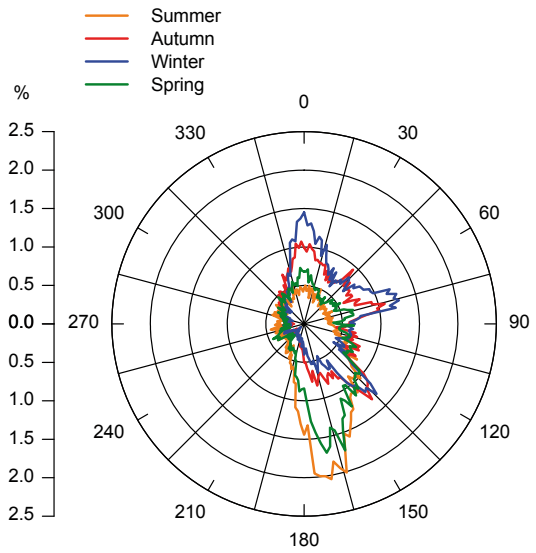


Wind diagrams

Speed



Directions



Responsible authors: K. Berger, A. Haensler & J. Luther-Mosebach

Soils

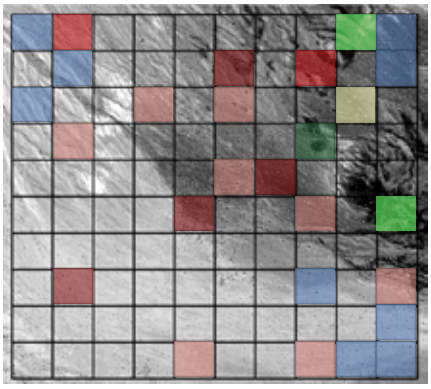
Year of sampling	Hectare plots sampled	SOTER unit
2001	28 (R1–26, R68, R69)	NA68
Soilscape	**Dominant soil group(s)**	**Reference group richness**
n.a.	Regosol	4
Soil unit richness	**Soil unit evenness**	**Soil ecotype richness**
7	0.443	6
Parametric space	**pH**	**Electrical conductivity**
3.41	7.2 (5.5–9.8)	28 (1–296) µS·cm-1
Organic carbon		
0.21% (0.12–0.58%)		

On this Observatory, the dominant reference groups are weakly developed Regosols and Cambisols. Further, in three profiles, Leptosols were encountered on slopes and rocky outcrops.

Soil properties and origin are very similar to Observatory S10 (Gellap Ost), with shale and colluvial material of different ages as parent material. Nevertheless, some differences can be found in the physical as well as the chemical properties. On this Observatory (Nabaos), the percentage of fine material is slightly lower, while the rooting space and pH values are slightly higher. Values for total as well as for plant available phosphorus are slightly higher, while the values for exchangeable magnesium are lower.

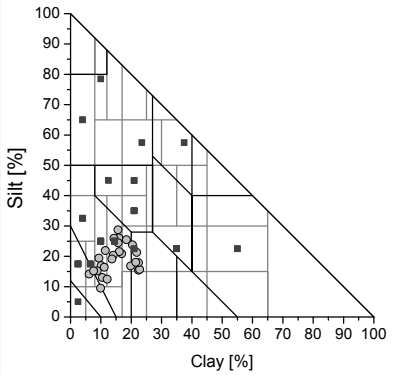
Electrical conductivity is also low, as already presumed in the description of Gellap Ost, caused by deep drainage of the soils. On this Observatory (Nabaos), another indicator for this theory can be found: an accumulation of transported soluble salts is visible at the northwestern part; thin salts crust occur at the transition from the loamier ridges to the drainage lines. The trend of higher pH values combined with the accumulation of sodium in the topsoil might be a result of the strong grazing pressure (see Article III.5.4). The ongoing heavy trampling on this Observatory has reduced topsoil aggregation, which in combination with reduced plant cover and water erosion results in continuous loss of soil material. Signs of sheet and rill erosion are prominent. Another alarming indicator for soil degradation might be the stronger development of vesicular layers in the topsoil, which also reduces infiltration. Higher temperatures in the topsoil due to reduced plant cover most likely support the development of these layers, which are common in this region.

Map of soil profiles

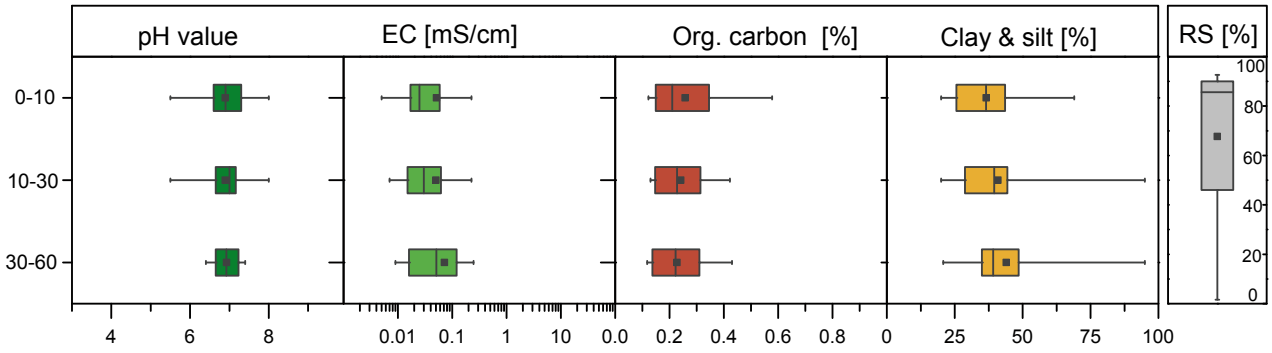


Haplic Regosol
Endoleptic Regosol
Collluvic Regosol
Haplic Leptosol
Paralithic Leptosol
Haplic Cambisol
Protic Arenosol

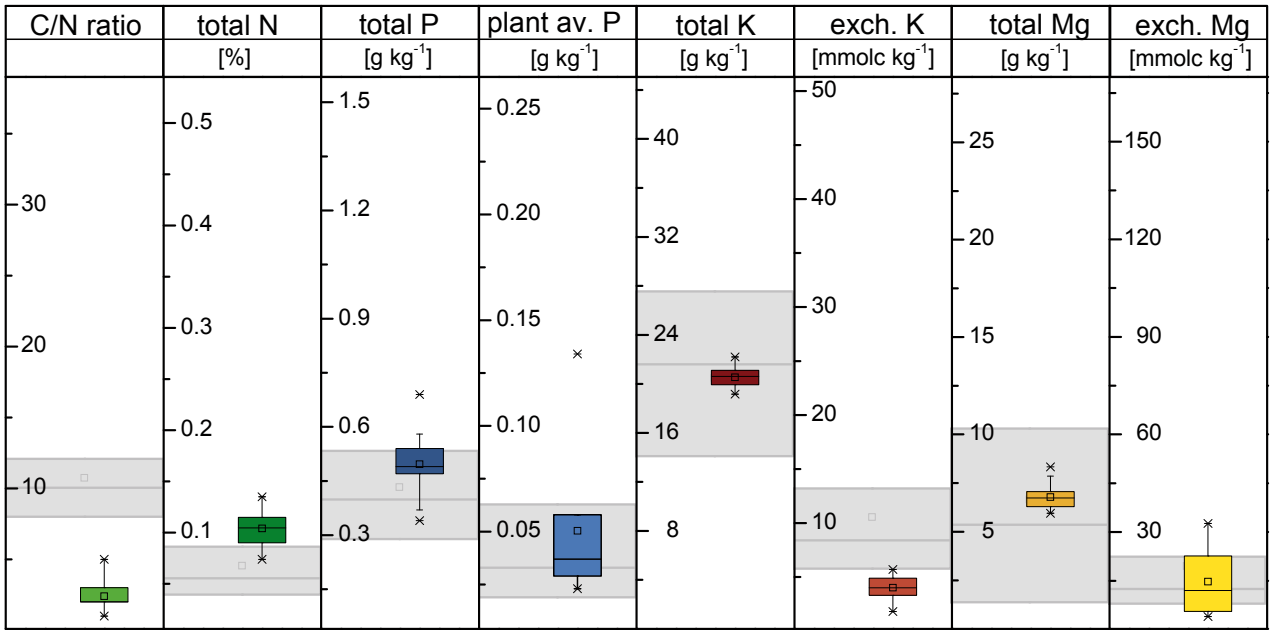
Soil texture triangle



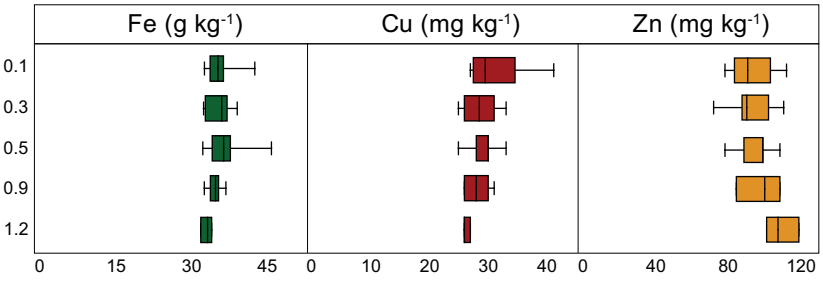
Soil characteristics



Soil nutrients



Soil micronutrients



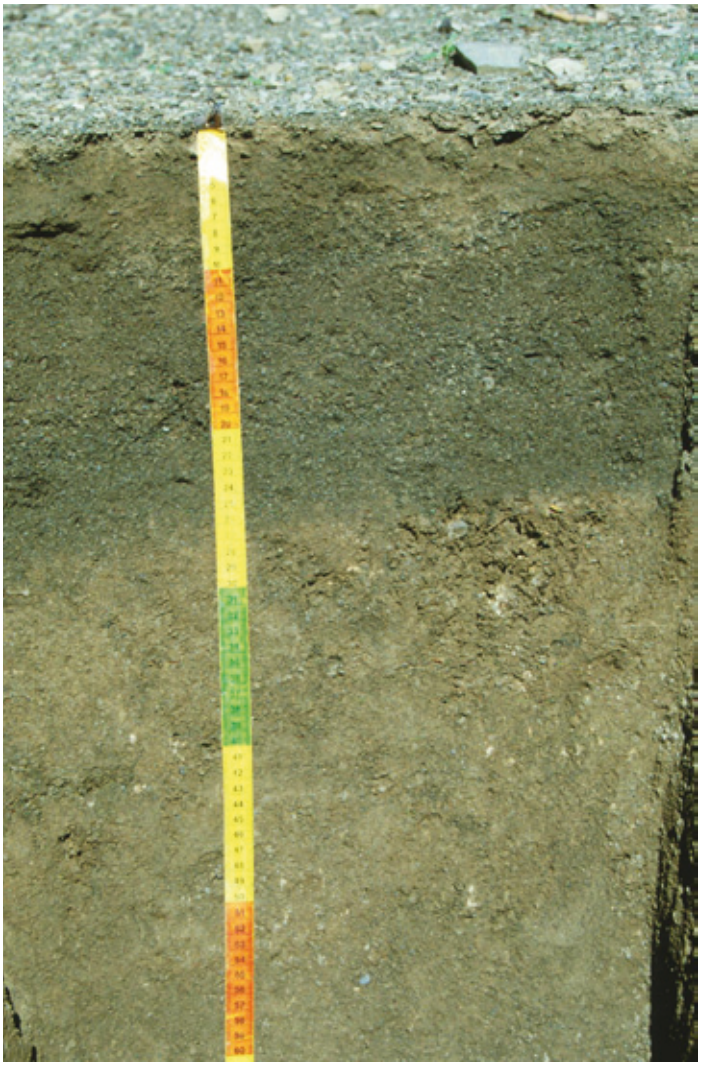
Reference profile (H31)

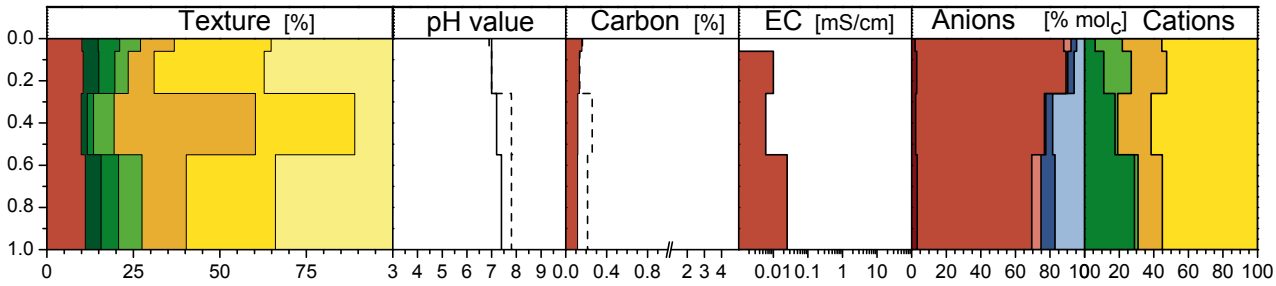
The **Haplic Regosol (Hypereutric, Aridic)** represents soils of the plains developed on young and sandy colluvial substrates. These soils are associated with deep developed Cambisols on loamier ridges, which are also of colluvial genesis.

This profile shows signs of stratification as a result of strong morphodynamic processes with massive substrate transport. From the profile morphology it can be concluded that at least three sedimentation events led to the actual substrate stratification with boundaries at 26 and 55 cm. All horizons consist of sandy loam, typical of young colluvial sediments with 10% of rock fragments within the whole profile. Differences between the sedimentation events are especially obvious in the third horizon with a strong reduction of the coarse sand fraction. However, except for the increase in calcium, the total element content shows no significant changes with profile depth, which is an indication for the homogeneity of the parent material.

Soil reaction is neutral in the topsoil and increases to slightly alkaline in the third horizon, corresponding with the presence of carbonate. The mean C/N ratio is 1.3. The content of water soluble ions is significantly low with 3 $mmol_c\ kg^{-1}$.

The root density is low, with only 3–5 roots dm^{-2} in the topsoil and 1–2 roots dm^{-2} below 26 cm.





Texture

- Fine silt
- Medium silt
- Coarse silt
- Clay
- Fine sand
- Medium sand
- Coarse sand

- pH ($CaCl_2$)
- pH (H_2O)
- Organic carbon
- Inorganic carbon
- Electrical conductivity

Water soluble ions

- Cloride
- Sulfate
- Nitrate
- Hydrocarbonate
- Fluoride, Bromide, Nitrite
- Calcium
- Magnesium
- Potassium
- Sodium

Responsible authors: U. Wisch, A. Petersen, A. Gröngröft & D. Mager

Lichens

Sampling period(s)	Hectare plots sampled	Cover
2001, 2004	10 (R1−R10)	0%
Total species richness	Species richness on soil [1 km²]	Species richness on rock [1 km²]
0	0	0
Species richness on plants [1 km²]	Species richness on soil [1000 cm²]	
0	0	

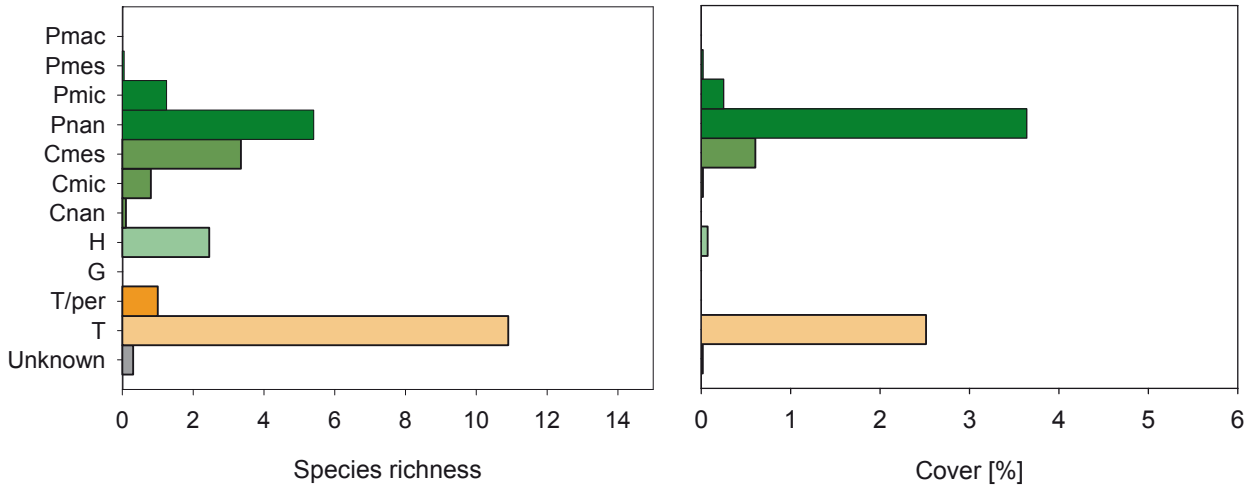
As is the case at the twin Observatory Gellap Ost (S10), lichens do not occur at this Observatory because lichen growth is limited by the same unfavourable climatic and soil conditions.

Responsible authors: L. Zedda & G. Rambold

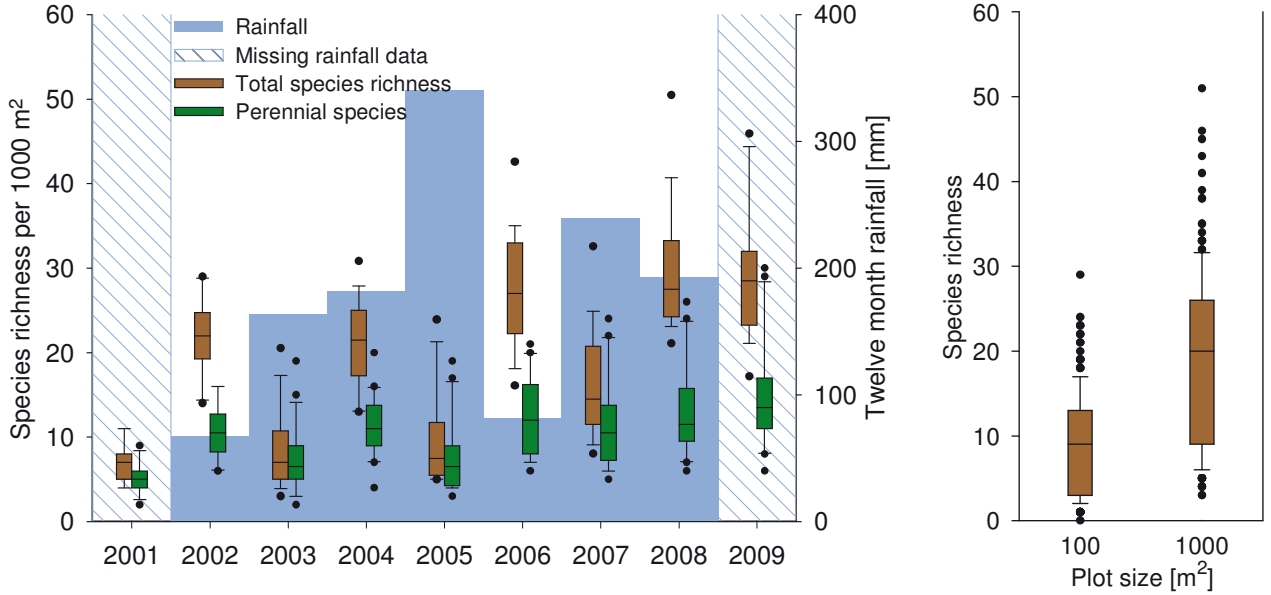
Vascular plants

Sampling period(s)	Hectare plots sampled	Biome
2001−2009	20 (R1−R20)	Nama Karoo
Vegetation unit (level 1)	Vegetation unit (level 2)	Identification rate
Dwarf Shrub Savanna	n.a.	73% − 91% − 91%
Cumulative family richness	Dominant families (cover)	Dominant families (richness)
44	Aizoaceae, Fabaceae, Bignoniaceae	Poaceae, Fabaceae, Asteraceae
Cumulative species richness (1 km²)	Species richness (1000 m²)	Species richness (100 m²)
230 − 102	18.9 (3−51)	8.9 (0−29)
z-value	Species richness change per year (1000 m²)	Evenness (1000 m²)
0.325 (0.079−1.041)	0.73	0.528 (0.029−0.857)
Evenness (100 m²)	Simpson (1000 m²)	Simpson (100 m²)
0.508 (0.034−0.971)	0.618 (0.012−0.914)	0.465 (0.000−0.902)

Life forms



Species richness



The vegetation at the Observatory Nabaos (S11) consists of consistently open, degraded shrublands with very scattered occurrences of trees. This is, at first sight, surprising, as various distinct habitat types occur. These habitats range from bare outcrops densely covered by shale-split and more cragged outcrops with extended footslopes in the eastern portion of the Observatory, to a catchment area of slightly sloping plains. The plains are characterised by loamy-sandy textured soils with increasing stone cover from east to west. In parts, eroded washes dissecting the catchment area have developed canyon-liked structures. Despite this environmental heterogeneity, the main vegetation type at a broader spatial

Unit 1. Photo: N. Dreber.

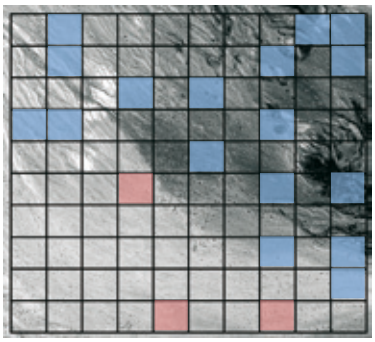
Classification table (2008)*

Column		Cover	All	1	2
Number of relevés			**20**	**3**	**17**
Mean cover [%]			10.7	18.5	9.3
Mean species richness (1000 m²)			28.3	28.0	29.9
Mean inclination [°]			4.8	4.0	4.9
Mean soil pH			7.36	7.20	7.39
Mean electrical conductivity [µS·cm^{-1}]			48	18	54
Fine material [%]			51.6	53.3	51.2
Gravel [%]			43.5	45.6	43.2
Stones 2-6 cm [%]			3.3	1.0	3.7
Stones 6-20 cm [%]			1.2	0.1	1.4
Stones 20-60 cm [%]			0.2	0.0	0.2
Abiotic crust [%]			1.7	0.8	1.8
Soft litter [%]			0.3	0.1	0.3
Unit 1: Limeum argute-carinatum-Calicorema capitata community					
Pnan	Sisyndite spartea	0.28	15	33	12
Cmic	Limeum argute-carinatum	0.04	40	100	29
H	Kohautia caespitosa	0.01	65	100	59
T	Hermannia modesta	0.01	10	33	6
T	Tephrosia dregeana	2.79	100	100	100
T	Limeum rhombifolium	0.01	30	33	29
Unit 2: Kissenia capensis-Tetragonia schenckii community					
T	Kissenia capensis	0.15	75	33	82
T	Microcharis disjuncta	0.02	90	67	94
Cmic	Dicoma schinzii	0.01	55	33	59
H	Sesuvium sesuvioides	0.02	20	.	24
Cmes	Lophiocarpus polystachyus	0.02	45	33	47
Pnan	Tetragonia schenckii	2.07	80	67	82
Most frequent companions					
T	Trianthema parvifolia	1.23	100	100	100
T	Indigastrum argyroides	0.85	100	100	100
T	Schmidtia kalahariensis	0.73	100	100	100
T	Aristida adscensionis	0.08	95	100	94
T	Mollugo cerviana	0.03	95	100	94
H	Stipagrostis uniplumis	0.03	95	100	94
n.a.	Amaranthus praetermissus	0.03	85	100	82
Pnan	Calicorema capitata	0.69	80	100	76
T	Boerhavia repens	0.10	70	67	71
Pnan	Acacia nebrownii	0.97	65	100	59
Pnan	Monechma genistifolium	0.09	65	100	59
H	Stipagrostis hirtigluma	0.02	65	100	59
Pmic	Boscia foetida	0.22	55	100	47
T	Aizoanthemum dinteri	0.13	55	33	59
H	Dicoma capensis	0.02	55	67	53
Cmes	Asparagus spp.	0.02	55	67	53
Pnan	Rhigozum trichotomum	0.87	50	100	41
Pmic	Acacia mellifera ssp. detinens	0.21	50	33	53
T	Enneapogon desvauxii	0.04	50	.	59
T	Lotononis platycarpa	0.01	50	33	53
Cmes	Salsola spp.	0.41	45	.	53
T	Chamaesyce glanduligera	0.01	45	100	35
Cmes	Phaeoptilum spinosum	1.03	40	33	41
Cmic	Leucosphaera bainesii	0.03	40	.	47
Cmes	Sericocoma heterochiton	0.01	40	.	47
Pnan	Cadaba aphylla	0.14	35	33	35
T	Enneapogon cenchroides	0.01	35	.	41
T	Forsskaolea viridis	0.01	35	.	41
Cmes	Peliostomum leucorrhizum	0.01	35	67	29

classification is based on data also including relevés outside the Observatory

continued on next page

Map of vegetation units



scale is quite similar in species composition. The shrub matrix generally contains the species *Acacia nebrownii* (Slapdoring), *Calicorema capitata*, and *Tetragonia schenckii* (Kooibos). The herbaceous layer is dominated by annual, generalist forbs (e.g. *Indigastrum argyroides*, *Tephrosia dregeana*, and *Trianthema parvifolia*) and annual grasses of low-medium grazing value such as *Aristida adscensionis* (Eenjarige Steekgras) and *Schmidtia kalahariensis* (Kalaharisuurgras). In contrast, perennial grasses such as *Stipagrostis uniplumis* (Blinkhaarboesmangras), which are dominant at the adjacent non-degraded Observatory Gellap-Ost, are very low in abundance. The tree species *Maerua schinzii* (Kringboom) is widespread in various habitat types but is very scattered. However, local variations in vegetation structure and composition are apparent at smaller spatial scales. For example, remnants of typical shallow soil communities are found on outcrops and the surrounding footslopes contain a variety of otherwise rare dwarf-shrubs, perennial grasses, and forbs. At the 1000-m² scale, these habitats often overlap with the 'ground matrix' in vegetation monitoring plots, resulting in high β-diversity, measured as z-value at smaller scales (100m²–1000m²), which is amongst the highest along the BIOTA transect. Species evenness is rather low due to the habitat heterogeneity at small spatial scales. This situation, together with the high degree of vegetation homogenisation caused by high grazing pressure over decades, are most likely responsible for the fact that only two vegetation units can

Unit 2. Photo: N. Dreber.

be differentiated at the scale of 1000-m^2 on the Observatory.

The *Limeum argute-carinatum-Calicorema capitata* community (unit 1), represented by only three plots, is a typical variation of the shrublands dominating on loamy soils in the south-western plains of the Observatory and catchment area, respectively. Of the mentioned widespread shrub species, the spiny *Calicorema capitata* has its main occurrence within this community. This blue-green shrub with sparse and inconspicuous leaves may be confused with the less abundant *Cadaba aphylla* (Swartstormbos), but has a more compact, cushion-like growth form (see Photo). Another characteristic shrub species of this community is *Boscia foetida* (Stinkbos), named after the unpleasant smell of the flowers, of which only very old individuals are to be found. The grazing-resistant *Rhigozum trichotomum* (Driedoring) is another characteristic shrub species, which tends to increase under high grazing pressure, but is nevertheless a valuable source of fodder within the degraded habitats. Similarly, the dwarf shrub *Monechma genistifolium* (Perdebos) is fairly abundant, but does not contribute much to the overall biomass production as it is heavily browsed. Besides *Trianthema parvifolia* and *Indigastrum argyroides*, prostrate growth forms are well represented within this community (e.g. *Limeum argute-carinatum*, *Limeum rhombifolium* and

Classification table (continued)

Column		Cover	All	1	2
Number of relevés			**20**	**3**	**17**
Pnan	Catophractes alexandri	0.10	30	.	35
H	Stipagrostis hochstetteriana	0.07	30	33	29
n.a.	Tribulus pterophorus	0.02	30	67	24
T	Anticharis senegalensis	0.01	25	33	24
Cmic	Limeum aethiopicum	0.01	25	33	24
Pmic	Maerua schinzii	0.12	20	.	24
Pnan	Commiphora pyracanthoides	0.11	20	.	24
T	Setaria verticillata	0.06	20	33	18
T	Enneapogon scaber	0.02	20	.	24
H	Leucophrys mesocoma	0.02	20	33	18
Pnan	Hibiscus elliottiae	0.11	15	.	18
n.a.	Geigeria pilifera	0.03	15	.	18
Cnan	Aptosimum spinescens	0.02	15	.	18
T	Monsonia umbellata	0.01	15	.	18
G	Cucumis sagittatus	0.01	15	.	18
T	Sesamum triphyllum	0.01	15	.	18
H	Stipagrostis ciliata	0.01	15	33	12

**classification is based on data also including relevés outside the Observatory*

Unit 2. Photo: N. Dreber.

Tribulus pterophorus), which form dense carpets on the otherwise completely bare soil surface during years of good rainfall. Denser stands of the woody forb *Tephrosia dregeana*, which is well utilised by goats, typically occur along small sandy-textured drainage lines.

The *Kissenia capensis-Tetragonia schenckii* community (unit 2) encompasses vegetation of the remaining, stonier or sandier parts of the catchment area, as well as of rocky outcrops and degraded washes. On sandier ground, the shrub *Phaeoptilum spinosum* (Brosdoring), which provides palatable fruits, and the woody forb *Lophiocarpus polystachyus* (Sandaarbossie) are prominent. The palatable shrub *Tetragonia schenckii* (Kooibos) forms locally dominant stands and often occurs along larger washes. This plant is typically found growing densely in brackish places, although this is not the case on the Observatory. The sub-shrub *Kissenia capensis,* with its characteristic white bark and sticky leaves, is also frequently found on sandy-textured soils on the plains, but also grows in loamy-stony soils and on outcrop slopes. A variety of characteristic species, which are absent or less abundant than in unit 1, occur within this community due to the abundance of shallow soils (see Photo). These include the shrubby *Catophractes alexandri* (Gabbabos) and *Hibiscus elliottiae*, the dwarf-shrubs *Indigofera pechuelii* and *Limeum aethiopicum*, and the valuable climax grasses *Enneapogon desvauxii* (Agtdaegras), *Enneapogon scaber* (Klipgras) and *Leucophrys mesocoma* (Withaargras). The yellow flowering *Aizoanthemum dinteri*, one of the few representatives of the Aizoaceae family in the area, is also prominent. This prostrate annual often grows together with dwarf-shrubs of the genus *Salsola* (Ganna), which are locally abundant and may indicate patches of saline soils.

Responsible authors: N. Dreber & J. Luther-Mosebach

Limeum argute-carinatum. Photo: N. Dreber.

Peliostomum leucorrhizum. Photo: Dreber.

Sesuvium sesuvioides. Photo: N. Dreber.

Tetragonia schenckii. Photo: N. Dreber.

Peliostomum leucorrhizum. Photo: N. Dreber.

Sisyndite spartea. Photo: N. Dreber.

Termites

Taxon richness	Abundance index	Dominant (sub-)family
3	12	Rhinotermitidae

The "sand termite" *Psammotermes allocerus* occurs most frequently at this Observatory. *P. allocerus* is the only species of this genus occurring in southern Africa. It is widespread along the BIOTA Southern Africa transects, except in the southernmost parts and the Thornbush Savanna in Namibia. This species is one of the few species that is able to thrive in the drier parts of Namibia, as demonstrated by its occurrence along the west-east transect through the Namib Desert. *P. allocerus* was collected mainly on baits. This species is able to build its nests without association to structures such as tree stumps in the soil. The upper parts of the nests sometimes become exposed by wind erosion.

List of taxa

Taxon	(Sub-)family	Frequency Index	Feeding substrate
Psammotermes allocerus	Rhinotermitidae	0.18	w, d
Hodotermes mossambicus	Hodotermitidae	r	g
Baucaliotermes hainesi	Termitidae (Nasutitermitinae)	r	s, w, g, l, m

Responsible authors: C. Grohmann & K.E. Linsenmair

True bugs

Sampling period(s)	Methods	Family richness
2001/IV; 2002/II, III, IV, X; 2003/V, XIII, X	Trapping (light, pitfall traps)	12
Species richness	**Individuals sampled**	**Fisher's alpha diversity**
23	183	6.95

The species diversity at the BIOTA Observatory Nabaos (S11) is much lower than in the neighbouring Observatory Gellap Ost (S10). Only one third of the species from Gellap Ost were recorded at Nabaos due to degradation of vegetation caused by grazing impacts. Nearly 70% of all specimens from pitfall traps were *Leptodemus irroratus* (Oxycarenidae), which are also common at Gellap Ost (S10), Koeroegap Vlakte (S18), Numees (S20), and Groot Derm (S21). Altogether, six species were collected in pitfall traps. The light trap attracted only five species of water bugs, which were also observed in the artificial water reservoir at Gellap Ost (S10). One *Micrometacanthus* sp. (Berytidae) was recorded exclusively at this Observatory and at Gellap Ost (S10) and Karios (S12), which are all located within the Nama Karoo Biome.

Species richness in families

Family	*S*
Lygaeidae	4
Miridae	3
Tingidae	3
Alydidae	2
Notonectidae	2
Oxycarenidae	2
Rhopalidae	2
Corixidae	1
Micronectidae	1
Reduviidae	1
Thaumastellidae	1
Berytidae	1
Total	**23**

Species abundances

Light traps

Species	Family	*N*	%
Sigara meridionalis	Corixidae	87	70
Micronecta spec.	Micronectidae	34	27
Anisops varius	Notonectidae	2	2
Anisops debilis	Notonectidae	1	1
Total		**124**	**100**

Pitfall traps

Species	Family	*N*	%
Leptodemus irroratus	Oxycarenidae	22	69
Miridae spec.	Miridae	6	19
Thaumastella namaquensis	Thaumastellidae	1	3
Rhopalidae spec.	Rhopalidae	1	3
Haemobaphus concinnus	Lygaeidae	1	3
Rhaphidosoma spec.	Reduviidae	1	3
Total		**32**	**100**

Responsible author: J. Deckert

Vertebrates

Total species richness	Reptile species richness	Bird species richness
25	1	13
Large mammal species richness	**Small mammal species richness**	
4	7	

Large mammals

Carnivora	**Carnivores**
Cynictis penicillata	Yellow mongoose
Ictonyx striatus	Striped polecat
Lagomorpha	**Lagomorphs, rabbits**
Lepus sp.	Hare
Artiodactyla	**Even-toed ungulates**
Raphicerus campestris	Steenbok

Reptiles

Squamata	**Lizards and snakes**
Bitis arietans	Puff adder

Puff adder (*Bitis arietans*). Photo: J. Deckert.

Small mammals

Macroscelidea	**Elephant shrews**
Elephantulus intufi	Bushveld elephant shrew
Rodentia	**Rodents**
Desmodillus auricularis	Cape short-tailed gerbil
Gerbillurus paeba	Hairy-footed gerbil
Gerbillurus vallinus	Bushy-tailed hairy-footed gerbil
Micaelamys namaquensis	Namaqua micaelamys
Rhabdomys pumilio	Xeric four-striped grass rat
Saccostomus campestris	Southern African pouched mouse

Yellow Mongoose (*Cynictis penicillata*). Photo: J. Deckert.

Birds

Passeriformes	**Perching birds**
Calandrella cinerea	Red-capped Lark
Parisoma subcaeruleum	Chestnut-vented Tit-Babbler
Lamprotornis nitens	Cape Glossy Starling
Prinia flavicans	Black-chested Prinia
Cercomela familiaris	Familiar chat
Eremomela icteropygialis	Yellow-bellied eremomela
Philetairus socius	Sociable weaver
Gruiformes	**Cranes, rails, coots, and allies**
Ardeotis kori	Kori bustard
Accipitriformes	**Birds of prey**
Melierax canorus	Pale chanting Goshawk
Terathopius ecaudatus	Bateleur
Columbiformes	**Doves and pigeons**
Oena capensis	Namaqua Dove
Pteroclidiformes	**Sandgrouse**
Pterocles namaqua	Namaqua Sandgrouse
Piciformes	**Woodpeckers and relatives**
Tricholaema leucomelas	Acacia Pied Barbet

Kori bustard (*Ardeotis kori*). Photo: J. Deckert.

Responsible authors: J. Deckert, A. Hoffmann & A. Mills

The people

Study period	Size of study area	Population in study area
2005–2008	126 km²	79
Population density	**Number of households**	**Mean household size**
0.63 inhabitant per km²	27	5.4 people
Mean age of farmers	**Education of farmers**	**Ethnicity of farm owners**
50 (35–62) years	5.5 (3–8) years	Predominantly Nama
Ethnicity of farm workers	**Fertility**	**Employment**
Nama, San	3 children per household	38%
Main sources of income	**Markets**	**Female headed households**
Wage labour, pensions and livestock	Speculators, local auctions for those who have transport means, Keetmanshoop, AGRA Co-operative Namibia for goats	33%

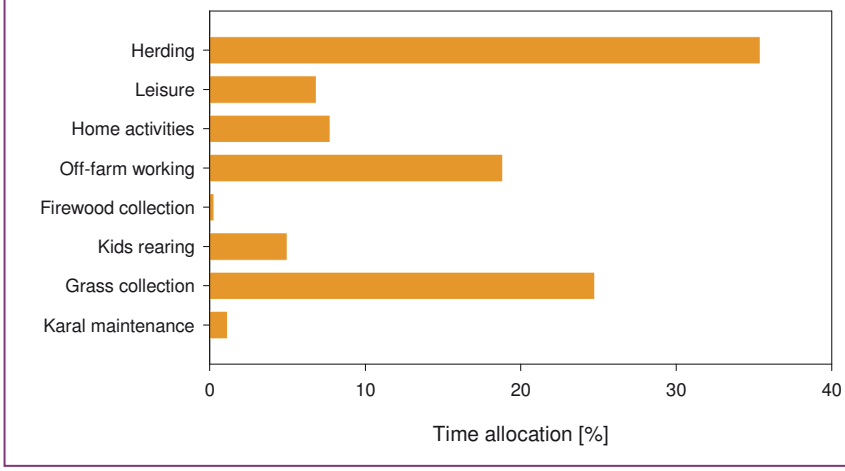


Fig. 11.1: Time allocated by farmers to different activities as a percentage of total active hours per household (T. Gibreel 2009).

The Nabaos Observatory is located on the Nabaos communal lands, about one kilometre east of the Nuwefontein settlement. The inhabitants of this settlement belong to the Nama tribe. Farmers from the community mainly keep goats and sheep, as well as donkeys, which are used for transportation. Goats are a vital source of income for the people of Nuwefontein. Descriptive analysis results of a survey conducted in 2009 showed that all households sold goats at the markets. The number of goats sold at markets amounts to an annual average of 55 per cent of the average goat herd size, and the number of goats slaughtered for home consumption is an average of 8% of the average goat herd size. Those goats not sold or slaughtered (33% of the herd size) are kept for herding.

Demographic characteristics

The average household size is five persons, which typically consists of the parents, two children and an aged person. The average age of household heads is 51 years for men and 45 years for women. Due to high unemployment rates in the area, older members of the community rely heavily on the natural woody vegetation on the communal lands. They regularly collect firewood for home consumption needs (27.3 kg·day^{-1} on average) as well as for generating cash income by selling firewood in the nearby city of Keetmanshoop. About 67% of communal households around the Observatory were found to be headed by males while the rest were female headed households.

The socio-cultural, institutional, and economic background

Access to the grazing land is granted by the commonage management committee and the municipality. The local municipality has set limitations on individual livestock ownership to 200 small stock units and collects a minimal grazing fee per livestock unit (Vollan 2008). New citizens are only allowed to use the grazing resource after 10 years of residence. Informal rules among community members that determine grazing areas and the location of water points during dry periods are well known. Regulations to avoid overutilisation of the pastoral resources have been put in place but are not enforced.

Goats are a vital component of the economy in the Namaland communal areas, including Nuwefontein. Gross household income of the communities surrounding the Observatory comes from state pensions (51%), followed by remittances (21%) from relatives who worked in city centres or abroad, whereas livestock sales and self-employment account for approximately 11% of the annual income, respectively. Income from employment (6%) was found to account for the smallest share in gross income. Farmers allocate most of their time to herding goats, off-farm work, grass collection, home activities, leisure time, and animal husbandry, while they spend the smallest portion of their time (3.3 [1.5–5.0] hours) collecting firewood (Fig. 11.1). This

Table 11.1: Farmer perceptions regarding the factors influencing veld quality and veld condition. Source: T. Gibreel, own data, 2009.

Influencing factors	Respondents
Positive influence on veld quality	
Sufficient rain	64.7%
Small number of livestock	35.3%
Negative influence on veld quality	
Insufficient rainfall	52.9%
High number of livestock	35.3%
High rainfall	5.9%
Changing the grazing regime	5.9%
Veld quality in the surrounding area	
Very good	29.4%
Good	52.9%
Not so good	5.9%
Very poor	11.8%

highlights the high dependency of the community on state transfers and natural rangeland resources in the Observatory area.

Biodiversity knowledge and environmental knowledge

The high grazing intensity in the area has led to a reduction in plant cover and/or shifts in the natural vegetation (e.g. bush encroachment). Reduced plant cover enhances water and wind erosion in the area. According to Vollan (2008), 51.5% of the interviewed farmers in Nuwefontein believe that they would gain additional income from livestock production if everyone would agree to reduce the number of livestock in the area. This highlights the fact that farmers are conscious that their private income is directly dependent on the actions taken by others within the community. Farmer perceptions regarding the factors influencing the quality of the veld and its conditions are shown in Table 11.1. The majority of the farmers stated that sufficient rainfall is the most important factor affecting the quality of the veld.

Responsible authors: T. Gibreel & U. Schneiderat

Landuse

Study area		
Study period	Size of study area	Recommended stocking rate
2008–2009	126 km²	10 ha·SSU^{-1}
Actual stocking rate	Mean number of farm worker households	Number of animals
8.7 ha·SSU^{-1}	3.6	Total: 242.5 LSU (109,130 kg) goats: 2,294; sheep: 225; donkeys:109; horses: 20 (2003)
Farming activities	Agricultural products	
Meat production (goat and sheep), breeding	Goat meat	

Land is tribally owned and held in trust to provide the resources for subsistence. Institutionally, the traditional authorities within Namaland have the right to allocate grazing lands and water-usage to members of the community. The grazing system in the communal area is characterised by an open access system of intensive selective breeding, which provides for the subsistence needs of community members. Goats are the dominant type of livestock around the Observatory. The Boer Goat is the breed preferred by livestock owners in the area (see below). On average, male headed households possess larger herd sizes (mean of 78 goats) than female headed households (mean of 24 goats). The average size of the grazing area per household is 466 ha (U. Schneiderat, Giessen University, unpublished data 2003).

Approximately 27 horses, 81 donkeys, 427 goats, and 222 sheep utilise the area around the Nabaos Observatory. Populations of sheep, horses, and donkeys are increasing in the area. The interviewed livestock owners mentioned that they allow their animals to roam the rangelands unattended in order to find the best resources for "fattening" (Akhtar-Schuster 2002). However, herders said they "would always try to monitor the movements of livestock".

The availability of water determines the location of stock posts. Farmers spend an average of one hour per day fetching water. There is little livestock management and the veld is continuously grazed. The stocking density is 8.2 kg/ha (U. Schneiderat, own data 2003), which is higher than the recommended stocking rate for the region (5 ha/SSU) and the stocking rate of the neighbouring Observatory (6 ha/SSU) (see Observatory S10/ Gellap Ost) (Fig. 11.2).

Newborn goat kids represents 53.6% of the total average herd size, while the purchase of new goats accounts for 10.4%, goat losses account for 4.2%, slaughtered goat for home consumption account for 6.7% and the marketed surplus is approximately 25.1%.

The importance of Boer Goats for the livelihoods of communal households

The Boer Goat was first bred in South Africa as a breed meant solely for meat production. The term "Boer" refers to the descendants of Dutch immigrants, or Boers, most of them farmers, who settled the country; thus, "Boer" Goat simply means "farmer's" goat. The Boer Goat is considered far superior to any other goat for meat production. It is known for its rapid weight gain and heavy muscling and has a high fertility. Boer Goats typically give birth to twins (Cutrer 1995). In the areas surrounding the Observatory, Boer Goats are mainly farmed to provide meat, milk and occasionally cash income. Milk and meat are both highly valued basics. Goats are the main type of livestock owned by farmers in this area (53 animals per household). Goats tend to graze more heavily than sheep (T. Gibreel, own data, 2009).

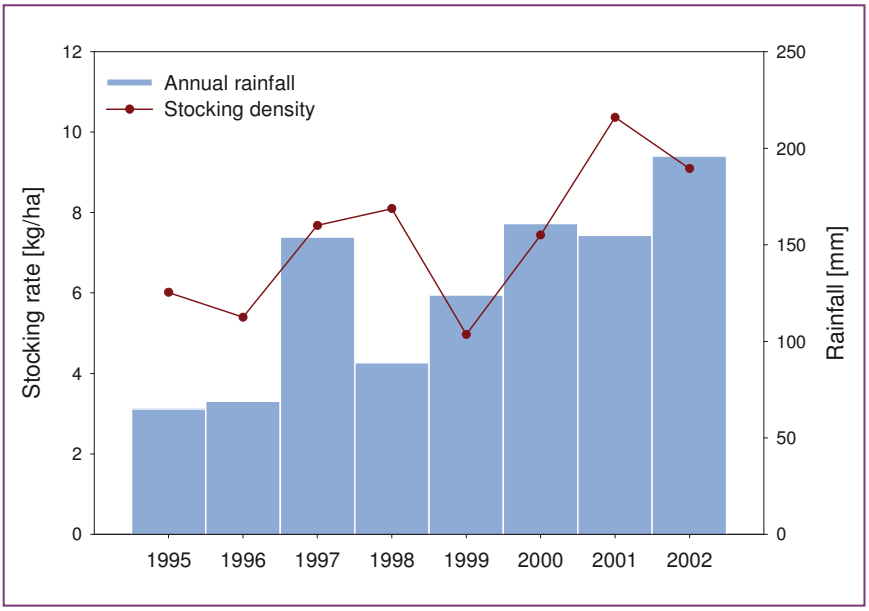


Fig. 11.2: Mean annual rainfall and stocking rates within the Nabaos-communities since 1995 (U. Schneiderat, T. Falk, and B. Bock, own data, 2001–2003).

Responsible authors: T. Gibreel & U. Schneiderat

The institutional framework guiding natural resource management of Nabaos communal farmers (S11.01)

[T. Falk]

Sustainable biodiversity management requires effective institutional incentives. Document analyses, expert interviews, and empirical surveys were applied to describe the multiple rules and norms guiding the management of communal farmers around the Observatory S11 (Nabaos).

Key results show that statutory and customary regulations exist. In particular, access to communal pastures is efficiently regulated. Nonetheless, traditional authorities are weaker in the Nabaos community compared to e.g. the Okamboro (S06) or Mutompo (S02) ones. Also, government capacities to regulate resource management are too limited. The currently implemented Rural Water Supply Reform increases incentives for sustainable ground water management. The committees established in its course extend their authority to other natural resources as well. In the large absence of statutory and traditional authorities at the local level, the newly founded committees fill institutional gaps.

Diverse rules and norms of resource use exist in the research area. In order to increase their efficiency in the interest of biodiversity maintenance and economic development a stronger integration of sectoral policies and a more polycentric governance approach is recommended.

► *See also* 'Ecological impacts of communal farming' in Subchapter IV.3.4.

Falk, T. (2008): Communal farmers' natural resource use and biodiversity preservation – A new institutional economic analysis from case studies in Namibia and South Africa. – Göttingen: Cuvillier.

Falk, T., Bock, B., Kirk, M. (2009): Polycentrism and poverty: experiences of rural water supply reform in Namibia. – Water Alternatives **2**: 115–137.

Falk, T., Vollan, B., Kirk, M. (2010): Analysis of material, social, and moral enforcement in natural resource management in southern Namibia – Paper presented at the 14th Annual Conference of The International Society for New Institutional Economics at the University of Stirling, Scotland, UK, June 17–19, 2010.

Preferences for livelihood strategies of the communal farmers in Namaland (S11.02)

[J. Bausch]

The communal farmers, who are still influenced by the effects of colonialism and apartheid, are keeping livestock in the Namaland communal area. This area is threatened by rangeland degradation. The topic of the case study was to investigate how farmers weigh the different livelihood options they have (their preferences) because it is assumed that their livelihood strategies are jointly responsible for the current state of degradation of the rangeland. Data-collection was conducted from February till April 2008 in the communal area surrounding (20 km) and including the Observatory Nabaos (S11). As methodology the conjoint analysis was used in combination with an ordinary questionnaire to improve results' accuracy. The sample included 48 farmers.

The results show that communal farmers prefer the option of animal production to ensure their daily survival, with a result from the conjoint analysis of 36.7%. The percentages reflect how important this livelihood option is in the whole strategy on average for the whole sample. This option is followed by gardening (21.2%), wage work (off-farm) (18.5%), using natural resources (14.7%), and family/leisure (8.9%). While men follow a strategy mainly based on animal production, women put more emphasis on the remaining options. This distribution resembles to the traditional gender distribution in Africa. In general, farmers having access to money (income, state pension) show lower preferences for the option of animal production and higher preferences for gardening and collecting field fruits, as compared to the group average. With the knowledge of farmers' preferences for livelihood options, farming strategies can be influenced more comprehensively. Therefore, this case study makes a contribution towards the reduction of degradation in the communal area.

Bausch, J. (2009): Präferenzmessung zur Lebensunterhaltssicherung von Pastoralisten mit Hilfe der Conjoint-Analyse – Fallstudie in der Karas Region, Namibia. – Masters thesis. Gießen: Justus-Liebig University Gießen.

Evaluating methods for soil seed bank quantification in arid grazing lands of Namibia

► *See* **S10.01**

Spatio-temporal seed bank dynamics in a degraded vs. non-degraded rangeland in southern Namibia

► *See* **S10.02**

Floristic similarity of soil seed banks over microsites and grazing intensities in arid Namibia

► *See* **S10.03**

Classification of the Nama Karoo vegetation in south-central Namibia

► *See* **S10.04**

Small mammals on Gellap Ost and Nabaos

► *See* **S10.08**

Analysis of Nama Karoo soils using LANDSAT satellite data

► *See* **S10.10**

Further studies

Herpel, N. (2008): The scale-dependent variability of topsoil properties reflecting ecosystem patchiness in drylands of southern Africa. – Hamburger Bodenkundliche Arbeiten **62**: 1–299. http://www.sub.uni-hamburg.de/opus/volltexte/2008/3831/

Popp, A. (2007): An integrated modelling approach for sustainable management of semi-arid and arid rangelands. – PhD thesis in Ecology. Potsdam: University of Potsdam.

Popp, A., Blaum, N., Jeltsch, F. (2009): Eco-hydrological feedback mechanisms in arid rangelands: simulating the impacts of topography and landuse. – Basic and Applied Ecology **10**: 319–329.

Popp, A., Domptail, S., Blaum, N., Jeltsch, F. (2009a): Landuse experience does not qualify for adaptation to climate change. – Ecological Modelling **220**: 694–702.

Popp, A., Vogel, M., Blaum, N., Jeltsch, F. (2009b): Scaling up eco-hydrological processes – the role of source-sink systems in water limited landscapes. – Journal of Geophysical Research – Biogeosciences **114**: 1–10.

General data

Number	Name	Alternative name(s)
S12	Karios	Gondwana Canyon Park
Implementation	**Country**	**Province/ region**
2001	Namibia	Karas
District/ constituency	**Locality**	**Farm name**
Karas	Gondwana Cañon Park	Karios
Latitude	**Longitude**	**Altitude**
27.676516 S	17.803958 E	909 m a.s.l.
Rainfall season	**Biome**	**WWF Ecoregion**
Summer	Nama Karoo	AT1314 Nama Karoo
Agro-Ecological Zone	**Relative intensity of land use**	**Tenure**
CPL4-9	Low	Private
Type and history of landuse	**Land owner**	
Conservation area (game)	Private	

**Data of some disciplines were sampled from the supplementary Observatories 1000 m to the east (S13), south (S14) or southeast (S15) (see respective sections)*

Karios (S12)

The leaf succulent tree *Aloe dichotoma* and the poisonous stem succulent shrub *Euphorbia gregaria* are the flagship species of the Karios Observatory. Photo: J. Deckert.

The Karios Observatory is located in the Karas Region of southern Namibia, 169 km inland from the Atlantic Ocean, 18 km East of the Fish River Canyon and 77 km north-east of the closest point of the Gariep River. At an altitude of 909 m a.s.l., the landscape around the Observatory is part of the region of the African plateau, which is subject to large-scale sheet erosion caused by the Gariep River and its tributaries (particularly the Fish River and the Gamka River). The plateau of the Klein Karas Mountains attain an altitude of more than 1400 m a.s.l. just 37 km north of the Observatory. The Observatory is located on a huge tilted pediment plain which transports water and sediments from an altitude of 1280 m (13.4 km east of the Observatory) to a large riverbed at an altitude of 760 m (3.5 km west of the Observatory next to the Cañon Lodge). Most of the tilted plain is characterised by a dynamic network of many shallow washes, which frequently branch and meet. The underlying metamorphic bedrock is of Mokolian age. Small dolerite ridges are exposed to the north and south of the Observatory. These ridges are orientated in a north-south direction.

The former farm Karios is now part of the large conservation area of the Gondwana Cañon Park. Small stock farming took place until the 1990s. When Managing Director Mannfred Goldbeck and the Gondwana team developed the ecotourism infrastructure of Nature Investments Inc., all stock (with the exception

of horses around the Cañon Lodge) and fences were removed and game was successfully re-introduced. The first Black Rhinoceros (*Diceros bicornis*) were re-introduced in 2009, nearly two centuries after their extinction in this area. Kudu (*Tragelaphus strepsiceros*) and Springbok (*Antidorcas marsupialis*) regularly graze at the Observatory, and Zebra (*Equus zebra*), Gemsbok (*Oryx gazella*) and Ostrich (*Struthio camelus*) are occasionally observed in the area.

The Karios research and monitoring site is 4 km^2 in size. This is due to Mannfred Goldbeck's kind offer to establish four (partly fenced) Observatories containing different compositions of game. Therefore, the four adjacent Observatories have been surveyed and permanently marked. During the study period BIOTA's research focus shifted from basic biodiversity science aspects towards human land management. Therefore the grazing experiments were cancelled. Observatory S12 is the main Observatory at Karios, used for botanical monitoring. Additional work was also done at the supplementary Observatories S13–S15.

Vegetation change at the Observatory over the study period was notable, especially within the populations of Quiver Trees and *Euphorbia* spp. (Melkbos). Changes to the vegetation were amongst the highest recorded for any Observatories.

Responsible authors: N. Jürgens, S.-E. Kanzler & D.H. Haarmeyer

Remote sensing and landscape

Geomorphology	Geological units	Lithological units
Plains, outcrops, rivier	Namaqua Metamorphic Complex in Namaqua Metamorphic Complex and related rocks	Complex
Mean EVI	**EVI absolute range**	**Mean leaf area index**
0.103 (0.082–0.164)	0.074 (2004)–0.244 (2006)	0.30

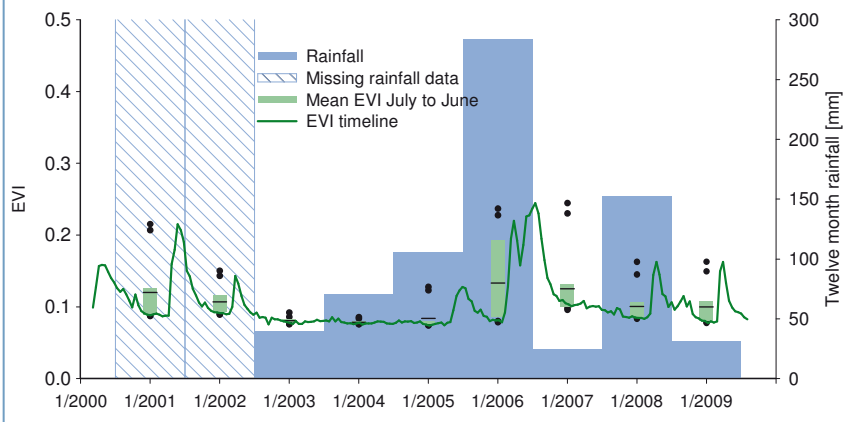
Grid map of Observatory

	0	1	2	3	4	5	6	7	8	9
0	87	23	75	89	24	70	26	5	39	11
1	50	29	81	60	37	6	10	54	76	21
2	57	32	93	8	48	83	3	27	53	13
3	55	80	84	44	72	78	47	79	35	99
4	49	71	30	34	62	42	14	65	69	33
5	64	97	7	31	58	52	59	67	88	51
6	73	77	9	19	61	90	56	28	1	40
7	91	45	22	46	43	100	92	96	95	4
8	36	66	2	85	94	82	38	20	12	86
9	18	68	63	16	41	25	15	74	17	98

1 *Euphorbia gregaria* shrubland on sandy plain
2 *Stipagrostis brevifolia* grassland on sandy plain
3 Transition between shrubland and grassland on sandy plain

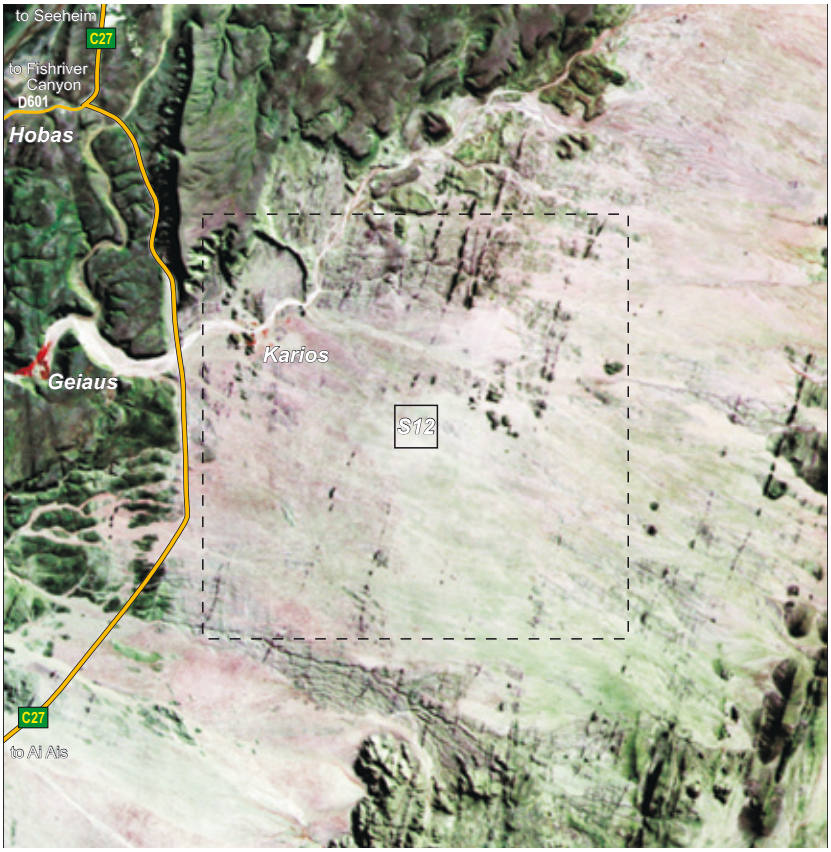
MODIS time series

Temporal patterns of annual rainfall, vegetation cover, and phenology



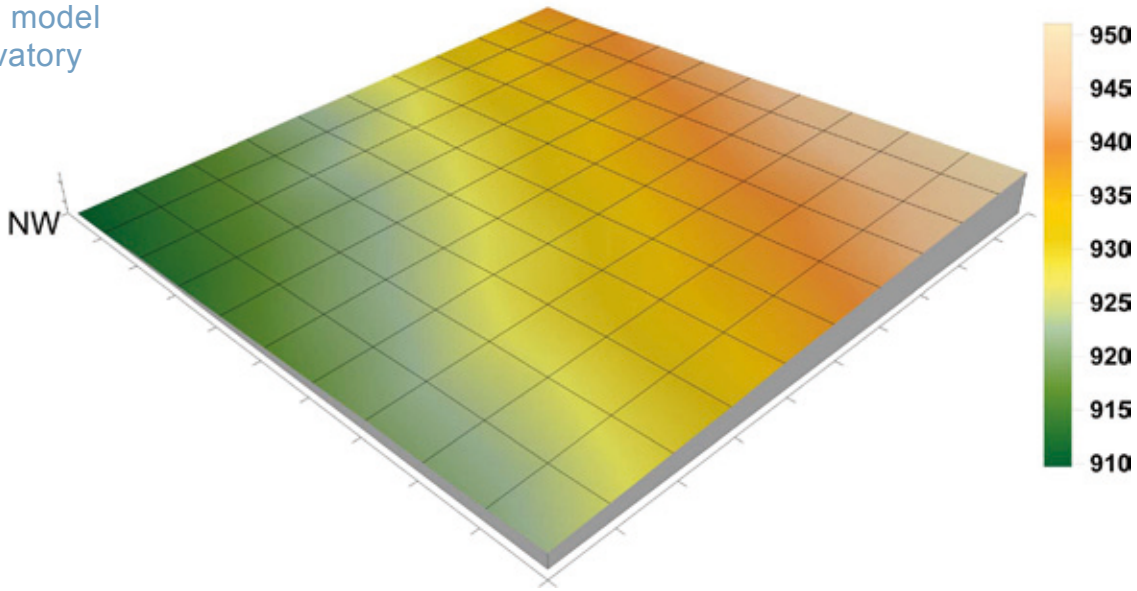
Landsat image

The Observatory of Karios is located on the sparsely vegetated plains (light pink to light grey-green) near the Fish River Canyon (outside the image, in the north-west), about 4 km south-east of a deep dissected tributary of the Fish River, which drains to the west (visible in the north-western part of the image). Dark green and dark grey colours indicate dwarf shrub vegetation and a diverse geology. A few small patches of dense woody vegetation are limited to the tributary of the Fish River (red-brown), near the Cañon Lodge.



Scene: 177/79, acquisition date: 11 May 2009

Elevation model of Observatory



Responsible authors: M. Keil & T. Labitzky

Climate

Data from BIOTA weather station

Location	Recorded period	Mean temperature
Karios (S12)	2001–2009	21.3 (1.2–42.9) °C
Mean solar radiation	**Mean wind speed**	**Mean annual precipitation**
622 (357–936) MJ·m^{-2}·month^{-1}	2.8 (7.9) m·s^{-1}	103 (35–268) mm
Mean annual potential evapotranspiration	**Interannual precipitation variability**	**Mean relative humidity**
1725 mm	189%	42% (26–63%)
Aridity index (UNEP)		
0.06 (arid)		

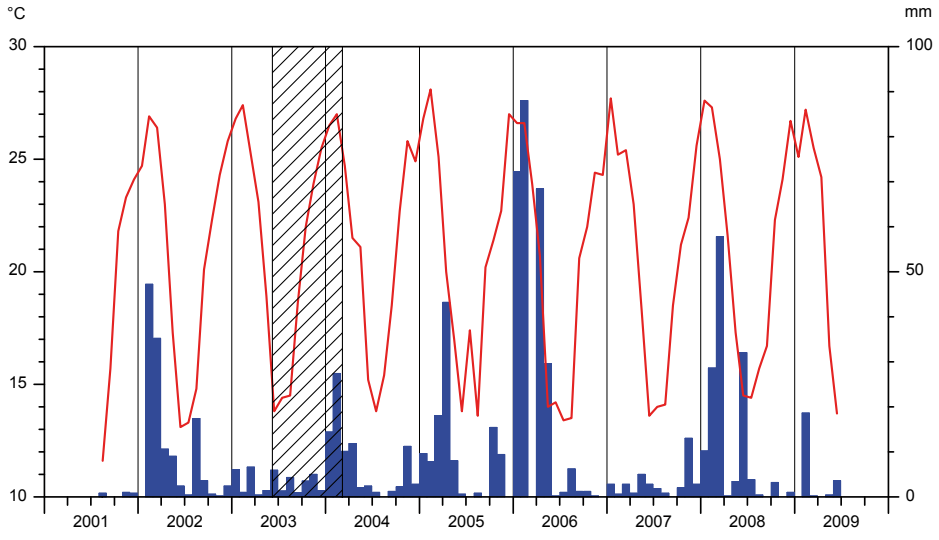
Modelled data

Mean temperature	Mean annual temperature range	Mean diurnal temperature range
19.1 (4.7–32.7) °C	12.3 °C	15.9 °C
Mean annual precipitation	**Precipitation seasonality**	**Percentage winter precipitation**
98 mm	80%	28% (summer)
Climate type	**Length of dry season**	**Aridity index (De Martonne)**
BWh	12 months	3.4 (dry)

The climate at the Observatory is characterised by arid conditions. Rainfall shows a moderate seasonality with a large portion of rain falling during the summer season, peaking in February. The mean annual rainfall over the observation period was 103 mm, which is fairly dry in comparison to the average rainfall recorded along the entire transect and within the Nama Karoo. However, substantial interannual variability is evident. The observed near-surface air temperatures show a moderate seasonal cycle. The mean annual temperature is 21.3°C and is therefore slightly warmer than the mean temperature of the Observatories within the Nama Karoo. Compared to the interpolated long-term data taken from the WorldClim dataset, a noticeably warmer mean annual temperature was observed at the BIOTA weather station. Furthermore, the station records of extreme temperatures deviate substantially from the interpolated data, showing warmer maximum and minimum temperatures. For precipitation, mean annual rainfall shows only minor differences to the WorldClim data. However, the rainfall peak observed at the station was one month earlier than in the WorldClim dataset.

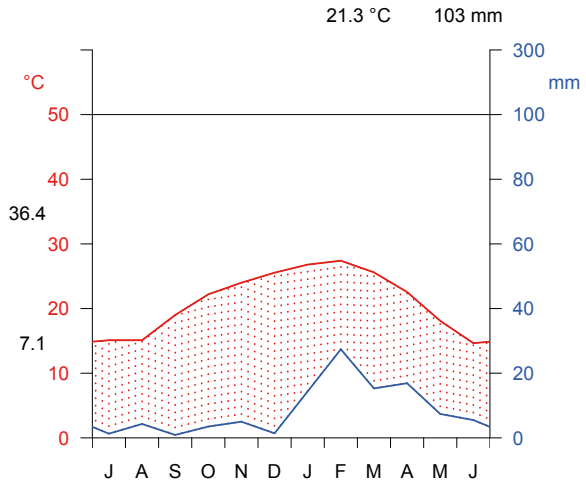
The observed near-surface winds at the Observatory are mainly constituted of south-westerly flows during spring and summer. During the autumn and winter seasons, the circulation changes to flows from northerly and north-easterly directions. Mean wind speed recorded in the evenings shows a pronounced annual cycle peaking in mid-summer. Winds observed during the mornings and early afternoons stay fairly constant throughout the year, with higher wind speeds in the early afternoons, reaching about 12 km/h.

Time series: rainfall and temperature

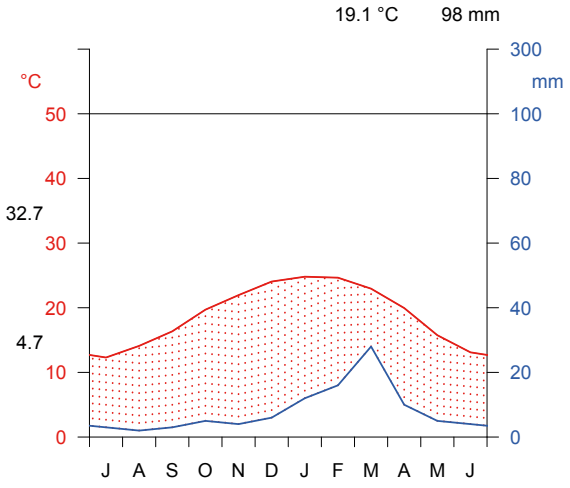


Climate diagrams

Recorded data (BIOTA)

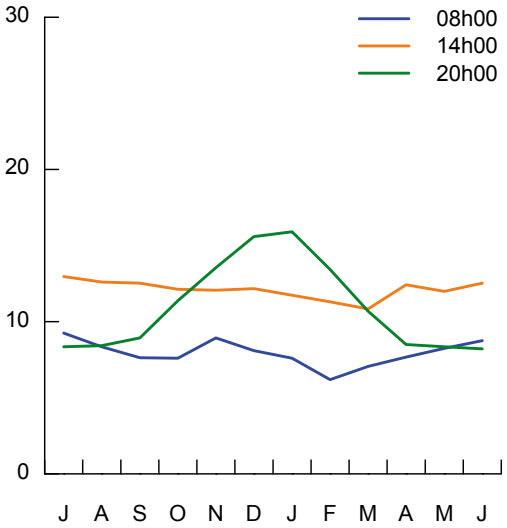


Modelled data (WorldClim)

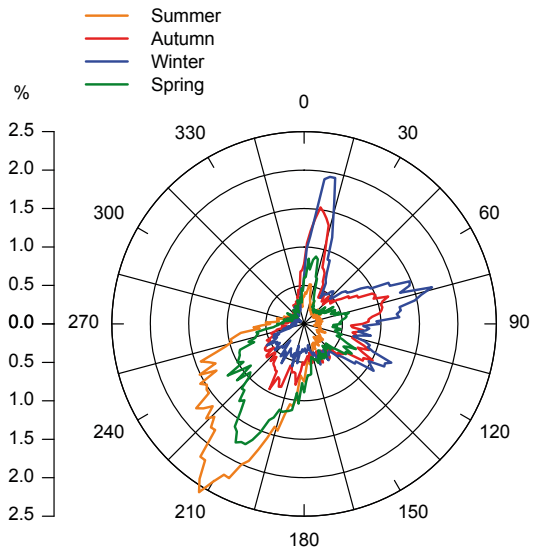


Wind diagrams

Speed



Directions



Responsible authors: K. Berger, A. Haensler & J. Luther-Mosebach

Soils

Year of sampling	Hectare plots sampled	SOTER unit
2009	25 (R1–25)	NA64
Soilscape	**Dominant soil group(s)**	**Reference group richness**
n.a.	Regosol, Arenosol	3
Soil unit richness	**Soil unit evenness**	**Soil ecotype richness**
4	0.374	n.a.
Parametric space	**pH**	**Electrical conductivity**
n.a.	8.4 (6.2–9.3)	44 (17–600) µS·cm-1
Organic carbon		
0.10% (0.06–0.28%)		

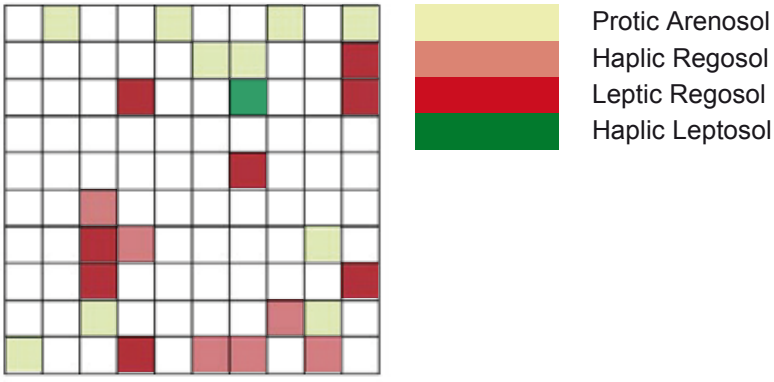
**Data derived from the supplementary Observatory 1000 m to the east (S13)*

Most of the soils on the Observatory are weakly developed Arenosols and Regosols, only in one profile adjacent to a dry river a Leptosol occurred. The Arenosols and Regosols are similar regarding their topsoil properties and are mainly subdivided by their rooting depth. Regosols occur where the soil is shallower and has a higher proportion of rock fragments than on Arenosol-sites. The fact that the underlying bedrock is very close to the surface is shown by the 'Leptic' prefix qualifier in half of the Regosols. All soils have a Hypereutric qualifier, reflecting high base-saturation and a texture composed of pure to slightly silty or loamy sand.

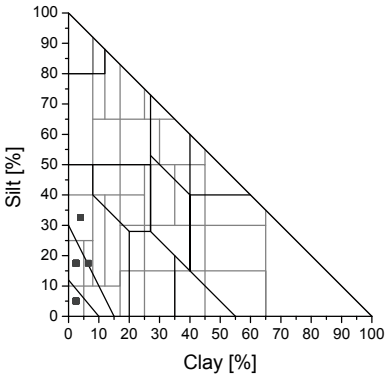
The parent material is mainly derived from weathering bedrock, which consists of metamorphic rocks underlying the soils and surfacing around the Observatory. A slight westward gradient of the area provides a constant delivery of new material from higher regions, sometimes resulting in signs of layering in the topsoil.

The high pH in the soil, ranging from 6.2 to 8.1 in the subsoil, might be a result of carbonate layers in the bedrock. The electrical conductivity follows this trend of a slight increase. The content of organic carbon is very low and nearly constant with depth, while the regularly found calcium carbonate occurring finely dispersed in patches or covering rock fragments often becomes more prominent with depth. With a median of 7, the C/N ratio is low, indicating a high degree of humification. The variability of most soil properties is low, underlining that the soils are weakly developed in a homogenous substrate. They are mainly differentiated by their content of calcium carbonate and rock fragments or the depth of the bedrock respectively.

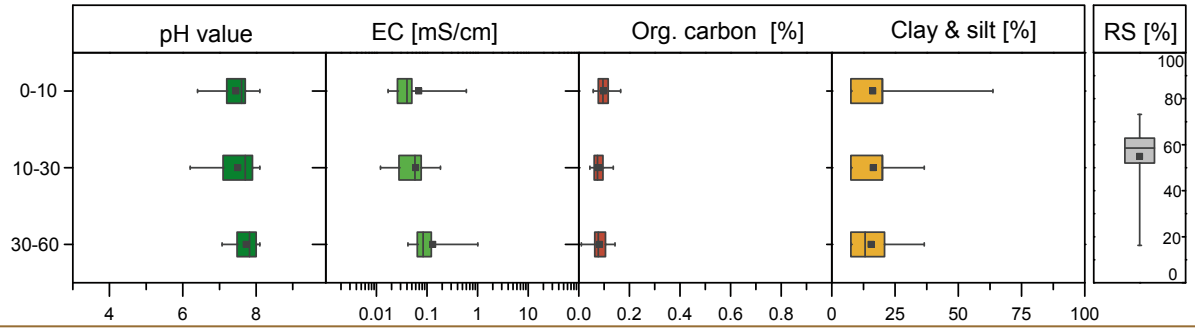
Map of soil profiles



Soil texture triangle

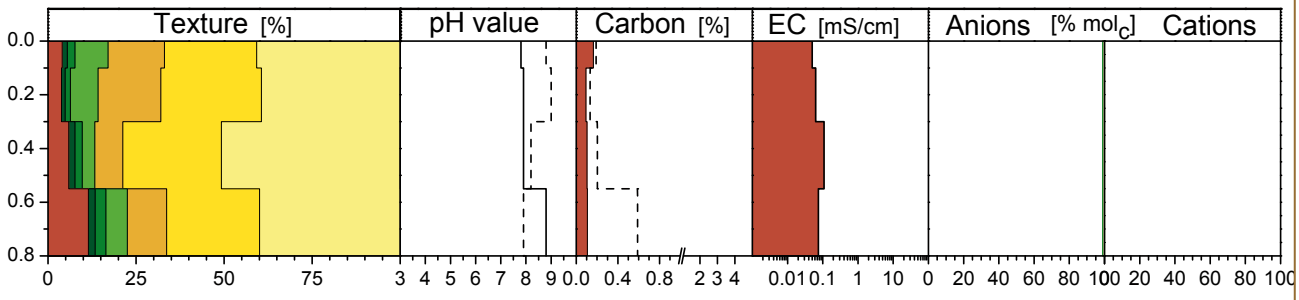


Soil characteristics



Reference profile (H63)

This **Leptic Regosol (Hypereutric)** is a typical example of soils of this Observatory. The texture is mainly sand and loamy sand. The content of rock fragments increases from approx. 10% to 40% of the volume in the subsoil. The soil structure is mainly single grain, but below 55 cm it is cemented by calcium carbonate, which in combination with the rock fragments results in a high excavation difficulty at this depth. The pH is alkaline in all layers and the electric conductivity is low. While the organic carbon content is constantly low in all layers, the content of inorganic carbon increases with depth, presumably due to elution by draining water into deeper layers. Rooting intensity is low (about 20 roots dm^{-2}), but roots reach deep into the subsoil with still 6–20 roots dm^{-2} at a depth of 80 cm.



Texture

- Fine silt
- Medium silt
- Coarse silt
- Clay
- Fine sand
- Medium sand
- Coarse sand

- pH ($CaCl_2$)
- pH (H_2O)
- Organic carbon
- Inorganic carbon
- Electrical conductivity

Water soluble ions

- Cloride
- Sulfate
- Nitrate
- Hydrocarbonate
- Fluoride, Bromide, Nitrite
- Calcium
- Magnesium
- Potassium
- Sodium

Responsible authors: U. Wisch, A. Petersen, A. Gröngröft & D. Mager

Biological soil crusts*

Sampling period(s)	Hectare plots sampled	Types of soil crusts
2002	4 (S12:H68, S13:H78; S14:H93; S15:H63)	1
Crust thickness	**Cover**	**Carbon [weight %]**
< 3 mm	up to 3%	2.650
Nitrogen [weight %]	**Chlorophyll *a* [mg/m²]**	**Chlorophyll *a+b* [mg/m²]**
0.009	9	10

**Data derived from the R1 plots of the four adjacent Observatories (S12, S13, S14, S15) and apply to an area of 4 km²*

On all four Observatories at Karios, the percentage cover of biological soil crust is low, and only initial stages are observed, since the crusts are outcompeted by the dense grass layer. The sparse crust occurrence is related to a very low biomass content (measured as chlorophyll) and species richness.

Cyanobacteria
Leptolyngbya foveolarum
Leptolyngbya sp.
Phormidium cf. *aerugineo-caeruleum*
Pseudanabaena cf. *starmachii*

Green algae
Chlorella sp. 1
Klebsormidium cf. *flaccidum*
Neochlorosarcina negevensis
Neospongiococcum cf. *punctatum*

Biological soil crust characteristics

	Obs S12 H68	Obs S13 H78	Obs S14 H93	Obs S15 H63
Soil characteristics	Reddish-brown fine to coarse sand, many fine pebbles; with gypsum	Reddish-brown fine sand, many fine pebbles; with gypsum	Light brown sand, many stones and small pebbles	Brown-red sand, many small pebbles
Crust characteristics	Few small pieces with light surface colour; mostly abiotic crust	Few small pieces with light surface colour; mostly abiotic crust	Few pieces of light BSC	Few small pieces with light surface colour; mostly abiotic crust
Chlorophyll a [mg/m²]	-	0.51	17.72	-
Chlorophyll a+b [mg/m²]	-	0.97	18.92	-
Carbon [weight %]	-	-	2.65	-
Nitrogen [weight %]	-	-	0.01	-

Responsible authors: B. Weber, K. Deutschewitz, S. Dojani, T. Friedl, T. Darienko, K. Mohr & B. Büdel

Lichens*

Sampling period(s)	Hectare plots sampled	Cover
2001, 2004	10 (R1−R10)	0%
Total species richness	**Species richness on soil [1 km²]**	**Species richness on rock [1 km²]**
4	0	4 (100%)
Species richness on plants [1 km²]	**Species richness on soil [1000 cm²]**	
0	0	

**Data derived from the supplementary Observatory 1000 m to the east (S13)*

This Observatory is very poor in lichen species because of the unfavourable climate, characterised by high mean temperatures, low rainfall, and very low air humidity. A few lichens were collected on rocks. Cyanolichens (*Peccania* sp., *Peltula obscurans* var. *hassei*) and the green algal genus Acarospora grow on granite, while endolithic lichens (*Polysporina* cf. *urceolata*) are found on calcareous stones. A few species of non-lichenised fungi grow on leaf succulent shrubs, but no lichens occur on these plants. No soil-inhabiting lichens were recorded in the investigated hectare plots. The absence of soil lichens seems to be mainly due to climatic conditions, as soil characteristics (e.g. high pH) appear to be potentially suitable for lichen growth.

List of Taxa

Terricolous (on soil):

No records

Saxicolous (on rock):

Acarospora sp.
Peccania sp.
Peltula obscurans var. hassei
Polysporina cf. urceolata (endolithic)

Epiphytic (on plants):

No records

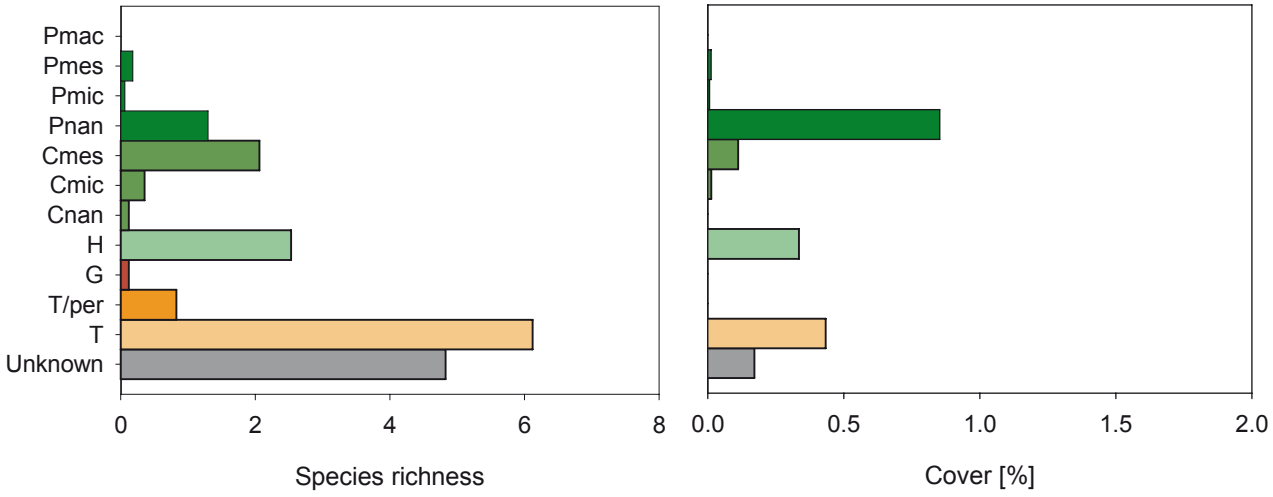
Peltula obscurans var. *hassei*. Photo: M. Schultz, L. Zedda & G. Rambold.

Responsible authors: L. Zedda & G. Rambold

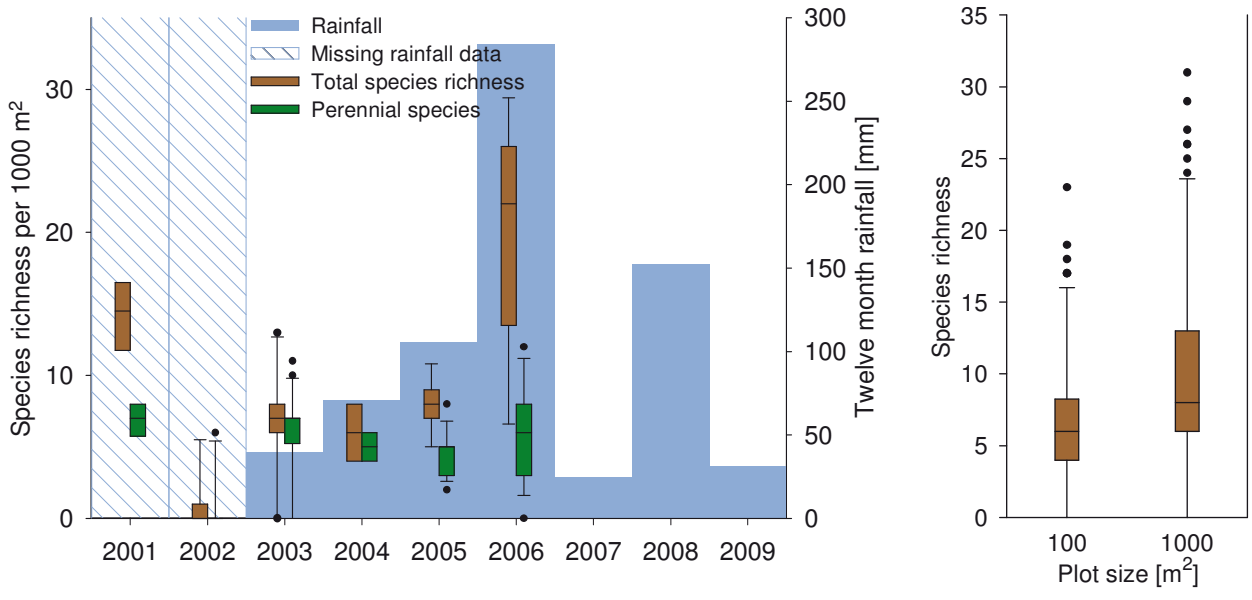
Vascular plants

Sampling period(s)	Hectare plots sampled	Biome
2001–2009	20 (R1–R20)	Nama Karoo
Vegetation unit (level 1)	**Vegetation unit (level 2)**	**Identification rate**
Dwarf Shrub Savanna	n.a.	38% – 71% – 69%
Cumulative family richness	**Dominant families (cover)**	**Dominant families (richness)**
34	Poaceae, Euphorbiaceae, Bignoniaceae	Asteraceae, Poaceae, Aizoaceae
Cumulative species richness (1 km²)	**Species richness (1000 m²)**	**Species richness (100 m²)**
237 – 186	9.9 (0–31)	6.8 (0–23)
***z*-value**	**Species richness change per year (1000 m²)**	**Evenness (1000 m²)**
0.163 (0.000–0.398)	0.86	0.512 (0.069–0.958)
Evenness (100 m²)	**Simpson (1000 m²)**	**Simpson (100 m²)**
0.569 (0.215–0.958)	0.561 (0.000–0.923)	0.539 (0.000–0.861)

Life forms



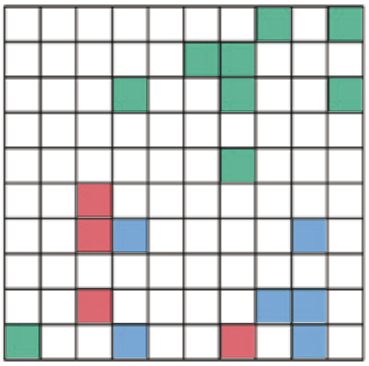
Species richness



Classification table (2009)

Column		Cover	All	1	2.1	2.2
Number of relevés			**20**	**5**	**6**	**9**
Mean cover [%]			8.4	7.9	6.9	9.7
Mean species richness (1000 m²)			10.8	9.2	8.3	13.2
Unit 1: Rhigozum trichotomum-Stipagrostis uniplumis community						
Pnan	Rhigozum trichotomum	2.19	40	100	17	22
Unit 2: Stipagrostis ciliata var. capensis-Aloe dichotoma community						
Pmes	Aloe dichotoma	0.10	40	.	50	56
H	Stipagrostis ciliata var. capensis	0.51	90	60	100	100
Unit 2.1: Stipagrostis ciliata var. capensis-Stipagrostis hochstetteriana community						
Pmic	Parkinsonia africana	0.10	25	20	67	.
H	Stipagrostis hochstetteriana	0.40	45	40	83	22
Unit 2.2: Stipagrostis ciliata var. capensis-Euphorbia gregaria community						
n.a.	Cleome foliosa var. lutea	0.10	35	.	.	78
Cmes	Galenia africana	0.10	20	.	.	44
Hper	Forsskaolea candida	0.08	20	.	.	44
Pnan	Pergularia daemia	0.10	15	.	.	33
Pnan	Kissenia capensis	0.10	15	.	.	33
T/Hper	Acanthopsis disperma	0.10	15	.	.	33
Pnan	Euphorbia gregaria	0.51	65	60	17	100
Most frequent companions						
H	Stipagrostis uniplumis	4.25	100	100	100	100
Cmes	Stipagrostis brevifolia	0.99	100	100	100	100
H	Stipagrostis obtusa	0.39	85	100	50	100
T	Schmidtia kalahariensis	0.15	85	80	83	89
T	Enneapogon cenchroides	0.10	40	60	.	56
Cmic	Aptosimum spinescens	0.10	40	40	67	22
Cmes	Salsola tuberculata	0.10	35	60	.	44
n.a.	Eriocephalus ambiguus	0.10	15	40	17	.
Cmes	Blepharis obmitrata	0.10	15	20	17	11
n.a.	Solanum rigescens	0.10	15	.	17	22
Cmes	Sarcocaulon salmoniflorum	0.10	15	.	17	22
T	Aristida parvula	2.55	10	.	.	22
T	Triraphis purpurea	1.55	10	.	.	22
Pnan	Sisyndite spartea	0.10	10	.	.	22
Pnan	Dyerophytum africanum	0.10	10	.	.	22
Pnan	Asparagus pearsonii	0.10	10	20	.	11
T	Mollugo cerviana	0.10	10	.	17	11
n.a.	Hydnora africana	0.10	5	.	.	11
n.a.	Pegolettia oxydonta	0.10	5	.	.	11
Pnan	Hermbstaedtia glauca	0.10	5	.	.	11
Cmes	Monechma spartioides	0.10	5	.	.	11
T/Hper	Tephrosia dregeana	0.10	5	.	17	.
Cmes	Lycium bosciifolium	0.10	5	20	.	.
T	Sesamum capense	0.10	5	.	.	11
Cnan	Hypertelis salsoloides var. salsolo	0.10	5	.	.	11
n.a.	Tripteris microcarpa ssp. septentri	0.10	5	.	.	11

Map of vegetation units



The vegetation of the Karios Observatory largely falls into the *Rhigozum trichotomum-Euphorbia gregaria* arid shrubland (*Euphorbia gregariae-Rhigozetum trichotomi*, Jürgens 2006), which is characterised by the combined dominance of the stem-succulent shrub *Euphorbia gregaria* (Melkbos) and the non-succulent shrub *Rhigozum trichotomum* (Driedoring). The vegetation cover is dominated by shrubs (P nan), perennial grasses (hemicryptophytes, H), and annuals (T). Species richness is higher among the dwarf shrubs (C mes) than the shrubs (P nan).

Poaceae are the most important floral element in term of cover and species richness (15 species) at the Observatory, which has a very low family richness in comparison to the other BIOTA Observatories in the Nama Karoo, as well as the Observatories for the whole of southern Africa. The Observatory, which experiences a very low annual rainfall, is generally characterised by relatively low plant diversity. Species richness (at the 100 m², 1000 m², and 1 ha scales) and the Simpson index (at the 100 m² and 1000 m² scales) are the lowest amongst the Nama Karoo Observatories and close to the values recorded for the Namib Desert Biome. Only at the Observatory scale the species richness of 115 species is above the mean value for all the Nama Karoo Observatories as well as for all the Observatories over the entire BIOTA transect. The low species richness at smaller plot-sizes results in low z-values that reflect the low β-diversity for the

transition 100 m²–1000 m². However, the above-mentioned high species richness at the Observatory-scale results in high mean *z*-values for the transition 1000 m²–1 km², which are amongst the highest values along the entire BIOTA transect.

The seemingly homogenous plain, on which the Observatory occurs, is structured into different topographies. There are (a) very flat areas, especially in the southern half of the Observatory and there are (b) areas, which are characterised by a number of dry riverbeds with intermittent terraces. These terraces are often only slightly elevated (by centimetres or decimetres) above the riverbed itself. However, some terraces rise several meters above the river. This more heterogeneous topography is well developed in the northern part of the Observatory.

Open grasslands predominantly occur on the flatter areas (a), with *Rhigozum trichotomum* shrubs occurring along drainage lines. In contrast, the heterogeneous topography type (b) is covered by an open to mid-dense shrubland dominated by *Euphorbia gregaria*, but also including other shrubs and even trees, especially the succulent Quivertree (*Aloe dichotoma*). These two main vegetation types are reflected by the three units in the vegetation table. There are two units within a grassland matrix dominated by *Stipagrostis brevifolia* (Kortblaarboesmangras) and *Stipagrostis uniplumis* (Boesmangras).

The *Rhigozum trichotomum-Stipagrostis uniplumis* community (unit 1) is characterised by open grassland with dense populations of *Rhigozum trichtomum* shrubs, which occur along the very shallow drainage lines in the flatter southern parts of the Observatory (a).

The *Stipagrostis ciliata* subsp. *capensis-Aloe dichotoma* community (unit 2) is characterised by a homogenous cover of perennial grasses such as *Stipagrostis ciliata* subsp. *capensis* and *Stipagrostis uniplumis* (dominant), interspersed by *Aloe dichotoma* trees. This community can be subdivided into two subunits. The *Stipagrostis ciliata* var. *capensis-Stipagrostis hochstetteriana* community (subunit 2.1) is essentially an open grassland with a high dominance of the grass species *Stipagrostis hochstetteriana*. Single individuals of *Aloe dichotoma* (Quivertree) and *Parkinsionia africana* also occur within this community. This unit occurs in both topographical units. The *Stipagrostis ciliata* var. *capensis-Euphorbia gregaria* community (subunit 2.2), is characterised by the sparse to mid-dense occurrence of *Euphorbia gregaria* bushes, accompanied by a few herbs, dwarf shrubs and climbers that use the larger *Euphorbia* shrubs as a protective and supporting structure (e.g. *Forsskaolea candida*). This unit occurs on the "terrace-and-riverbed" topography type in the northern parts of the Observatory (b).

This general pattern is dynamic and can change rapidly from year to year, probably mainly driven by the amount and timing of rainfall. In 2006, for example, *Stipagrostis uniplumis* was abundant in unit 1, but very sparse in unit 2, whereas this species was equally abundant in all units during 2009, as shown in the

Unit 1. A population of *Rhigozum trichotomum* next to a shallow dry riverbed. Photo: N. Jürgens.

Unit 2.1, H 68, *Stipagrostis uniplumis* and *Aptosimum spinescens*, 2009. Photo: N. Jürgens.

Unit 2.2, H 16, *Aloe dichotoma*, 2009. Photo: N. Jürgens.

vegetation table. The spatial distribution of soil water is also a strong driver of the vegetation patterns and dynamics. For example, there was a drastic die-back of the toxic shrub *Euphorbia gregaria* along the riverbeds following the extraordinarily good rainfall years since 2000. The number of individuals decreased from seven individuals in 2002 to two in 2009 at hectare H07 and from five in 2003 to only one individual in 2009 in hectare H46. Over the last decade, lines of dying or dead large *Euphorbia* bushes dominated the landscape. However, during the same time, *Euphorbia gregaria* strongly expanded its distribution by invading into the former grassland of unit 2. Both changes took place since the Gondwana Canyon Park was established and livestock was replaced by game. In conclusion, the above observation does not support the hypothesis that the occurrence of large populations of the toxic *Euphorbia gregaria* is a result of overgrazing by domestic livestock.

The often disputed hypothesis of a decline of the Quivertree *Aloe dichotoma* due to climate change is also not supported by the monitoring data. The Observatory data rather suggests very specific population dynamics, which only rarely allows the establishment of a new cohort of Quivertrees, probably at intervals of decades. After germination triggered by good rains, young plants increase in size and develop storage tissues very slowly. During this period, they remain protected within the branches of their nurse plant, the grass *Stipagrostis brevifolia.* During this phase, they are easily killed by a weevil beetle that destroys the growth point and the youngest leaves of the plants. Many plants survive by producing one to four side branches from dormant buds. Later, after having reached a critical size and stem diameter, and probably again triggered by a good rainfall year, the surviving individuals start a very rapid growth phase without branching. During this state of development, the impact caused by the weevil beetle is controlled by ant populations. These ants also depend on aphids, which colonise the leaves and young stems of *Aloe dichotoma*, feeding on the plant sap and thereby damaging the plant. These ants

Dead *Euphorbia gregaria* plant, H07, 2009. Photo: N. Jürgens.

Young *Aloe dichotoma* plant inside a *Stipagrostis brevifolia*, 2006. Photo: N. Jürgens.

also aggressively attack and eventually expel the weevil beetles from the plants. Young adults *Aloe dichotoma* plants are also often damaged by browsing animals such as Kudu. It may be due to the risk of being damaged by browsing that the young single-stemmed phase of *Aloe dichotoma* is characterised by very rapid growth. The speed of growth declines and branching commences only after the plants reach a height of more than 2 to 3 meters, finally creating the characteristic broad crown of the Quivertree. It is the abovementioned process that gives the impression that there is no recruitment within *Aloe* populations: the many young *Aloes* are hidden amidst their nurse plants and the subsequent young adult stage is merely a very brief transition period. This impression certainly strongly contributes to the opinion that there is a general lack of regeneration of Quivertree populations, which is not supported by the findings at this site.

Top: On the 21 September 2003 one young *Aloe* plant already reached a considerable height. Photo: N. Jürgens.

Left: The same plant on the 25 April 2009 is about one meter higher and did not branch. It now has attracted populations of aphids and ants, which harvest the aphids. Photo: N. Jürgens.

A weevil is feeding on young *Aloe* leaves. This beetle was responsible for the death of more than 90% of all young *Aloe* plants at the Karios Observatory. Photo: N. Jürgens.

Left: Adult Kokerbooms are protected against the weevils by ant populations. The ants very aggressively attack the weevils (Curculionidae [Brachycerinae], genus Brachycerus) when they try to climb the *Aloe* trees. Photo: N. Jürgens.

Responsible authors:
N. Jürgens, U. Schmiedel &
J. Luther-Mosebach

Millipedes

Sampling period(s)	Species richness
2001/IV	1

The undescribed millipede species *Harpagophora* sp. nov. was found to occur at this Observatory. Adults of this dark-brown species reach about 9 cm in length. This species belongs to the family Harpagaphoridae. A diagnostic characteristic of this family is the epiproct which is elongated into a spine. Harpagophoridae are generally found in arid areas such as Gobabeb in the Namib Desert.

Millipede species

Species	Family	Relative frequency	Feeding group
Harpagophora sp. nov.	Harpagaphoridae	n.a.	Litter

Responsible author: K. Vohland

Termites

Taxon richness	Abundance index	Dominant (sub-) family
4	n.a.	n.a.

According to Vohland & Deckert (2005), four taxa were encountered at this Observatory.

List of taxa

Taxon	(Sub-)family
Hodotermes mossambicus	Hodotermitidae
Psammotermes allocerus	Rhinotermitidae
Baucaliotermes	Termitidae (Nasutitermitinae)
Trinervitermes	Termitidae (Nasutitermitinae)

Responsible authors: C. Grohmann & K.E. Linsenmair

True bugs

Sampling period(s)	Methods	Family richness
2001/III, IV; 2002/IV, X; 2003/III, IX; 2007/XII; 2008/IV, XI, XII; 2009/II, III	Trapping (light, pitfall traps, Malaise); beating of plants; hand collecting	18
Species richness	**Individuals sampled**	**Fisher's alpha diversity**
74	490	24.21

Species abundances

Light traps

Species	Family	*N*	%
Macroscytus brunneus	Cydnidae	189	65
Edocla quadrimaculata	Reduviidae	15	5
Nysius spec.	Lygaeidae	12	4
Hyalochilus scudderi	Rhyparochromidae	11	4
Miridae spec. 1	Miridae	9	3
Oncylocotis nasutus	Enicocephalidae	6	2
Others (33)		50	17
Total		**292**	**100**

Pitfall traps

Species	Family	*N*	%
Macroscytus brunneus	Cydnidae	1	17
Lethaeus spec.	Rhyparochromidae	1	17
Sciocoris orbicularis	Pentatomidae	2	33
Thaumastella namaquensis	Thaumastellidae	2	33
Total		**6**	**100**

Species richness in families

Family	*S*
Miridae	23
Reduviidae	11
Pentatomidae	7
Rhyparochromidae	6
Lygaeidae	5
Alydidae	4
Rhopalidae	4
Berytidae	2
Cydnidae	2
Stenocephalidae	2
Coreidae	1
Corixidae	1
Enicocephalidae	1
Geocoridae	1
Nabidae	1
Notonectidae	1
Thaumastellidae	1
Tingidae	1
Total	**74**

Miridae, Reduviidae, and Pentatomidae make up 55% of all species at the Observatory Karios. Species numbers are about the same as in Gellap Ost (S10). About 40% of the species are identical. A notable portion of the sampled Heteroptera species (N = 30, 40%) were only recorded as a single specimens.

Macroscytus brunneus (Cydnidae) was the most frequently collected species at light traps (65%) and in pitfall traps (17%). This species is widely distributed throughout the Ethiopian Region and Oriental Region. Burrower bugs (Cydnidae) are generally known to be attracted to light in great numbers, mainly during the first hour after sunset.

Assassin bugs (Reduviidae) are well represented, with 11 species. *Edocla quadrimaculata* (Reduviidae) was subdominant at light traps. Most of the identified species collected at light traps (excluding Miridae species) are widely distributed throughout Namibia. Two specimens of *Thaumastella namaquensis* (Thaumastellidae) were collected in pitfall traps. This species was recorded at Gellap Ost (S10) and Nabaos (S11) in higher abundances.

Coponia capensis (Pentatomidae) reaches its northern distribution limit in southern Namibia. This species was formerly only known from South Africa. An undescribed species of *Aloea* (Miridae) which lives on Quiver Trees (*Aloe dichotoma*) was also recorded at the Karios Observatory.

Responsible author: J. Deckert

Butterflies and moths

Sampling period(s)	Number of samples (moths)	Species richness (total)
2001/III–IV; 2002/II; 2003/III; 2007/X–XII; 2008/IV, XII	8	80
Species richness (butterflies)	**Species richness (all moths)**	**Species richness (Microlepidoptera)**
9	71	17
Species richness (Pyraloidea)	**Species richness (Macrolepidoptera)**	**Species richness (Noctuidae)**
21	9	24
Individuals sampled (moths)	**Fisher's alpha diversity (moths)**	
2707	13.6	

**Data derive from plots located 1000 m east of the Observatory*

Butterflies

There were many visits to the Observatory but none of them coincided with the short time window after good rain, which stimulates the emergence of resident butterflies. As a consequence few butterflies were observed and most of the recorded species were strays from places outside the Observatory. The only exception is *Chilades trochylus*, a true resident, which was encountered repeatedly in different months.

Moths

In contrast to butterflies, moths are on the wing all year round. Especially the smaller Microlepidoptera have well defined flight periods and emerge independently of rain. Many ubiquitous species can be recorded during all seasons. Apart from such species, the moth assemblages are well delineated and differ considerably between spring, summer, and autumn. Among the Microlepidoptera, the spring assemblage was dominated by *Paraptica concinerata* (Tineidae) (see Photo) and *Parapsectris* sp. (Gelechiidae). They are replaced by *Ochrodia subdiminutella* (Gelechiidae) and several *Scythris* species (Scythrididae) during the summer months. In autumn the most abundant species are *Acutitornus munda* and *Pseudurgis* sp. (see Photo). The Pyraloidea are represented by the large *Namibiopsis* sp. and *Epicrosis nigrinella,* both having long flight periods (Pyralidae: Phycitinae). At least five species of *Hypotia* (Pyralidae: Pyralinae), whose larvae feed on dead organic matter, were collected at the Observatory. In autumn, *Staudingeria mimeugraphella* (Pyralidae: Phycitinae) (see Photo) becomes a dominant species together with one of the *Hypotia* species. The common and widespread *Pseudozarba schencki* (Noctuidae) and several *Centrarthra* species (Noctuidae) dominate the Macrolepidoptera assemblage.

Taxonomic spectrum of moths

Collection period: III/2003

Family	S	N
Tineidae	3	9
Scythrididae	2	3
Cosmopterigidae	3	4
Gelechiidae	8	56
Tortricidae	1	1
Microlepidoptera	**17**	**73**
Pyralidae	17	112
Crambidae	4	7
Pyraloidea	**21**	**119**
Cossidae	4	5
Sphingidae	1	3
Geometridae	3	3
Arctiidae	1	1
Noctuidae	24	2507
Macrolepidoptera	**33**	**2519**
Total	**71**	**2711**

Male of *Paraptica concinerata*.
Photo: W. Mey.

Male of *Pseudurgis* sp. Photo: W. Mey.

Female of *Staudingeria mimeugraphella*.
Photo: W. Mey.

Responsible author: W. Mey

Vertebrates

Total species richness	Reptile species richness	Bird species richness
17	n.a.	17
Large mammal species richness	**Small mammal species richness**	
n.a.	n.a.	

Large mammals

Artiodactyla	**Even-toed ungulates**
Antidorcas marsupialis	Springbok
Lagomorpha	**Lagomorphs, rabbits**
Lepus sp.	Hare
Tubulidentata	**Aardvarks**
Orycteropus afer	Aardvark

Small mammals

Rodentia	**Rodents**
Pedetes capensis	Springhare

Amphibians and Reptiles

Squamata	**Lizards and snakes**
Psammophis leightoni trinasalis	Fork-marked Sand Snake
Testudines	**Tortoises, turtles**
Geochelone pardalis	Leopard Tortoise

Leopard Tortoise (*Geochelone pardalis*). Photo: J. Deckert.

Birds

Strigiformes	**Owls**
Bubo africanus	Spotted Eagle-Owl
Passeriformes	**Perching birds**
Chersomanes albofasciata	Spike-heeled Lark
Cinnyris fuscus	Dusky Sunbird
Crithagra albogularis	White-throaded Canary
Oenanthe monticola	Mountain Wheatear
Onychognathus nabouroup	Pale-winged Starling
Passer melanurus	Cape Sparrow
Philetairus socius	Sociable Weaver
Prinia flavicans	Black-chested Prinia
Serinus albogularis	White-throated Canary
Sporopipes squamifrons	Scaly-fronted Weaver
Accipitriformes	**Birds of prey**
Circaetus pectoralis	Black-chested Snake-Eagle
Falconiformes	**Birds of prey**
Falco naumanni	Lesser Kestrel
Coliiformes	**Mousebirds**
Colius colius	White-backed Mousebird
Gruiformes	**Cranes, rails, coots, and allies**
Eupodotis rueppellii	Rueppell's Bustard
Columbiformes	**Doves and pigeons**
Oena capensis	Namaqua Dove
Pterocles bicinctus	Double-banded Sandgrouse
Streptopelia capicola	Ring-necked Dove

Rueppell's Bustard (*Eupodotis rueppellii*). Photo: J. Deckert.

Responsible authors: J. Deckert, A. Hoffmann & A. Mills

Photo: N. Jürgens

Namib Desert

Boundaries
- International Boundary
- Provincial Border

Hydrography
- River
- Periodical River
- Salt Pan
- Lake
- Wetland

Contour Levels
- up to 300 m
- up to 600 m
- up to 900 m
- up to 1200 m
- up to 1500 m
- up to 1800 m
- more than 1800 m

Communications
- Motorway
- Road
- Railway

Populated Places
- City
- Provincial Capital
- Capital

- Transect
- S32 Elandsberg — BIOTA Observatory

0 250 500 km

Uwe Ulrich Jäschke & Karen Langner • HTW - University of Applied Sciences Dresden

The open landscape of the Namib Desert. Photo: J. Deckert.

Namib Desert

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II.5.2 Kleinberg (S34) 500
II.5.3 Gobabeb (S35) 516
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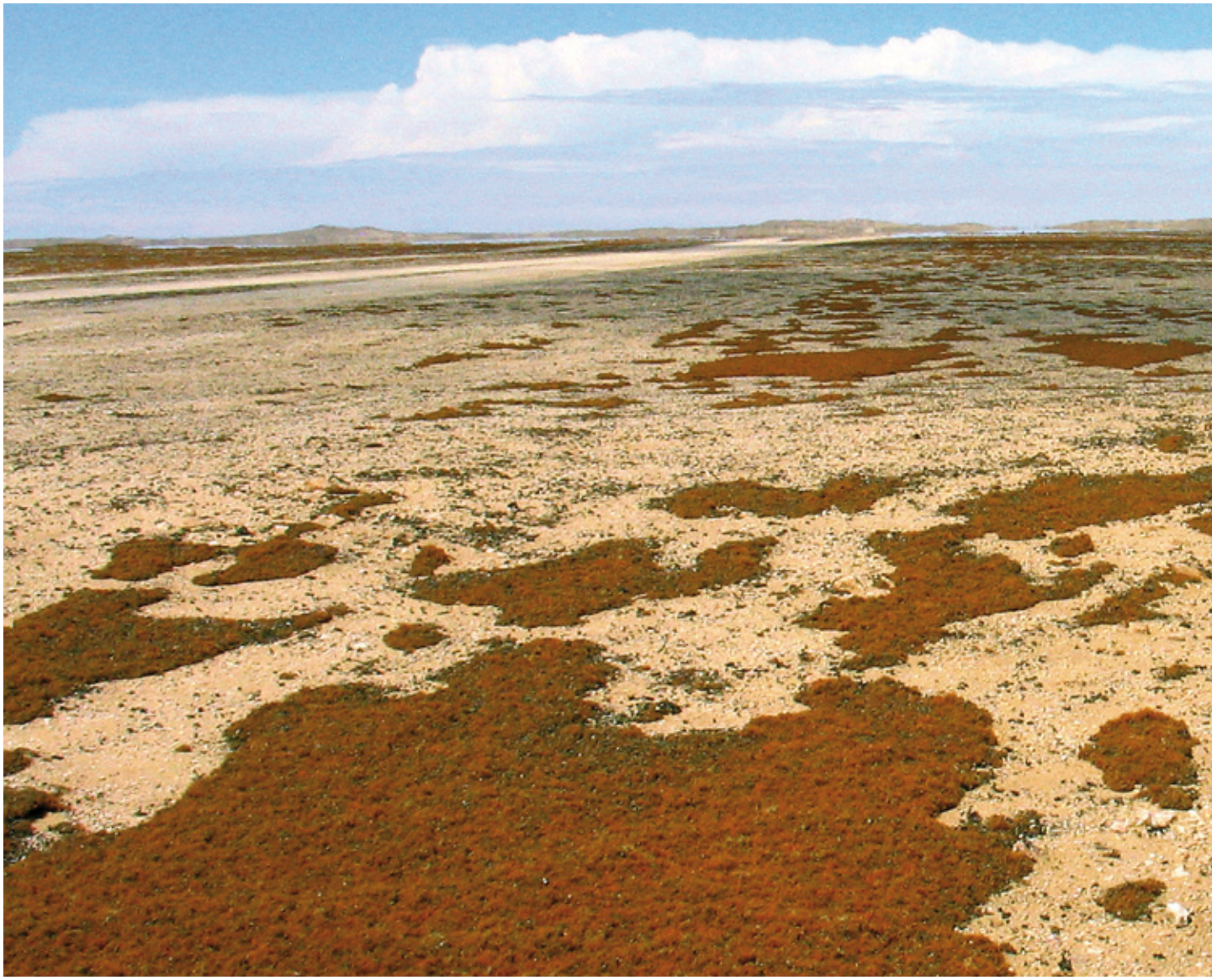
The Namib Desert Biome covers a large area of Namibia and stretches into South Africa. It is characterised by an extremely sparse cover of vascular plants, although there are high densities of lichens in certain parts where there is frequent fog occurrence. In both countries this biome has at times covered a much larger area during the history of this region and it is projected by most climate change models to undergo a rapid and large expansion within this century. While the potential expansion of deserts threatens the surrounding regions, the Namib Desert Biome itself is threatened by degradation caused by a combination of factors including a general increase of human activities in vulnerable dryland ecosystems, which is driven by rapid coastal development, the mining industry, and increasing numbers of tourists.

Four Observatories are situated in the Namib Desert Biome. They were selected to monitor the dynamics of the unique lichen fields of the Namib in terms of the impacts of human activities (e.g. off-road driving), and the impacts of climatic events (i.e. strong bergwinds) as well as long-term climatic changes. Two Observatories are very close to the coast in the Succulent Karoo vegetation type of the Namib Desert (S16 Wlotzkasbaken and S34 Kleinberg) whereas the Gobabeb Observatory (S35) and Ganab Observatory (S36) follow climatic gradients along the central Namibian west-east transect that stretches from the coastal Namib Desert to the Thornbush Savanna further inland. [U. Schmiedel]



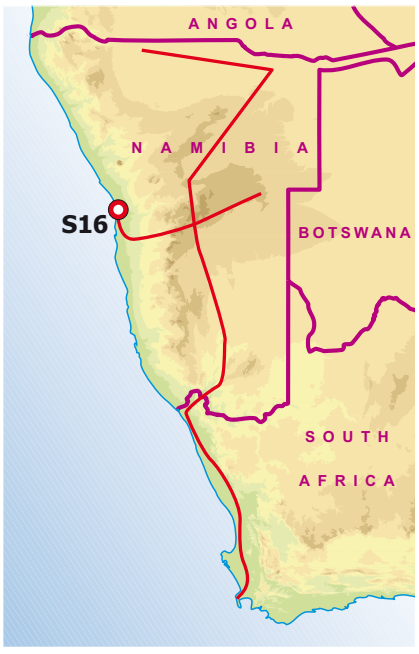
General data

Number	Name	Alternative name(s)
S16	Wlotzkasbaken	Mile 14
Implementation	Country	Province/ region
2001	Namibia	Erongo
District/ constituency	Locality	Farm name
Swakopmund	Wlotzkasbaken	Wlotzkasbaken - Mile 14
Latitude	Longitude	Altitude
22.315003 S	14.459480 E	73 m a.s.l.
Rainfall season	Biome	WWF Ecoregion
Summer	Namib Desert/ Succulent Karoo	AT1315 Namib desert
Agro-Ecological Zone	Relative intensity of land use	Tenure
NAM6	None	State
Type and history of landuse	Land owner	
Conservation area	Government of Namibia	

Wlotzkasbaken (S16)

The lichen fields of the Namib Desert are a globally unique feature. The photo shows a site with the strongest cover by the fruticose lichen *Teloschistes capensis*, damaged by a strong sand storm in 2003. The BIOTA square kilometer Observatory is located in the hilly area at left hand side, ca. 2000 m NE of the site of this photograph. Photo: N. Jürgens.

The Wlotzkasbaken Observatory is located directly between Swakopmund and Hentiesbay, 4.3 km inland from the coast of the Atlantic Ocean. It forms part of the coastal plain of the Central Namib Desert, which is tilted at an angle of 1° towards the coast. The ecology is strongly controlled by the Benguela fog belt, which provides a water source to the globally unique lichen fields occurring in this region. The underlying gneissitic or schist rock (Swakop group and Damara sequence) is often exposed and results in a slightly undulating topography. Nevertheless, most of the surface is covered by a shallow layer of fine material soil with a gravel layer at the surface. These gravel plains are interrupted by one larger and a group of smaller dolerite ridges, which run in a NE-SW direction, and one broad but flat band of quartzitic hills, which runs roughly in a N-S direction from H01 to H95. As a result of these topographical barriers, three larger rivers and many smaller washes wind their way from the NE to the SW. Gypsum crusts and related soil polygons are frequent and, along the river margins, larger blocks of gypscrete are elevated by pedoturbation (water uptake of gypsum). The climate is arid with a mean summer rainfall of 35 mm per year as measured by the BIOTA weather station at the Observatory between 2001 and 2010 (compared to a long term value of 15 mm per year recorded at Swakopmund).



The Observatory falls on state land and there is no agricultural landuse. Rec-

reational use has given rise to hundreds of offroad car tracks. The worst destruction was caused in the 1990es, when a local rally passed right through the eastern part of the Observatory. The Observatory is situated 3750 m inland from the coastal salt road and air pollution still limited. It is situated only 5000 m away from a recently built (2010) desalination plant and the new pipeline, which will transport water to the Trekkopje Uranium Mine (Areva). The Observatory allows for the monitoring of potential changes to biodiversity in the area (Jürgens 2008).

The Observatory was established primarily to monitor one landscape segment of the globally unique lichen fields of the Namib Desert. Together with Kleinberg (S34) and Gobabeb (S35), the Wlotzkasbaken Observatory facilitates the measurement of environmental changes within the Central Namib Desert. The most important change observed so far was the major destruction of the formerly much denser lichen fields by an extreme sandstorm, which approached from the east in 2003. Lichens were reduced to ca. 10% of their former density and biomass on the plains.

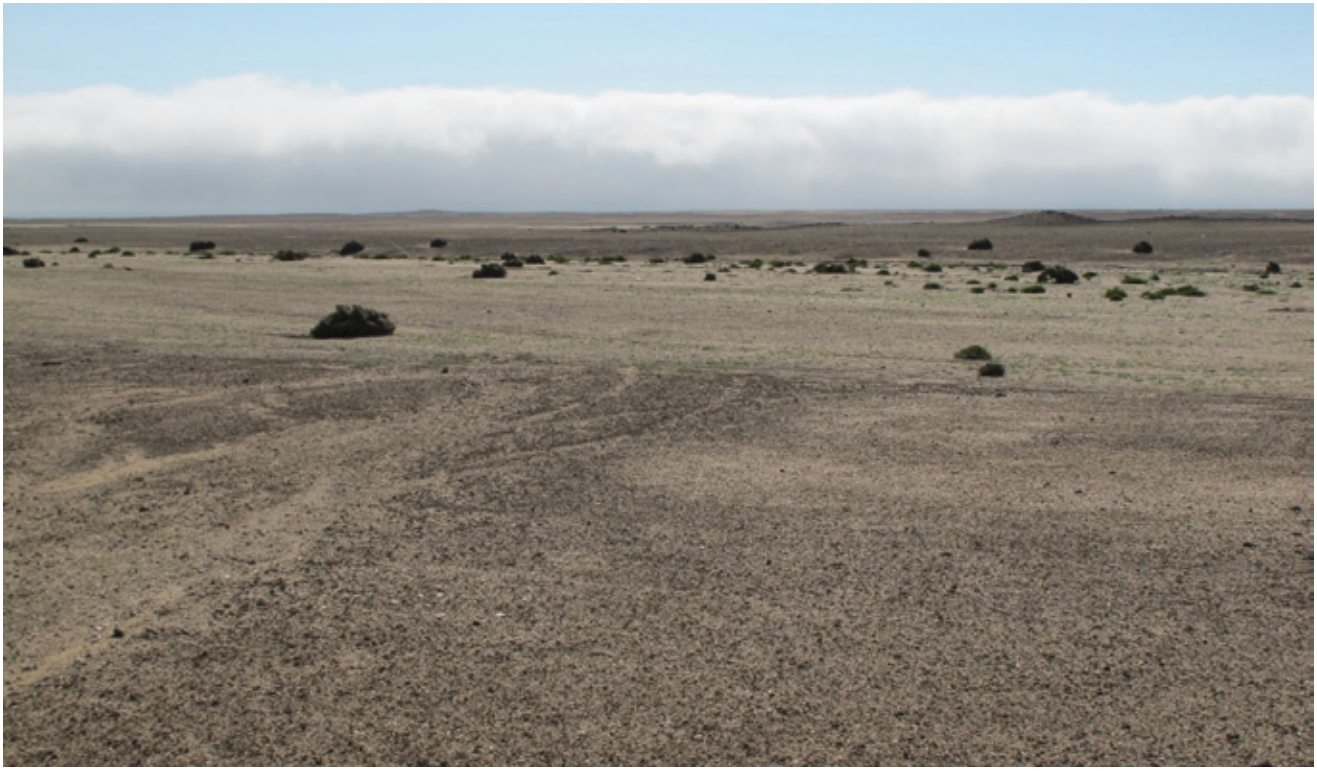
Similar to the crustose lichen fields at Kleinberg, the fields at Wlotzkasbaken should also be regarded as an indicator of environmental changes. While the lichen fields were damaged by bergwind sand storms and, to a lesser extent, by off-road driving in the past, there may be changes to the occurrence or amount of fog, or increased sand blasting due to bergwinds in the future, both due to climate change. Sulphur and other chemical emissions from the Atlantic Ocean, as well air pollution from the coastal road, desalination plant, and pipelines may also affect the lichen field.

The Observatory is dissected by dolerite ridges abundantly covered by lichen species. Most of the plains in the distance are devoid of vegetation, while many shrubs are seen along rivers and washes. Photo: N. Jürgens.

In the eastern part of the Observatory, offroad driving in the context of a rallye caused long-term damage to the lichen field. Photo: N. Jürgens.

A large pipeline has been built to transport water from the Wlotzkasbaken desalination plant to the new Trekkopje Uranium Mine (Areva). The pipeline has been moved to a more southern location in order to reduce the impact on the lichen field, as a result of the environmental impact study. Photo: N. Jürgens.

Teloschistes capensis accumulated around an *Arthraerua leubnitziae* plant after heavy berg wind. Photo: N. Jürgens.



The view towards the coast shows a large river bed with shrubs of *Arthraerua leubnitziae*. In the distance the coastal fog is present, during daytime. Photo: N. Jürgens.

Responsible authors: N. Jürgens & D.H. Haarmeyer

Remote sensing and landscape

Geomorphology	Geological units	Lithological units
Plains, accumulation and transition areas, dolerite ridge and slopes	Swakop Group in Damara Supergroup and Gariep Complex	Schists and dolomites
Mean EVI	**EVI absolute range**	**Mean leaf area index**
0.079 (0.067–0.089)	0.052 (2004)–0.098 (2006)	0.00

Grid map of Observatory

	0	1	2	3	4	5	6	7	8	9
0	60	27	89	90	53	79	17	57	46	100
1	84	45	97	1	23	71	11	92	66	50
2	77	28	13	98	44	43	70	48	72	59
3	85	37	81	32	63	9	12	86	36	15
4	18	38	6	69	30	29	10	42	58	62
5	25	34	61	78	82	47	52	8	41	74
6	91	73	54	75	21	95	64	40	26	20
7	4	96	14	2	56	93	87	51	80	67
8	94	22	5	65	55	99	7	68	33	88
9	76	16	19	83	24	3	35	39	31	49

1 Lichen field on gravel plain in coastal plain

2 Lichen field on gravel plain with wash or rivier in coastal plain

3 Lichen field on gravel plain with dolerite ridge in coastal plain

4 Lichen field on gravel plain with gentle slopes on quartzitic rock in coastal plain

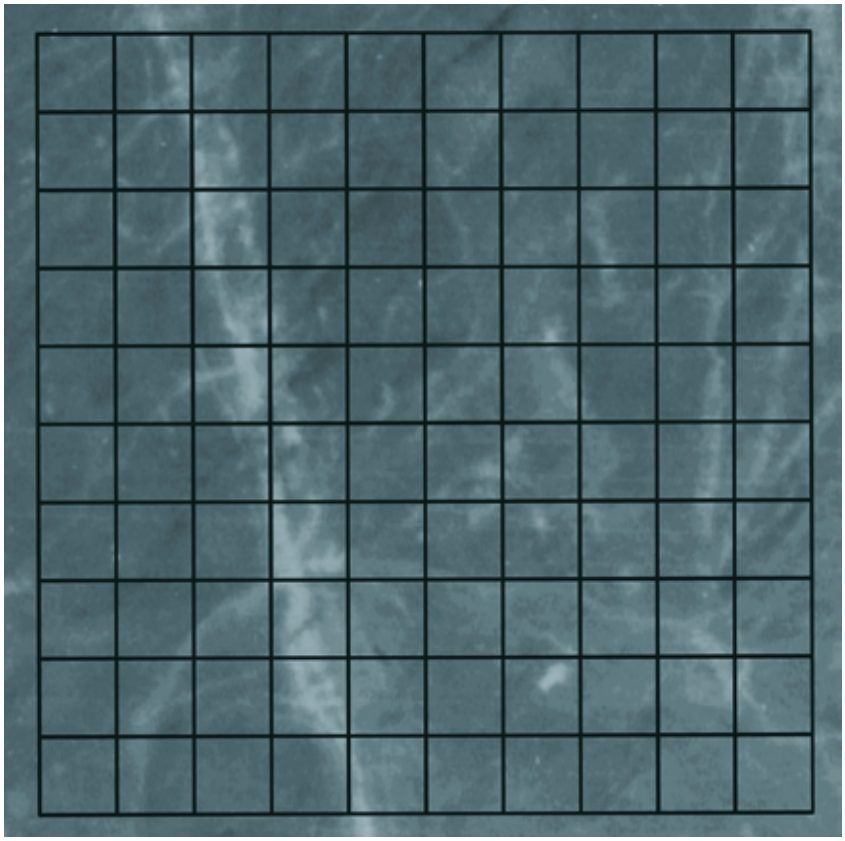
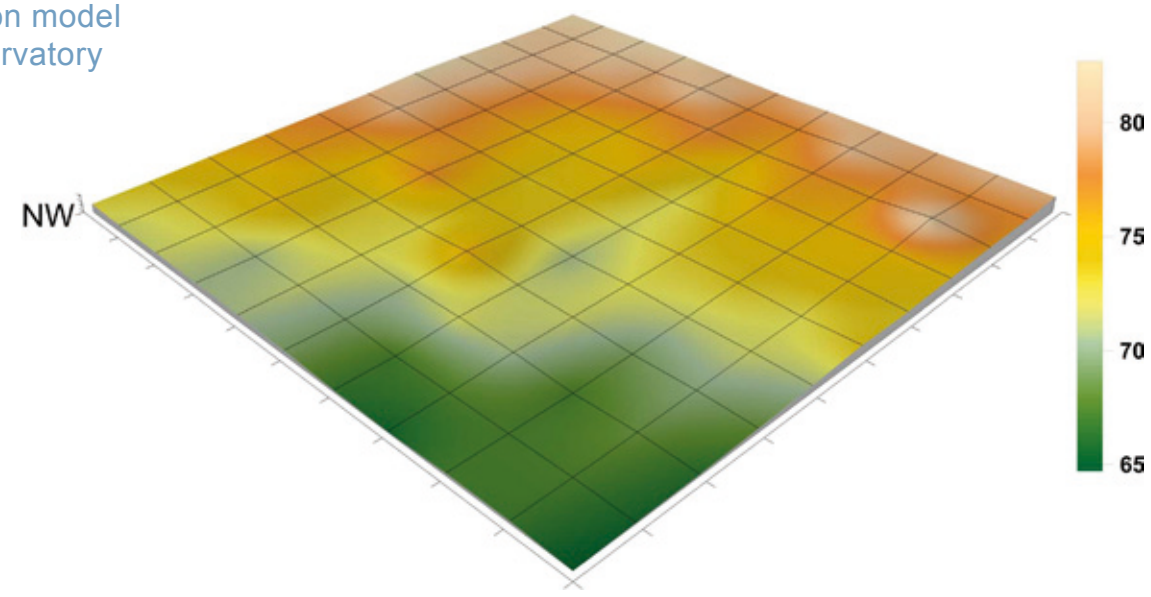


Image: aerial photograph

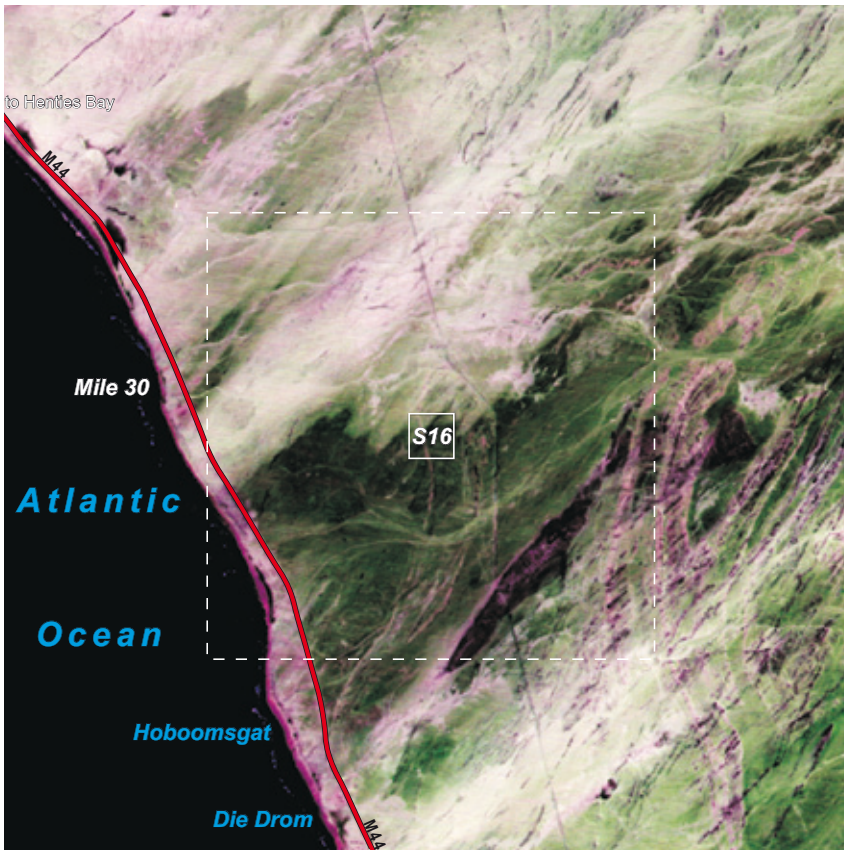
Elevation model of Observatory



Landsat image

White to bright grey colours indicate bare surfaces, underlying rocks, gravel layers, and shallow layers of fine material soil in the northern part of the image. In the south-eastern part of the image, a group of dolerite ridges can be detected by the nearly black coloured strips, which are orientated in a north-east-southwest direction. The bright band within the Observatory, running roughly in a north-south direction depicts a chain of quartzite hills.

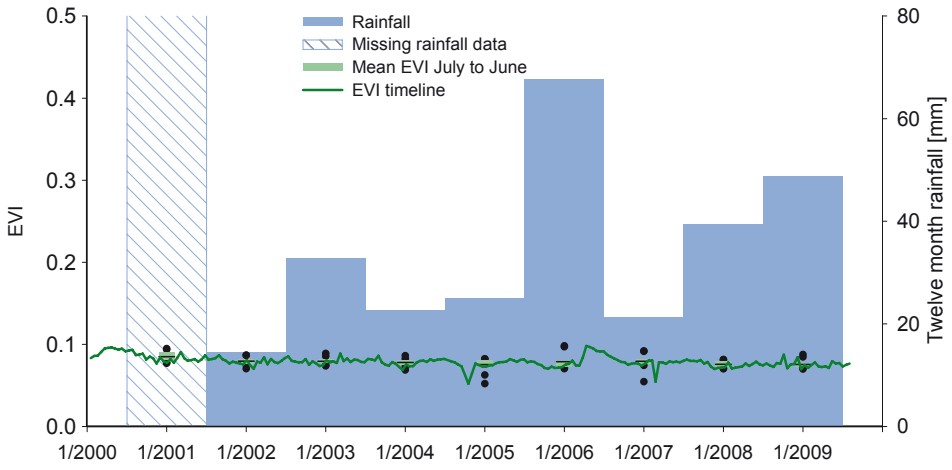
Even though there is no tall vegetation in the area, the satellite signal indicates large areas of photosynthetic activity which show up as green tones. The reason is a dense coverage of lichens on the soil-surface especially in a zone from the west to the north-east. These lichen fields cover most of the Observatory. The washes towards the ocean cut through the lichen fields and indicate natural disturbance events, e.g. rill erosion by flooding after thunderstorms.



Scene: 180/75, acquisition date: 09 August 2005

MODIS time series

Temporal patterns of annual rainfall, vegetation cover, and phenology



Responsible authors: M. Keil & T. Labitzky

Climate

Data from BIOTA weather station

Location	Recorded period	Mean temperature
Wlotzkasbaken (S16)	2001–2009	17.2 (3.3–39.7) °C
Mean solar radiation	**Mean wind speed**	**Mean annual precipitation**
581 (374–801) MJ·m^{-2}·month^{-1}	3.0 (14.4) m·s^{-1}	35 (18–69) mm
Mean annual potential evapotranspiration	**Interannual precipitation variability**	**Mean relative humidity**
1315 mm	193%	86% (25–100%)
Aridity index (UNEP)		
0.03 (hyperarid)		

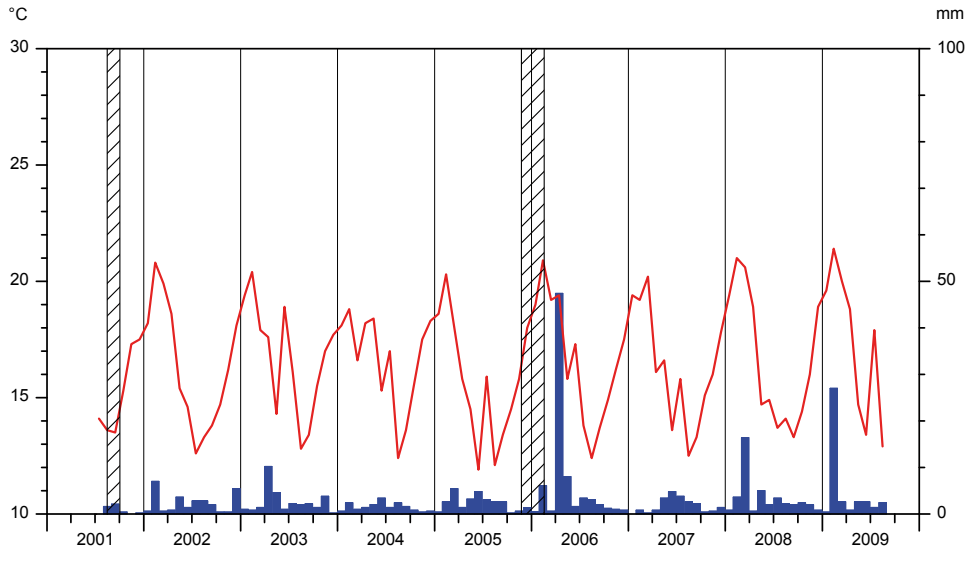
Modelled data

Mean temperature	Mean annual temperature range	Mean diurnal temperature range
16.9 (7.6–24.8) °C	5.4 °C	12.2 °C
Mean annual precipitation	**Precipitation seasonality**	**Percentage winter precipitation**
12 mm	68%	17% (strong summer)
Climate type	**Length of dry season**	**Aridity index (De Martonne)**
BWh	12 months	0.4 (dry)

The climate at the Observatory is characterised by hyper-arid conditions. Rainfall shows a weak seasonality with the major portion of rain falling between January and June. The mean annual rainfall over the observation period was 35 mm, making it one of the driest Observatories along the transects. However, substantial interannual variability is evident. It is one of the wetter Observatories within the Namib Desert because of the substantial, and ecologically important, additional water supply from coastal fog, which forms above the cold Benguela current of the Atlantic Ocean and moves inland in the early mornings. The observed near-surface air temperatures show a weak seasonal cycle. The mean annual temperature is 17.2°C and is therefore slightly lower than the mean temperature of all Observatories, and the lowest recorded for the Observatories in the Namib Desert. Compared to the interpolated long-term data taken from the WorldClim dataset, only minor differences in the near surface temperature are evident. For precipitation however, the observed mean annual rainfall at the station is almost three times higher than the WorldClim dataset.

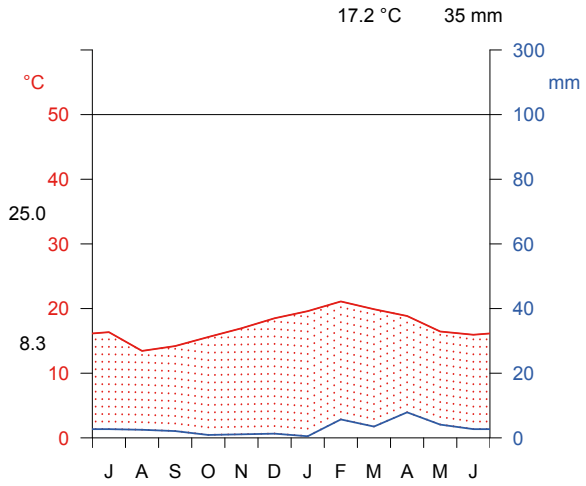
Mean wind speed is highest during the early afternoons, reaching about 18 km/h, and shows only minor variations over the course of the year.

Time series: rainfall and temperature

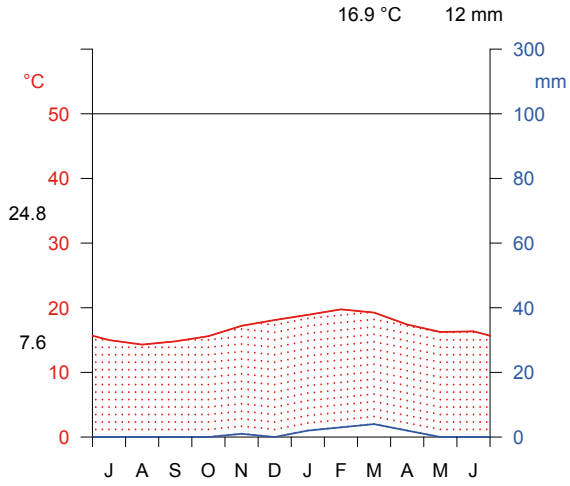


Climate diagrams

Recorded data (BIOTA)

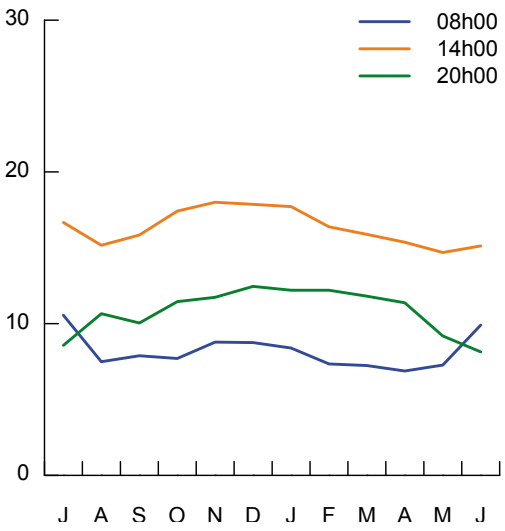


Modelled data (WorldClim)



Wind diagrams

Speed



Responsible authors: K. Berger, A. Haensler & J. Luther-Mosebach

Soils

Year of sampling	Hectare plots sampled	SOTER unit
2003	20 (R1–20)	NA44
Soilscape	**Dominant soil group(s)**	**Reference group richness**
Solonchak	Leptosol, Solonchak	3
Soil unit richness	**Soil unit evenness**	**Soil ecotype richness**
8	0.654	7
Parametric space	**pH**	**Electrical conductivity**
3.56	8.3 (7.8–9.4)	2130 (106–35,300) µS·cm^{-1}
Organic carbon		
0.24% (0.06–0.49%)		

The two main soil units on the Observatory are Solonchaks and Leptosols. Approximately one third of the profiles are Solonchaks, which are predominantly found in the plain habitat and characterised by a salic horizon. However, these soils are shallow and partly with a high gypsum content, as expressed by the qualifier 'Gypsic'. Profiles with shallower bedrock and lower gypsum content are classified as Leptosols. In some places, especially on the calcite marble, only very shallow soils or substrate layers cover the bedrock. This is marked by the qualifier 'Lithic'. A common feature of nearly all profiles is the combination of a desert pavement with ventifacts overlying a thin layer of silt, low organic carbon content and alkaline topsoil conditions marked by the suffix qualifier 'Aridic'.

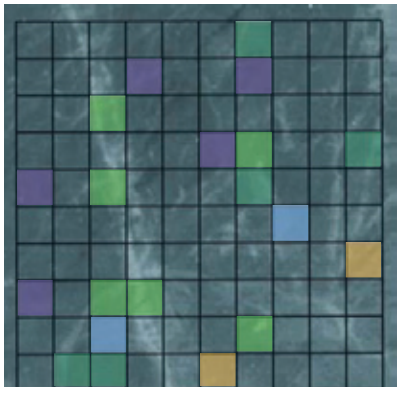
The pH values as well as the electrical conductivity show a relatively small range and no variation with depths. The lower values in pH and electrical conductivity occur in sandy soils of drainage courses with regular run-off events. Within the topsoil layer, the large range of organic carbon reflects the varying amounts of biological soil crust in the samples. Additionally, the silt particles of aeolian origin have higher contents of organic carbon than the pure sands in the drainage courses. The fine particle fraction (clay and silt) varies significantly in the topsoil layer whereas the second horizon shows lower content and a smaller variability. The rooting space is generally low and varies only slightly between the profiles.

Except nitrogen, total nutrient content was high, especially the content of phosphorus was exceptional compared to all other Observatories. Total content of magnesium is high; while the exchangeable cation has a medium to low range compared to other Observatories. The levels of iron, copper, and zinc are intermediate (approximately 20 g kg^{-1} and 20 and 47 mg kg^{-1} in the topsoil, respectively) compared to any other site.

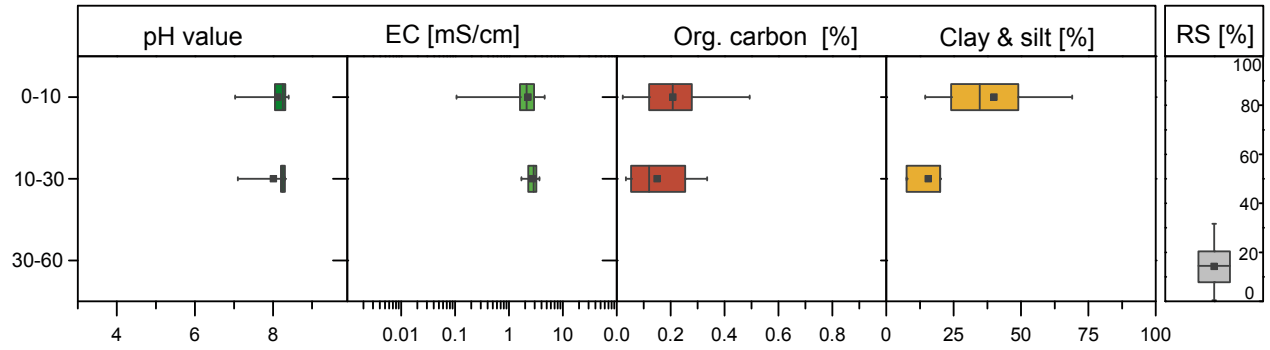
Texture ranges from sand to silty sand and sandy silt. Clay contents are very low. With regard to the sand fraction, the samples can be split into two groups. The sand fraction of the silt-rich and probably aeolian deposited topsoil material is dominated by over 50% fine sand and some medium sand. The 'subsoil' or second horizon, which is derived from bedrock weathering, contain only few amounts of fine sand and consist mainly of medium and coarse sand.

Pattern analogies in the soil and vegetation distribution are not very prominent but evident and are analogous to topographic features. Higher plants are concentrated along the drainage courses that (i) receive more water by run-on effects and (ii) have lower salt contents by run-off salt export. Although the annual rainfall is very low, a few events within decades might suffice to transport at least the highly soluble salts into deeper topographical positions or even out of the system. They accumulate in pans or flow into the ocean. Within the Observatory, few depressions are highly enriched in soluble salts (NaCl, $EC_{2.5}$ = 15 mS cm^{-1}) resulting in an unstable surface where lichens are not able to colonise.

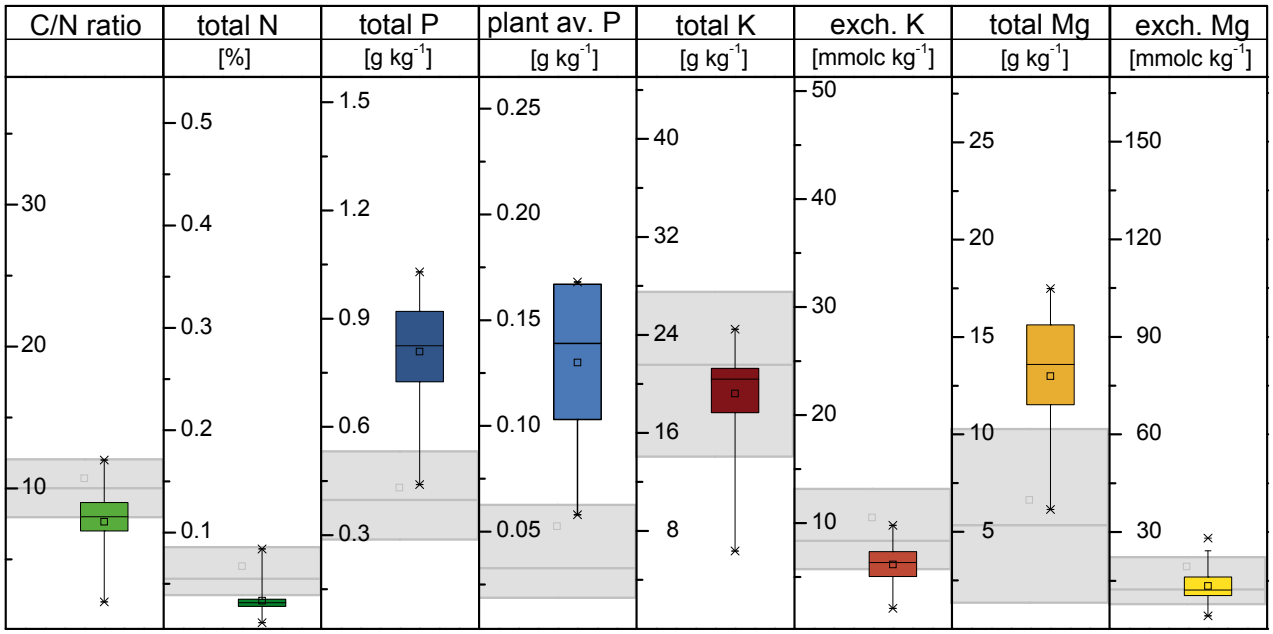
Map of soil profiles



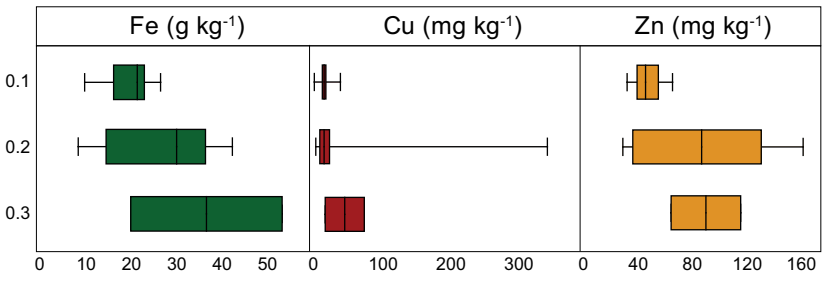
Soil characteristics



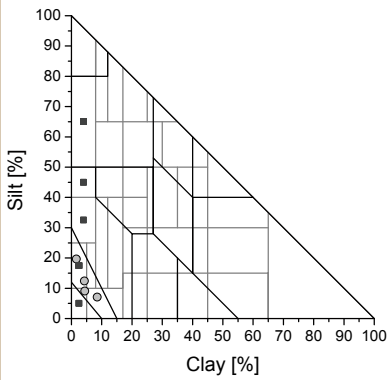
Soil nutrients



Soil micronutrients



Soil texture triangle

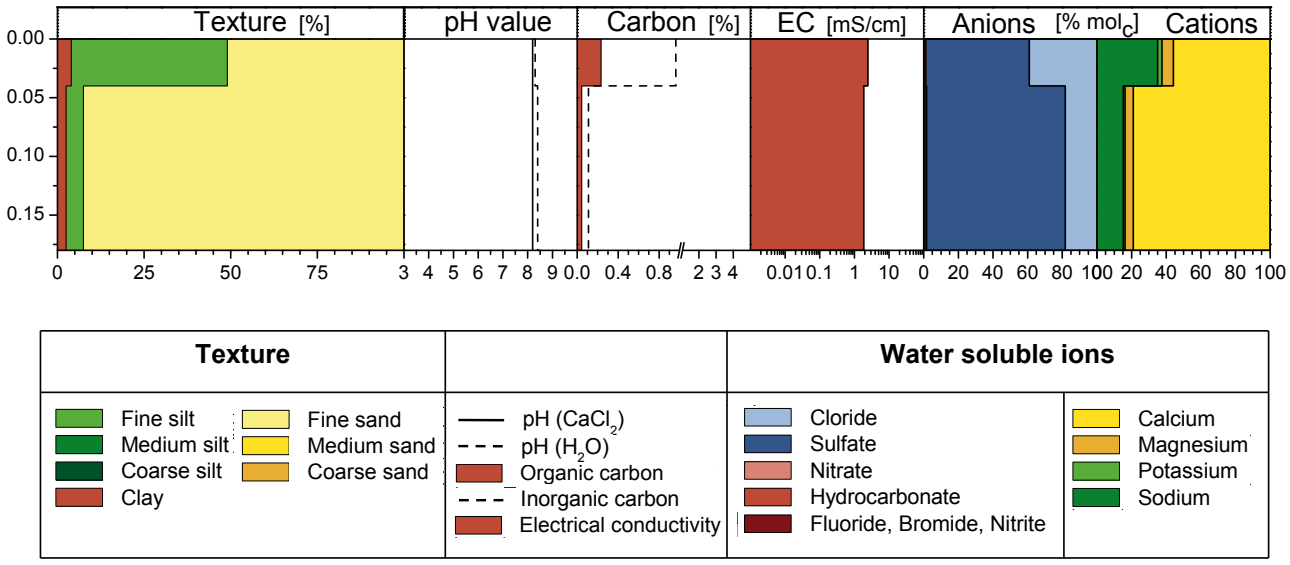


Reference profile (H70)

The **Epileptic Gypsisol (Aridic)** is a typical example of the soils of this Observatory, which are developed in a thin weathered zone of the underlying schist and granites. The texture is medium sand with small amounts of silt. The thin topsoil has a dense desert pavement and a slightly cemented structure. This layer also shows elevated concentrations of organic and inorganic carbon.

The electrical conductivity is relatively high for sandy substrates, resulting in high osmotic potential of 1–2 MPa (calculated). However, the fact that the electrical conductivity does not exceed 2 mS cm^{-1} and that the quotient of $EC_{2.5}$/EC_5 is 1.2 indicates the dominance of gypsum (see Methods section for explanation). Consequently, the osmotic potential does not reach such high values as calculated because the solubility of gypsum is relatively low.

The moderately high pH is constant over depth whereas the total element content decreases in the sandier substrate except for titanium and calcium. The dominance of calcium and sulphate in the water soluble ions is caused by the high content of gypsum in the soil. The exceptionally high values of exchangeable cations with up to 1400 $mmol_c$ kg^{-1} are the result of a strong dissolving process of calcium carbonates and powdery gypsum during the extraction procedure, resulting in high calcium contents.



Along the river margins, larger blocks of gypscrete are elevated by pedoturbation (water uptake of gypsum). Photo: N. Jürgens.

Soil polygons are formed by pedoturbation due to water uptake (volumetric expansion) and losses (volumetric shrinking) of gypsum in the soil. Photo: N. Jürgens.

Responsible authors: U. Wisch, A. Petersen, A. Gröngröft & D. Mager

Biological soil crusts

Sampling period(s)	Hectare plots sampled	Types of soil crusts
2001	3 (R1−R3)	6, 7
Crust thickness	**Cover**	**Carbon [weight %]**
> 4 mm	up to 70%	1.757
Nitrogen [weight %]	**Chlorophyll *a* [mg/m²]**	**Chlorophyll *a+b* [mg/m²]**
0.026	164	258

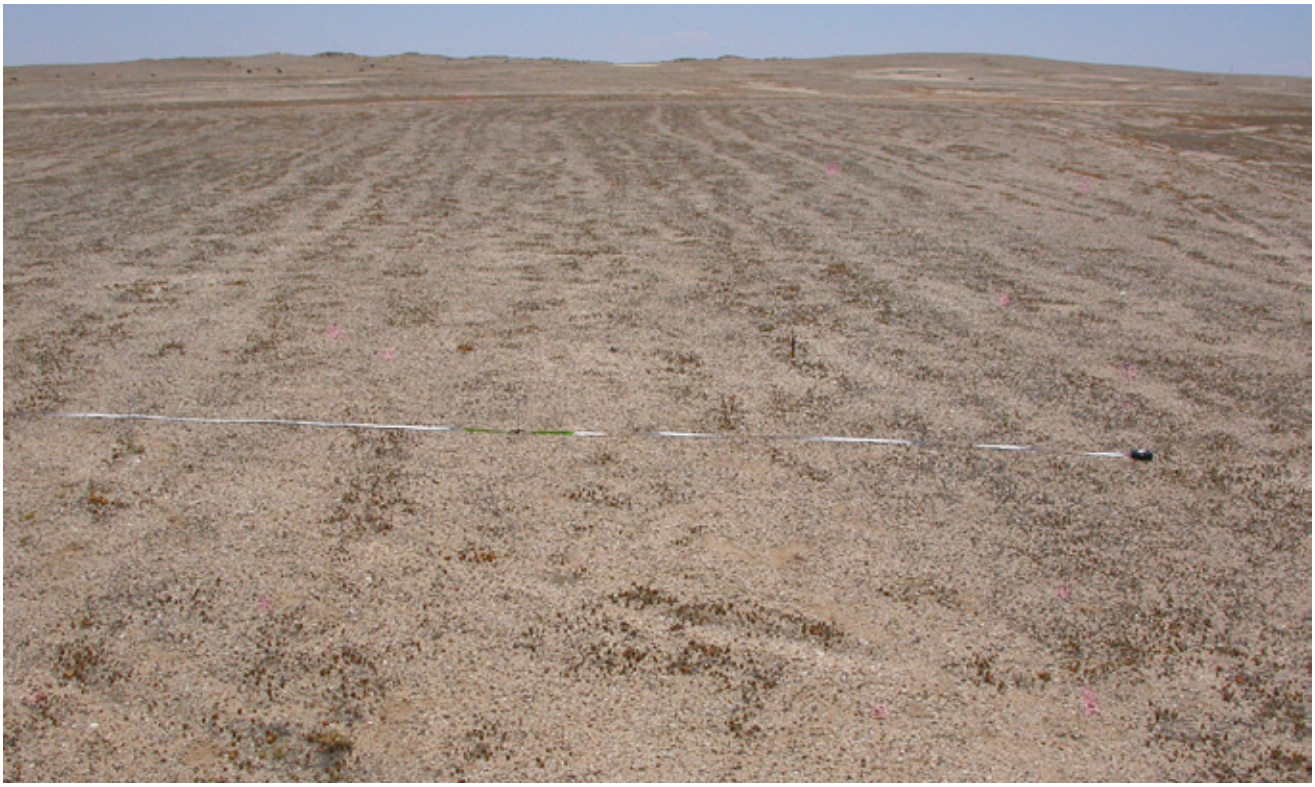
The lichen fields of the Namib Desert, which occur within this Observatory (see Photo), are characterised by an extremely high cyanobacteria richness as well as the extraordinary lichen diversity, which is described in Article III.3.4. Cyanobacteria are particularly abundant under quartz pebbles (hypolithic) but also occur in the soil and under lichen thalli. The highest crust-biomass for the whole transect was observed in this observatory, accompanied by relatively high organic carbon content. Especially taxa containing UV protective pigments, like *Scytonema* and *Schizothrix*, colonise the soil surface of the Namib Desert. The large variety of cyanobacterial taxa comprises small filamentous genera like *Pseudanabaena* and *Leptolyngbya* as well as large ones such as *Tolypothrix*. The presence of the coccal taxon *Chroococcidiopsis* supports the assumption that the communities in the Observatory have reached a late successional stage.

Cyanobacteria
Chroococcidiopsis sp.
Leptolyngbya cf. *scottii*
Leptolyngbya sp. 1
Leptolyngbya sp.
Microcoleus chthonoplastes
Microcoleus sp.
Nostoc sp. 1
Nostoc sp.
Oscillatoria sp.
Phormidium cf. *nigrum*
Phormidium chlorinum
Phormidium sp. 1
Pseudanabaena cf. *starmachii*
Pseudanabaena sp.
Pseudophormidium hollerbachianum
Schizothrix lardacea
Schizothrix sp.
Scytonema millei
Scytonema ocellatum
Scytonema sp.
Symploca sp.
Tolypothrix bouteillei
Tolypothrix distorta
Trichocoleus cf. *delicatulus*

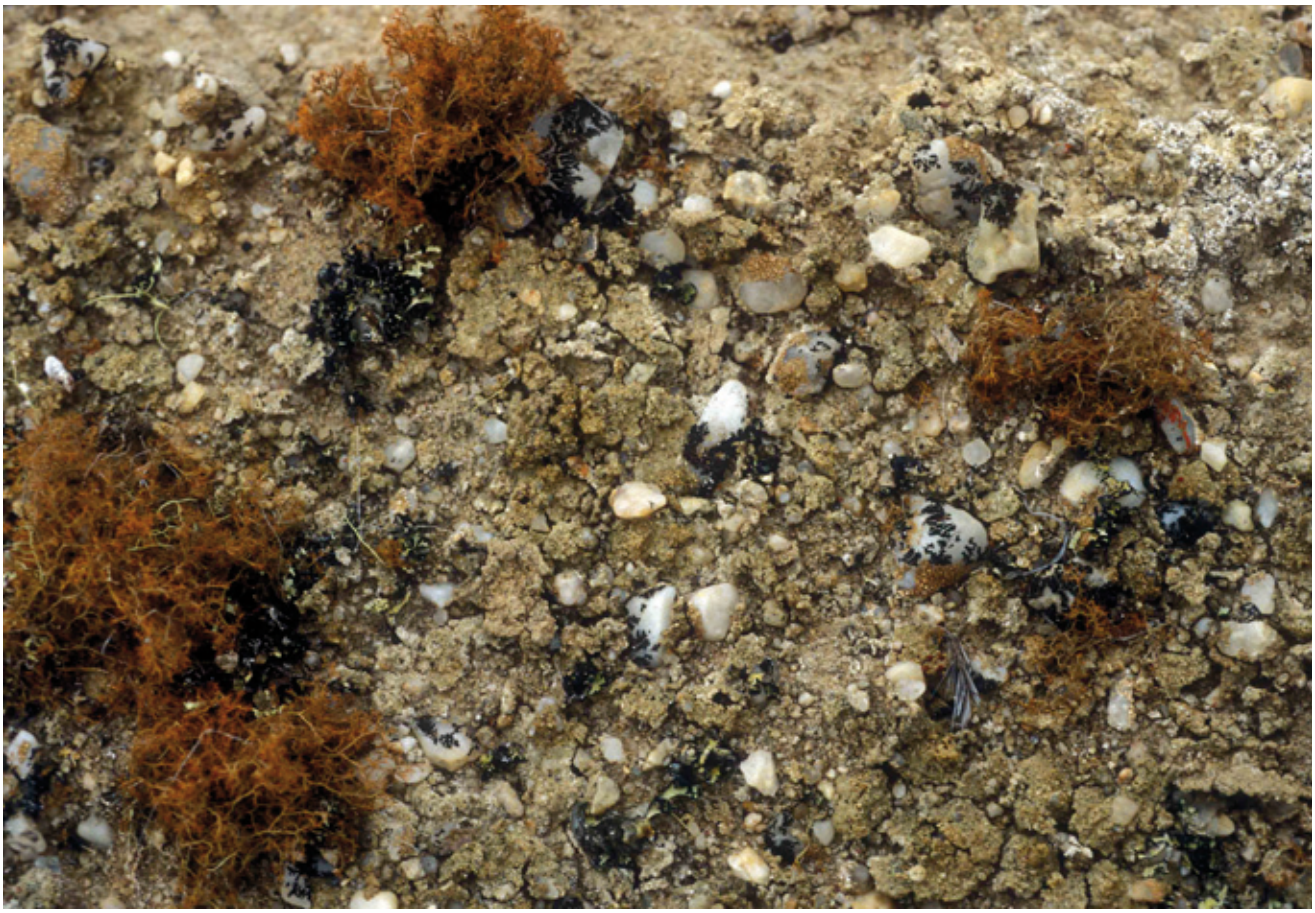
Green algae
Chlorosarcinopsis bastropiensis
Diplosphaera cf. *chodatii*
Myrmecia israeliensis
Trebouxia cf. *arboricola*

Biological soil crust characteristics

	H13	H73	H95
Soil characteristics	-	Grey silty sand, gypsum and small pebbles	Yellow to grey fine sand, pebbles, mica
Crust characteristics	-	Only few fragile pieces, that cannot obviously be identified as BSC	Dark cyanobacteria-dominated BSC covering large areas
Chlorophyll a [mg/m²]	108.82	262.73	119.78
Chlorophyll a+b [mg/m²]	201.32	413.33	158.8
Carbon [weight %]	-	1.41	2.11
Nitrogen [weight %]	-	0.03	0.02



At first sight, the lichen field area at Wlotzkasbaken looks relatively bare. Photo: K. Deutschewitz.



At a closer look, a variety of crustose, foliose, and fruticose lichens can be observed. Photo: B. Büdel.

Responsible authors: B. Weber, K. Deutschewitz, S. Dojani, T. Friedl, T. Darienko, K. Mohr & B. Büdel

Lichens

Sampling period(s)	Hectare plots sampled	Cover
2001, 2002	11 (R1–R11)	55% (6.5–90%)
Total species richness	**Species richness on soil [1 km²]**	**Species richness on rock [1 km²]**
26	9 (35%)	19 (73%)
Species richness on plants [1 km²]	**Species richness on soil [1000 cm²]**	
n.a.	7 (2–10)	

This Observatory is one of the richest in lichen diversity due to extremely favourable climatic conditions characterised by high air humidity, dew and fog precipitation. Lichens occur abundantly on soil and rock as well as on plants, which however, were not examined in further detail. Several of the recorded taxa are endemic to the Namib Desert, and one species, *Phloeopeccania pulvinulina*, was recorded for the first time in Africa (Schultz et al. 2009). The abundance of soil lichens is also a result of favourable soil characteristics, in particular the presence of gypsum in the soil. Competition with vascular plants is mostly irrelevant due to their low cover as a consequence of the high degree of aridity and soil salinity. The majority of soil lichens are green algal species, which are indicative of high air humidity or of the occurrence of fog. This contrasts to the situation in several other inland Observatories (i.e. S39/Narais and S40/Duruchaus), where cyanobacterial lichens dominate. The majority of lichens are crustose, followed by fruticose taxa, with the occurrence of the latter being explained by the elevated air humidity.

Species growing on small pebbles and gravel (e.g., *Xanthoparmelia* spp.) are included in the vegetation sampling of soil-inhabiting taxa since these are an important component of the lichen fields in the Namib Desert. Compared to other Observatories, lichen cover on soil is very high. The lichens here are also very diverse with six morphogroups occurring. Soil-inhabiting lichens occur abundantly in nearly all hectare plots, except for H86, located on a dolorite ridge. Most of the hectare plots have similar species compositions. Only H42 deviates significantly with its community of calciphilous species that belong to undescribed *Bacidia*, *Buellia*, *Carbonea*, *Fulgensia* and one cyanolichen species. One morphogroup of crustose lichens (MG05) exhibits the greatest cover within all the hectare plots but foliose and fruticose lichens (MG06 and MG13) are also abundant. Disturbance by vehicle tracks occurs at this Observatory, but these tracks are to some degree recolonised by crustose lichens such as *Lecidella crystallina*, *Buellia sipmanii* and *Caloplaca volkii*.

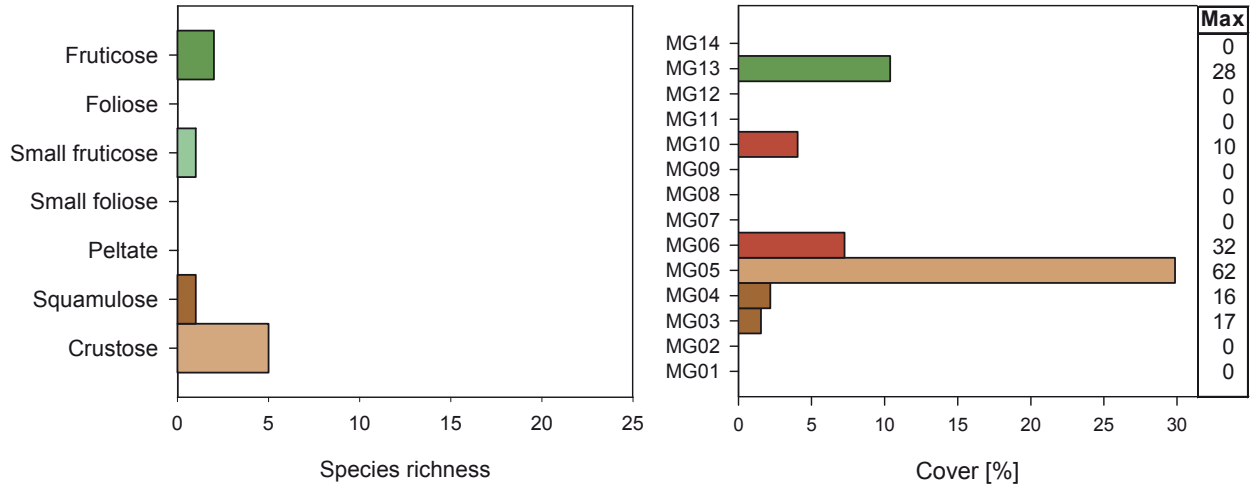
List of Taxa

Terricolous (on soil):
Acarospora sp. 01 (M-0038950)
Buellia sipmanii
Caloplaca volkii
Diploschistes henssenii
Lecidella crystallina
Phloeopeccania pulvinulina
Ramalina sp.
Teloschistes capensis
Toninia lutosa

Saxicolous (on rock):
Acarospora spp. (2)
Bacidia sp.
Buellia spp. (4)
Caloplaca elegantissima
Caloplaca namibensis
Caloplaca rubelliana
Caloplaca testudinea
Carbonea sp.
Fulgensia sp.
Neofuscelia namibiensis
Phloeopeccania pulvinulina
Santessonia hereroensis
Teloschistes capensis
Xanthoparmelia dregeana
Xanthoparmelia hottentotta
Xanthoparmelia walteri s.l.

Epiphytic (on plants):
No records

Life forms



Xanthoparmelia walteri s.l. Photo: L. Zedda & G. Rambold.

Caloplaca elegantissima. Photo N.Jürgens.

Teloschistes capensis. Photo: L. Zedda & G. Rambold.

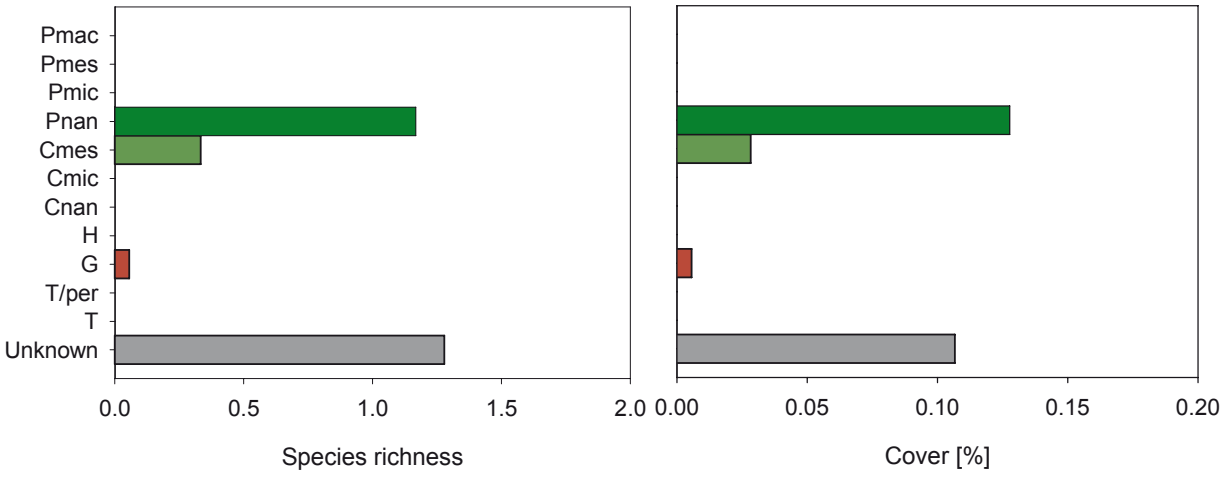
Phloeopeccania pulvinulina. Photo: L. Zedda & G. Rambold.

Responsible authors: L. Zedda & G. Rambold

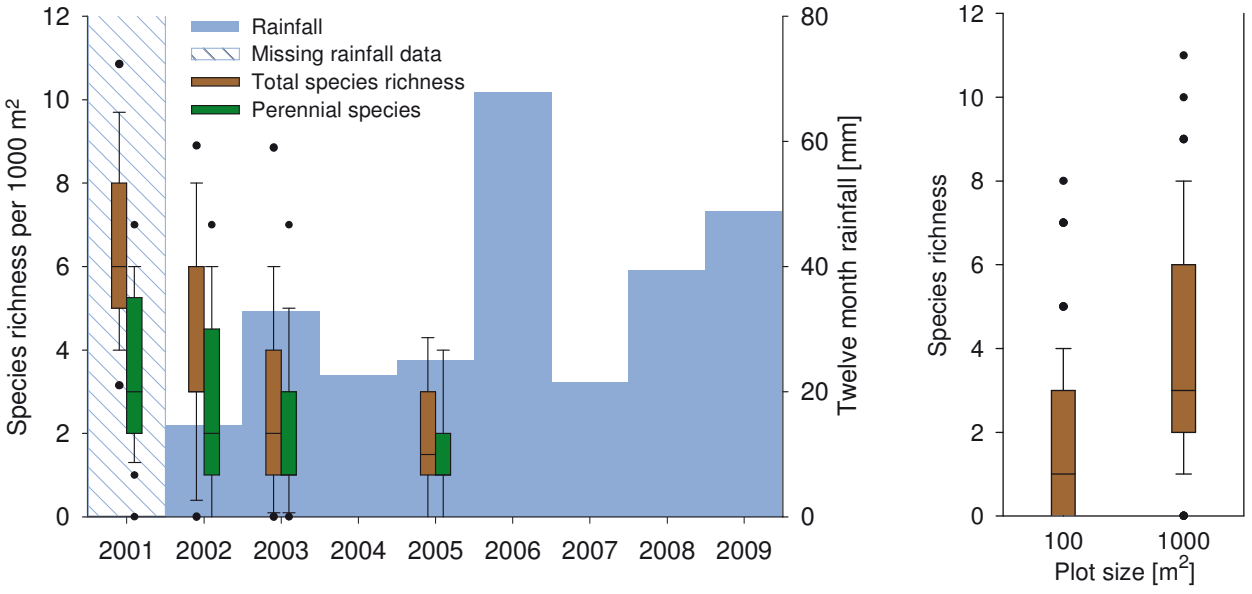
Vascular plants

Sampling period(s)	Hectare plots sampled	Biome
2001–2003, 2005, 2010	20 (R1–R20)	Namib Desert/ Succulent Karoo
Vegetation unit (level 1)	**Vegetation unit (level 2)**	**Identification rate**
Central Namib	n.a.	71% – 96% – 99%
Cumulative family richness	**Dominant families (cover)**	**Dominant families (richness)**
11	Aizoaceae, Amaranthaceae, Zygophyllaceae	Aizoaceae, Poaceae, Asteraceae
Cumulative species richness (1 km²)	**Species richness (1000 m²)**	**Species richness (100 m²)**
28 – 15	3.9 (0–11)	1.8 (0–8)
***z*-value**	**Species richness change per year (1000 m²)**	**Evenness (1000 m²)**
0.340 (0.000–0.778)	-0.97	0.666 (0.091–0.960)
Evenness (100 m²)	**Simpson (1000 m²)**	**Simpson (100 m²)**
0.606 (0.182–0.964)	0.458 (0.000–0.799)	0.274 (0.000–0.726)

Life forms



Species richness



Species list (2010)

Column		Cover	All
Number of relevés			**20**
Mean cover [%]			2.4
Mean species richness (1000 m²)			6.8
Mean soil pH			8.12
Mean electrical conductivity [µS·cm^{-1}]			2264
Organic carbon [%]			0.21
Nitrogen [%]			0.03
T	Zygophyllum spongiosum	1.60	100
Pnan	Arthraerua leubnitziae	0.30	81
G	Stipagrostis namibensis	0.05	81
Cmes	Tetragonia reduplicata	0.04	67
Cmes	Jamesbrittenia maxii	0.01	62
T	Senecio engleranus	0.06	38
T	Heliotropium tubulosum	0.36	33
n.a.	Ornithogalum stapffii	0.01	33
n.a.	Aizoanthemum membrumconnectens	0.10	33
T	Mesembryanthemum cryptanthum	0.01	29
Pnan	Zygophyllum stapffii	0.26	24
Cmes	Galenia africana	1.37	14
H	Sesuvium sesuvioides	0.10	14
T	Cleome carnosa	0.10	14
Cmes	Lycium oxycarpum	0.10	10
Cmes	Psilocaulon salicornioides	0.00	10
Cmes	Drosanthemum luederitzii	0.10	5
Cmes	Kleinia longiflora	0.10	5
n.a.	Aizoanthemum galenioides	0.10	5
T	Eragrostis nindensis	0.10	5
G	Ornithoglossum vulgare	0.10	5
Pnan	Brownanthus kuntzei	0.10	5
Cmes	Galenia papulosa	0.00	5

The Wlotzkasbaken Observatory contains a good example of the vegetation of the coastal Namib Desert, combining coastal elements of the Namib Desert with strong affinities to the Succulent Karoo and the Cape Flora. In addition, the Observatory represents the largest of Namibia's lichen fields, which are a globally unique feature.

Shrubs (P nan) and dwarf shrubs (C mes) are the most species-rich groups in terms of life-form composition. They also contribute most to the vegetation cover. Annuals also occur with high abundances during good rainfall years.

Aizoaceae are the most important plant family in terms of species richness and cover. Many of the Aizoaceae species belong to the subfamilies Mesembryanthemoideae and Ruschioideae, which indicates the strong affinity of this Observatory to the Greater Cape Flora of the Succulent Karoo. A total of 11 species belong to the Aizoaceae: *Aizoanthemum galenioides*, *Aizoanthemum membrum-connectens*, *Brownanthus kuntzii*, *Drosanthemum luederitzii*, *Galenia africana*, *Galenia papulosa*, *Lithops ruschiorum*, *Mesembryanthemum cryptanthum*, *Psilocaulon salicornioides*, *Sesuvium sesuvioides*, and *Tetragonia reduplicata*. Other important families are the Poaceae (three species) and Amaranthaceae (second highest cover, one species) indicating the influence of the Nama Karoo, which is part of the Palaeotropis (Jürgens 1991). Species richness and the Simpson index at Wlotzkasbaken are amongst the lowest of all southern African Observatories. Like the other Namib Desert Observatories, Wlotzkasbaken has comparatively high *z*-values, indicating a high species turnover at the transition 100 m²–1000 m². However, species turnover at the transition 1000m²–1 km² is below the transect-wide mean values. High variance in rainfall results in high inter-annual differences in species richness, particularly for annuals.

There is no clear pattern of different vegetation subunits at Wlotzkasbaken. Also, the main habitat types (plains, ephemeral rivers, and dolerites ridges) do not possess clearly separated species pools. This pattern can be explained by two factors.

Firstly, the extremely low rainfall and generally flat topography mean that small-scale topography, such as shallow depressions of a few meters in diameter, gain in importance compared to larger topographical units. For example, the riverbeds at Wlotzkasbaken are mostly bare and only *Arthraerua leubnitziae* (Pencil Bush) and *Zygophyllum stapffii* (Dollar Bush) plants seem to be able to benefit from the additional soil water in the riverbed and therefore occur along the river margins. However, these species also grow in many other places where dolerite rocky outcrops result in water runoff. Secondly, small topographical structures (at the scale of centimetres or decimetres) enable plants to capture fog at a height, which is above that of the surrounding plants. Such topographical structures (e.g. small rock outcrops) are randomly distributed in many parts of the Observatory.

In conclusion, in this extremely arid environment, small-scale variations in the amounts of water drive vegetation patterns in an unusual way. The resulting spatial distribution pattern of the vegetation is de-coupled from the usual vegetation patterns, which are usually determined by soil water availability.

Nevertheless, some species on the Wlotzkasbaken Observatory show spatial patterns that are described below.

There is one overarching vegetation unit comprising the annual leaf-succulent *Zygophyllum spongiosum* and the annual grass *Stipagrostis namibensis*. This unit encompasses all hectares investigated. Within this unit, there is a clear subunit, comprising the halophytic stem-succulent shrub *Arthraerua leubnitziae* and the leaf-succulent shrub *Tetragonia reduplicata*. These two species jointly occur on a number of hectares that include at least one ephemeral river, as well as on several hectares that have a dolerite ridge. There is little doubt that both species exploit soil water, which is available for prolonged time periods within the soils and rocks of the dolerite ridges or next to the dry riverbeds. The occurrence of these two species on the dolerite ridges is perhaps partly also due to water storage and runoff from the rocks, and perhaps also due to improved exposure to fog.

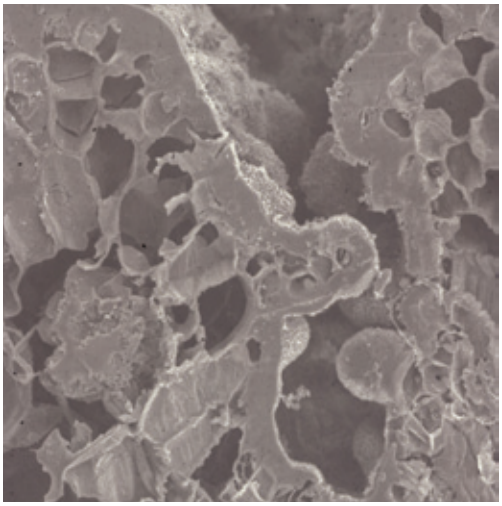
Zygophyllum stapffii, another leaf-succulent dwarf shrub at Wlotzkasbaken, makes use of the water resources along the dry riverbeds but avoids the dolerite ridges, whereas *Drosanthemum luederitzii* and *Kleinia longiflora* occur at dolerite ridges with very low frequencies.

The only plant species occurring on the plains are lichens.

A large proportion of the individuals of *Arthraerua leubnitziae, Zygophyllum stapffii,* and *Tetragonia reduplicata* occur along the (mostly dry) river beds or small washes, as shown in the picture. Photo: N. Jürgens.

Habitus of the shrub *Arthraerua leubnitziae*, surrounded by loose airborne lichen masses of *Teloschistes capensis*. Photo: N. Jürgens.

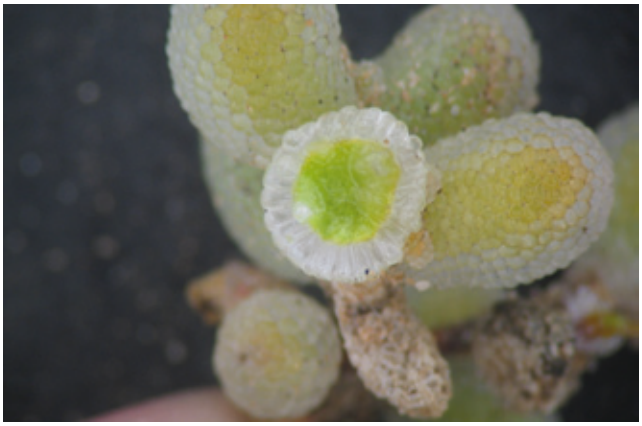
The stem succulent halophyte *Arthraerua leubnitziae* with the typical longitudinal striation of the internodes. Photo: N. Jürgens.



A cross section under the electron scanning microscope shows that the striation is connected to tunnel-like caverns. At their bottom the stomata of this plant are found, probably enabling uptake of fog water. Photo: N. Jürgens.

The vegetation of quartz hills is characterised by populations of *Drosanthemum luederitzii*. Photo: N. Jürgens.

Drosanthemum luederitzii with succulent leaves and attractive white flowers. Photo: E. Erb.



A cross section of the leaf of *Drosanthemum luederitzii* shows the succulent water storing tissue surrounded by very large bladder cell idioblasts. Photo: N. Jürgens.

Responsible authors: N. Jürgens, E. Erb & J. Luther-Mosebach

True bugs

Sampling period(s)	Methods	Family richness
2007/ I; 2009/ I	Trapping (light); hand collecting	4
Species richness	**Individuals sampled**	**Fisher's alpha diversity**
7	30	2.87

Seven species from four families were collected by hand and using a light trap at the Observatory Wlotzkasbaken (S16). Two nights of light trapping yielded no records of Heteroptera because of strong winds and cold temperatures. During one night, two specimens of two species were attracted to the light: an unidentified Miridae and *Reduvius nigricephalus* (Reduviidae), a species found also at S38 (Claratal), S10 (Gellap), and S12 (Karios).The number of ground-living Heteroptera would certainly have been higher if sampling was conducted using pitfall traps.

Nysius ericae (Lygaeidae) was the most common species. It is a widespread seed bug, often recorded as *Nysius natalensis* or *Nysius albidus* in southern Africa. The species is polyphagous, but breeds mostly on Asteraceae.

Unidentified Miridae species, associated with local plants, are possible candidates as Namib endemics.

Species richness in families

Family	S
Miridae	4
Pentatomidae	1
Lygaeidae	1
Reduviidae	1
Total	**7**

Species abundances

Light traps

Species	Family	N	%
Reduvius nigricephalus	Reduviidae	1	50
Miridae spec.	Miridae	1	50
Total		**2**	**100**

Responsible author: J. Deckert

Butterflies and moths

Sampling period(s)	Number of samples (moths)	Species richness (total)
2007/I; 2008/IV; 2009/I	3	43
Species richness (butterflies)	**Species richness (all moths)**	**Species richness (Microlepidoptera)**
2	41	5
Species richness (Pyraloidea)	**Species richness (Macrolepidoptera)**	**Species richness (Noctuidae)**
9	6	0
Individuals sampled (moths)	**Fisher's alpha diversity (moths)**	
21	12.7	

Butterflies

Two species were recorded on the Observatory: *Azanus jesous jesous* and *Vanessa cardui*. Because of the lack of food-plants at Wlotzkasbaken they could not have developed at the Observatory but were migrants from elsewhere. Both species are common residents in Namibia and are able to fly over large distances.

Moths

The number of recorded species and specimens were unexpectedly high for a desert locality. In the open land without hills and trees the light of the traps and the light tower attracts moths over large distances, despite the sometimes foggy weather. Many species of Noctuidae appear in comparatively large numbers, especially at the end of the rainy season. They are usually good fliers and might have been migrants from the interior of Namibia. *Ectochela nigrilineata* (Noctuidae), however, can be considered an autochthonous species because it was always present and abundant. Another true resident on the Observatory

Taxonomic spectrum of moths

Collection period: IV/2008

Family	S	N
Tineidae	1	1
Plutellidae	1	2
Holcopogonidae	2	2
Gelechiidae	1	11
Microlepidoptera	**5**	**16**
Pyralidae: Pyralinae	1	75
Pyralidae: Phycitinae	1	1
Crambidae	7	29
Pyraloidea	**9**	**105**
Cossidae	1	1
Sphingidae	2	12
Geometridae	1	1
Arctiidae	2	4
Noctuidae	21	168
Macrolepidoptera	**27**	**186**
Total	**41**	**307**

is *Pecticossus gaerdesi* (Cossidae) and probably also the two unidentified species of the family Cossidae. The larvae of the former bore into the roots and stems of *Zygophyllum staffi*. The host plants of the latter species are unknown, but a possible candidate is *Arthraerua leubnitziae,* which has stems and roots that are thick enough to accommodate the boring caterpillars of these large species. These two unidentified species are true endemics of the Namib Desert. Other remarkable inhabitants of the area are two species of the genus *Eilema* s. l. (Arctiidae). Larvae of the species from this genus are known to feed on lichens (Pinhey 1973). Both species are not restricted to lichen-fields in the Namib Desert, but also occur in the mountains of the neighbouring escarpment. The detritophagous *Hypotia bolinalis* is the dominant species among the Pyraloidea. It has a wide distribution in south-western Africa with records from Namibia to Cape Town.

Responsible author: W. Mey

Vertebrates

Total species richness	Reptile species richness	Bird species richness
2	n.a.	2
Large mammal species richness	**Small mammal species richness**	
n.a.	n.a.	

Large mammals

Artiodactyla	**Even-toed ungulates**
Antidorcas marsupialis	Springbok

Birds

Passeriformes	**Perching birds**
Ammomanes grayi	Gray's Lark
Cercomela tractrac	Tractrac Chat

Responsible authors: J. Deckert, A. Hoffmann & A. Mills

General data

Number	Name	Alternative name(s)
S34	Kleinberg	n.a.
Implementation	**Country**	**Province/ region**
2004	Namibia	Erongo
District/ constituency	**Locality**	**Farm name**
Walvis Bay	Walvis Bay	Kleinberg
Latitude	**Longitude**	**Altitude**
22.989838 S	14.725183 E	188 m a.s.l.
Rainfall season	**Biome**	**WWF Ecoregion**
Summer	Namib Desert/ Succulent Karoo	AT1315 Namib desert
Agro-Ecological Zone	**Relative intensity of land use**	**Tenure**
NAM6	None	State
Type and history of landuse	**Land owner**	
Conservation area	Government of Namibia	

Kleinberg (S34)

A large number of individuals of *Arthraerua leubnitziae* are bound to the direct vicinity of the water resources along smaller washes. Photo: N. Jürgens

The Kleinberg Observatory is located east of the city of Walvis Bay, just 21 km inland from the Atlantic Ocean coastline. The study site forms part of the slightly undulating coastal plain of the Central Namib Desert. The bedrock mainly consists of schist of the Swakop group, and partly of Damaran granite, which are replaced by strongly eroded flat dolerite banks in certain areas. Localised granite outcrops also occur on the landscape surface.

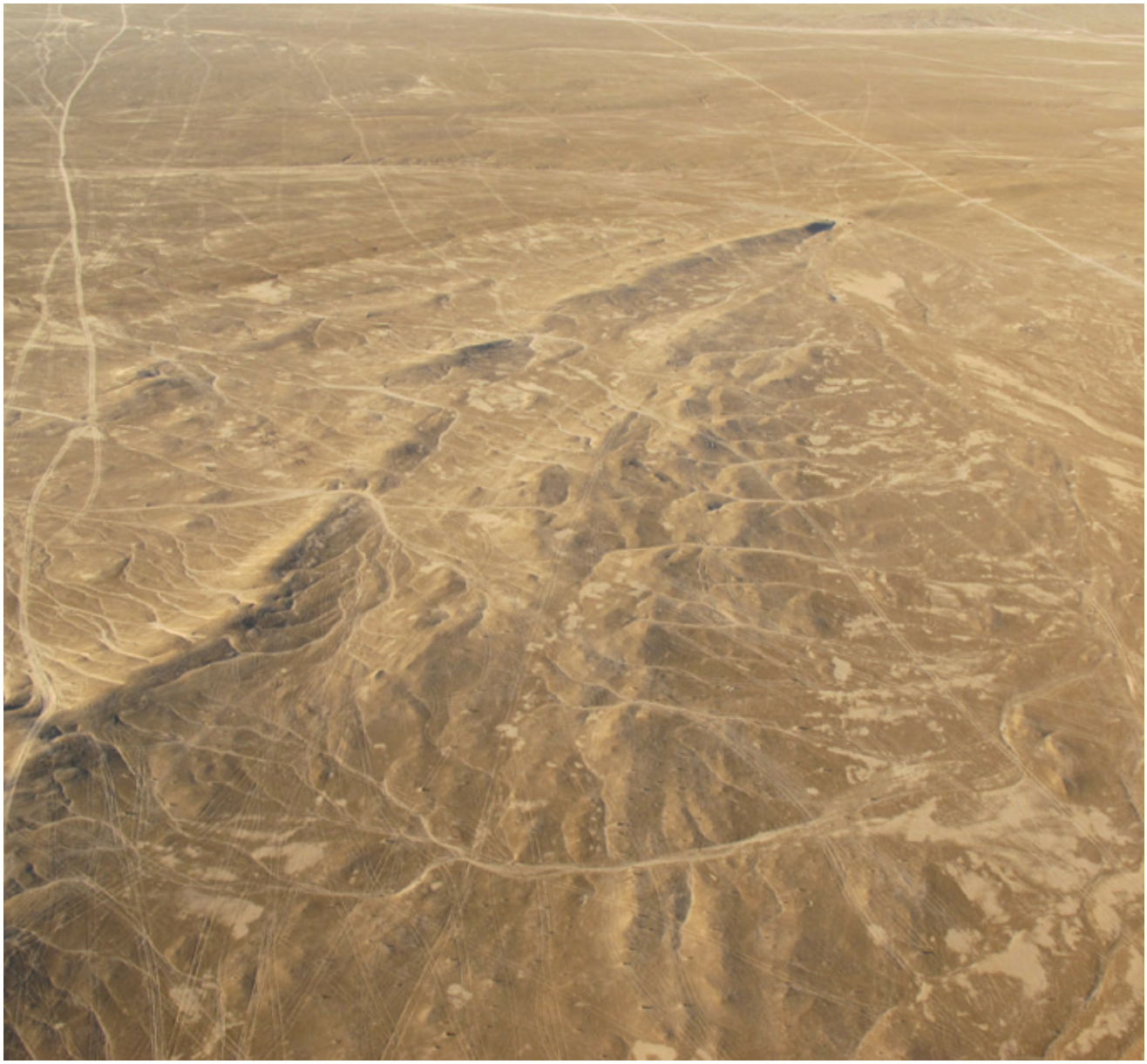
Gypsilsols are important and gypsum crust elements are frequently seen at the surface, especially along washes.

Rainfall at the Observatory was very low during the recording period (a mean annual rainfall of 22 mm over the last 6 years). However, the Observatory is exposed to the frequent fogs moving in from a south-westerly direction, i.e. from the coastal region between Sandwich Harbour and Walvis Bay. The coastal fog supports extensive lichen fields, which are limited in their extent, perhaps due to the abrasive force of wind-blown sands. The Kleinberg Observatory is fairly close to the coastal dune fields and, probably more important, well protected from easterly sand storms by a series of hills east of the study site. The Kleinberg Observatory is a representative example of the "Crustose soil lichen fields" which are typical of the southern parts of the Central Namib Desert. The vascular plant flora is extremely sparse and consists of only four species (the most dominant species being *Arthraerua leubnitziae* or

Pencil Bush) and is representative of a vast proportion of the coastal fog desert. The surface crusts formed by various crustose lichens can reach cover values of more than 50%. Directly north of the Observatory, sand storms from the north-east have eroded the lichen fields (compare also Article III.3.6).

There is no agricultural landuse in the area. However, off road driving caused extensive long-term destruction and the landscape is scarred by a web of vehicle tracks.

This Observatory forms part of the Namibian west-east transect, which was primarily established in order to monitor and describe the steep climatic coast-inland gradient.



An aerial view of the landscape next to the Kleinberg Observatory shows the topography and the intense destruction caused by off-road driving. Photo: N. Jürgens.

Large surface areas of the Observatory are devoid of any higher vegetation. Only where the soil above bedrock is very shallow redistribution of water allows establishment and survival of a few individuals of *Arthraerua leubnitziae*. Photo: N. Jürgens.

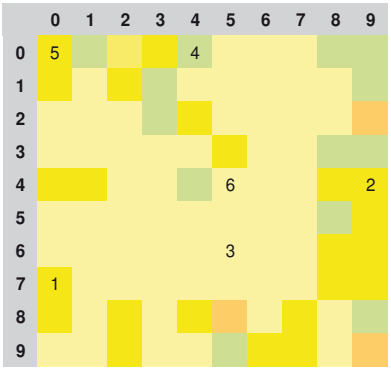
Car tracks destroy the lichen crust. Rehabilitation obviously takes decades. Photo: N. Jürgens.

Responsible authors: N. Jürgens & D.H. Haarmeyer

Remote sensing and landscape

Geomorphology	Geological units	Lithological units
Rolling plain, slope, wash, outcrop	Swakop Group in Damara Supergroup and Gariep Complex	Schists and dolomites
Mean EVI	**EVI absolute range**	**Mean leaf area index**
0.080 (0.073–0.088)	0.071 (2008)–0.093 (2006)	0.00

Grid map of Observatory



1 Undulating plain

2 Undulating plain with intersection of rivier, wash and sedimentation fan

3 Undulating plain with planated dolerite bank

4 Gentle slopes

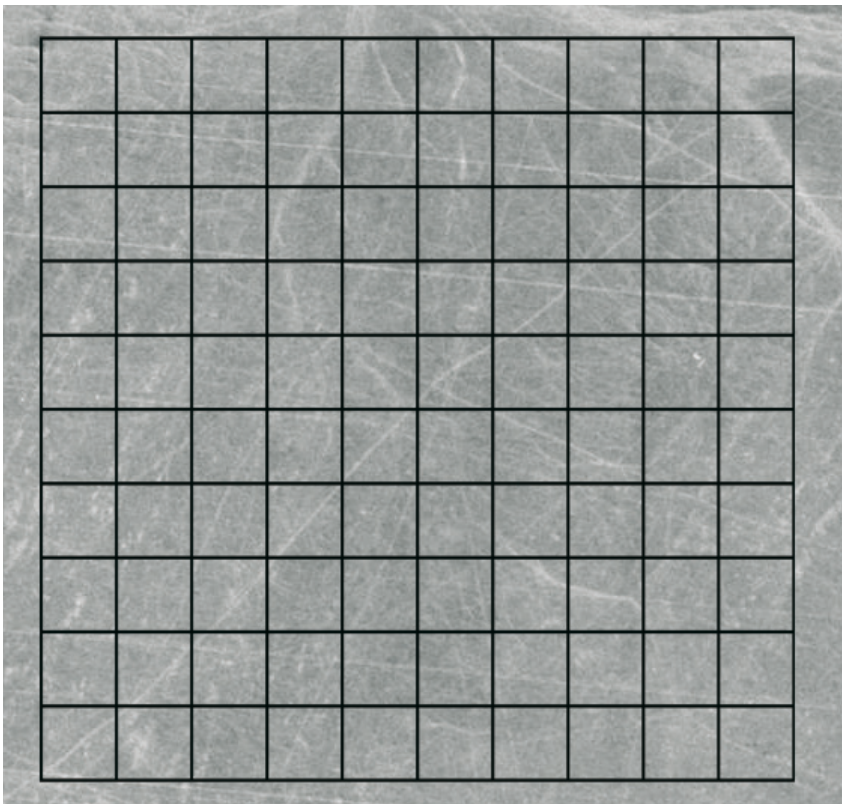
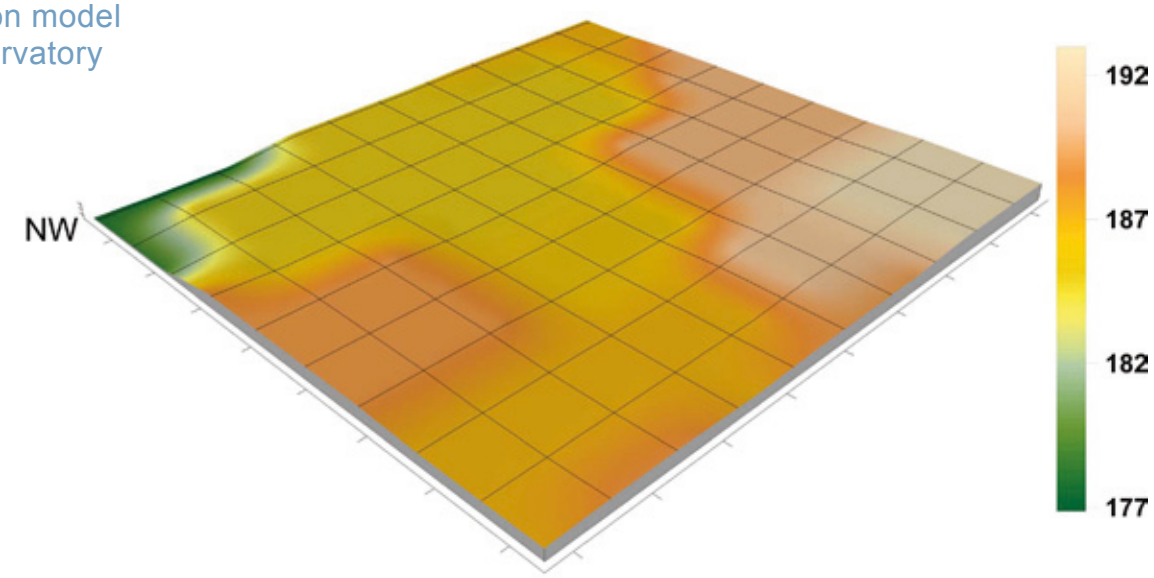


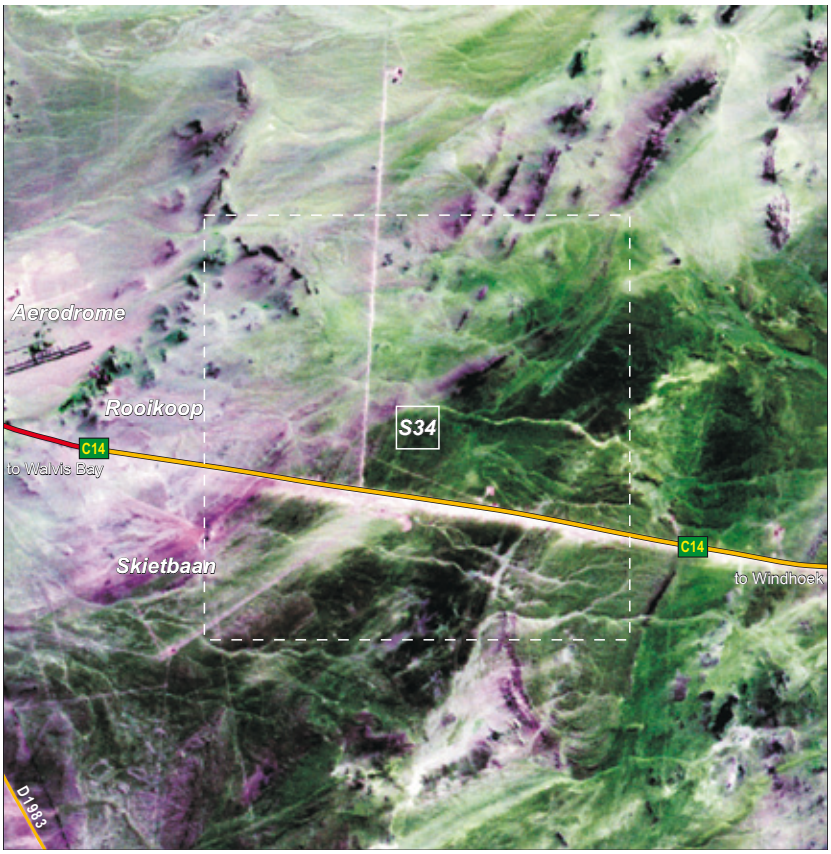
Image: aerial photography

Elevation model of Observatory



Landsat image

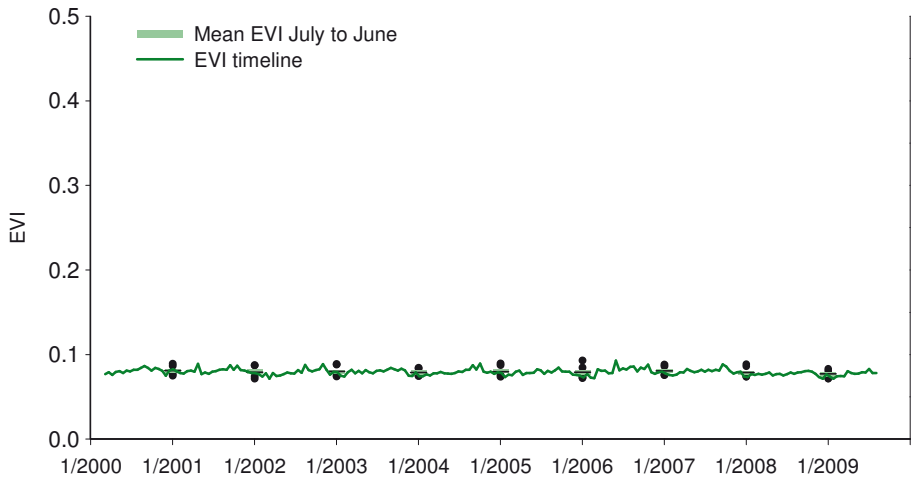
The Namib Desert around the Observatory Kleinberg is flat, apart from a few dolerite ridges (dark blue-grey lines). The surface is covered by gravel, lichens, annual grasses, and sparse dwarf shrubs (green tones). White structures are unvegetated temporal riverbeds, and the broad, straight white line about 1 km south of the Observatory is the road from central Namibia to Walvis Bay.



Scene: 179/76, acquisition date: 01 May 2003

MODIS time series

Temporal patterns of vegetation cover, and phenology



Responsible authors: M. Keil & T. Labitzky

Climate

Data from BIOTA weather station

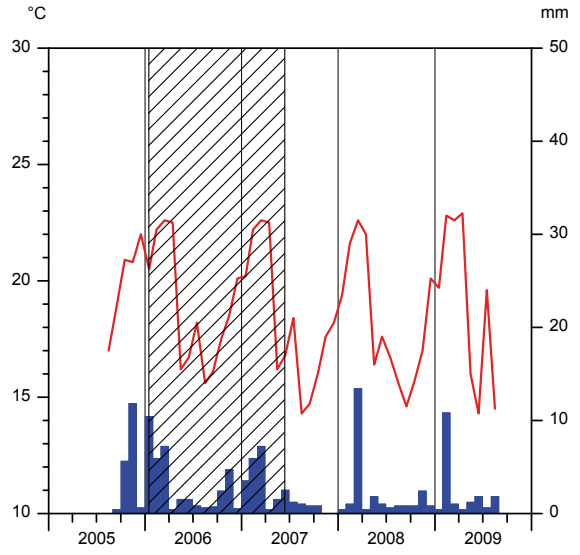
Location	Recorded period	Mean temperature
Kleinberg (S34)	2005–2009	19.9 (-1.3–36.6) °C
Mean solar radiation	**Mean wind speed**	**Mean annual precipitation**
570 (381–737) MJ·m^{-2}·month^{-1}	3.4 (8.6) m·s^{-1}	30 (24–24) mm
Mean annual potential evapotranspiration	**Interannual precipitation variability**	**Mean relative humidity**
1295 mm	164%	72% (49–81%)
Aridity index (UNEP)		
0.02 (hyperarid)		

Modelled data

Mean temperature	Mean annual temperature range	Mean diurnal temperature range
17.6 (7.8–25.9) °C	5.6 °C	12.5 °C
Mean annual precipitation	**Precipitation seasonality**	**Percentage winter precipitation**
16 mm	90%	19% (strong summer)
Climate type	**Length of dry season**	**Aridity index (De Martonne)**
BWk	12 months	0.6 (dry)

The climate at the Observatory is characterised by hyper-arid conditions. Rainfall is fairly uniformly distributed throughout the year. The mean annual rainfall over the observation period was 30 mm, which is typical of the Observatories within the Namib Desert, and makes it the driest Observatory of the entire transect. However, substantial interannual variability is evident. Observed near-surface air temperatures show a weak seasonal cycle. The mean annual temperature is 19.9°C, which is slightly above the average for this biome. Compared to the interpolated long-term data taken from the WorldClim dataset, a noticeably warmer mean annual temperature is evident at the BIOTA weather station. In particular, the maximum temperature differs substantially. For precipitation, mean annual rainfall observed at the station is almost twice the amount of the WorldClim dataset.

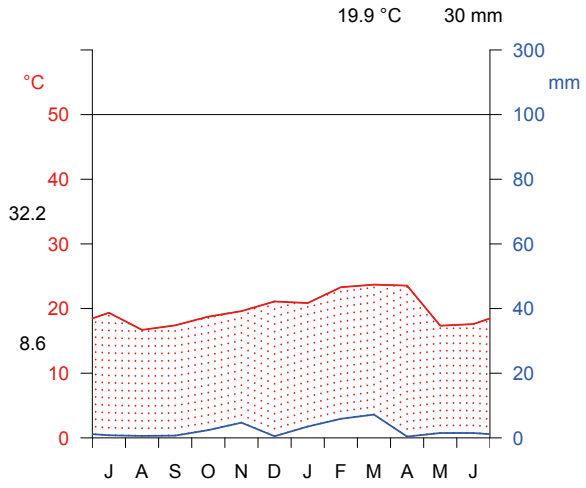
Time series: rainfall and temperature



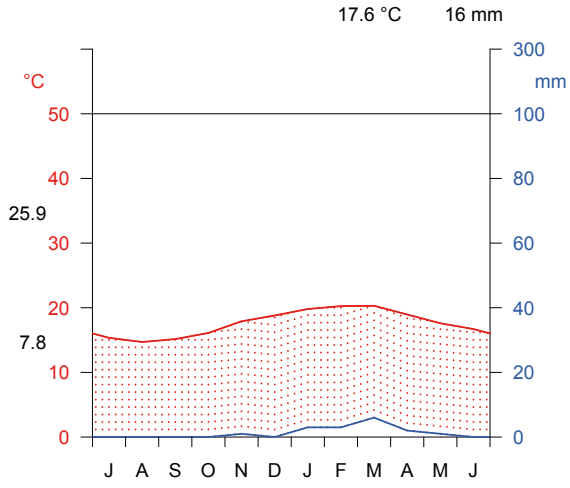
The mean wind speed at the Observatory is highest during the early afternoons, reaching about 15 km/h. Winds during that time of the day, as well as in the mornings, remain fairly constant throughout the year, whereas a weak annual cycle is evident for mean wind speeds during the evenings.

Climate diagrams

Recorded data (BIOTA)

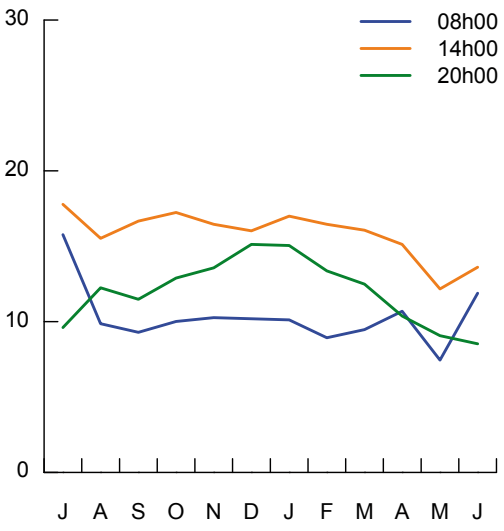


Modelled data (WorldClim)



Wind diagrams

Speed



Responsible authors: K. Berger, A. Haensler & J. Luther-Mosebach

Biological soil crusts

Sampling period(s)	Hectare plots sampled	Types of soil crusts
2004	3 (R4, R62, R95)	7
Crust thickness	**Cover**	**Carbon [weight %]**
> 4 mm	about 50%	0.712
Nitrogen [weight %]	**Chlorophyll a [mg/m²]**	**Chlorophyll a+b [mg/m²]**
0.041	163	207

Despite the extremely low mean annual rainfall of only 16 mm (section on climate), a high biological soil crust cover, containing mostly crustose and foliose lichens occurs (see Photo). These functional groups depend on coastal fog to grow or activate their metabolism, which occurs on many days of the year. The high coverage of biological soil crusts is related to high chlorophyll content, whereas the organic carbon and nitrogen content is relatively low. Determination of cyanobacteria and algae is not finally treated yet.

At a first glance, the surface area covering the Observatory at Kleinberg looks fairly bare. Photo: K. Deutschewitz.

Biological soil crust characteristics

	H49	H65	H70
Soil characteristics	Light grey fine sand with many gypsum crystals and small stones	Grey to yellow fine sand with mica and quartz pebbles	Grey to yellow fine sand with mica and quartz pebbles
Crust characteristics	Lichen-dominated BSC	Lichen-dominated BSC, partly with cyanobacteria	Lichen-dominated BSC
Chlorophyll a [mg/m²]	197.84	188.57	102.02
Chlorophyll a+b [mg/m²]	252.09	239.52	129.98
Carbon [weight %]	0.98	0.83	0.33
Nitrogen [weight %]	0.06	0.05	0.02

At a closer look, however, a dense coverage of mainly crustose and foliose lichens can be observed. Photo: K. Deutschewitz.

Responsible authors: B. Weber, K. Deutschewitz, S. Dojani, T. Friedl, T. Darienko, K. Mohr & B. Büdel

Lichens

Sampling period(s)	Hectare plots sampled	Cover
2005	n.a.	n.a.
Total species richness	Species richness on soil [1 km²]	Species richness on rock [1 km²]
12	3 (25%)	7 (58%)
Species richness on plants [1 km²]	Species richness on soil [1000 cm²]	
2 (17%)	n.a.	

This Observatory, close to the Atlantic coast, is clearly influenced by diurnal fog formation. With 12 taxa, the lichen richness is nevertheless lower than on the Observatory S16 (Wlotzkasbaken: 26 taxa), which is located closer to the sea. The absence of fruticose lichens, which is the growth-form most dependent on air humidity, could be interpreted as indicating less air humidity or fog. On the other hand lichens are common on all available substrates at this Observatory. Especially soil-inhabiting crustose lichens, like *Lecidella crystallina*, even reach extreme cover values. At the majority of the 100 hectare plots the cover by crustose lichens reaches 10 to 40%, in some cases even up to 70%! Therefore, either the close vicinity to major dune fields and the sand-blasting effect of wind-blown sand or the chemistry of the fog water may also be involved. Lichen growth on soil is supported by the presence of gypsum in the uppermost soil layers.

List of Taxa

Terricolous (on soil):

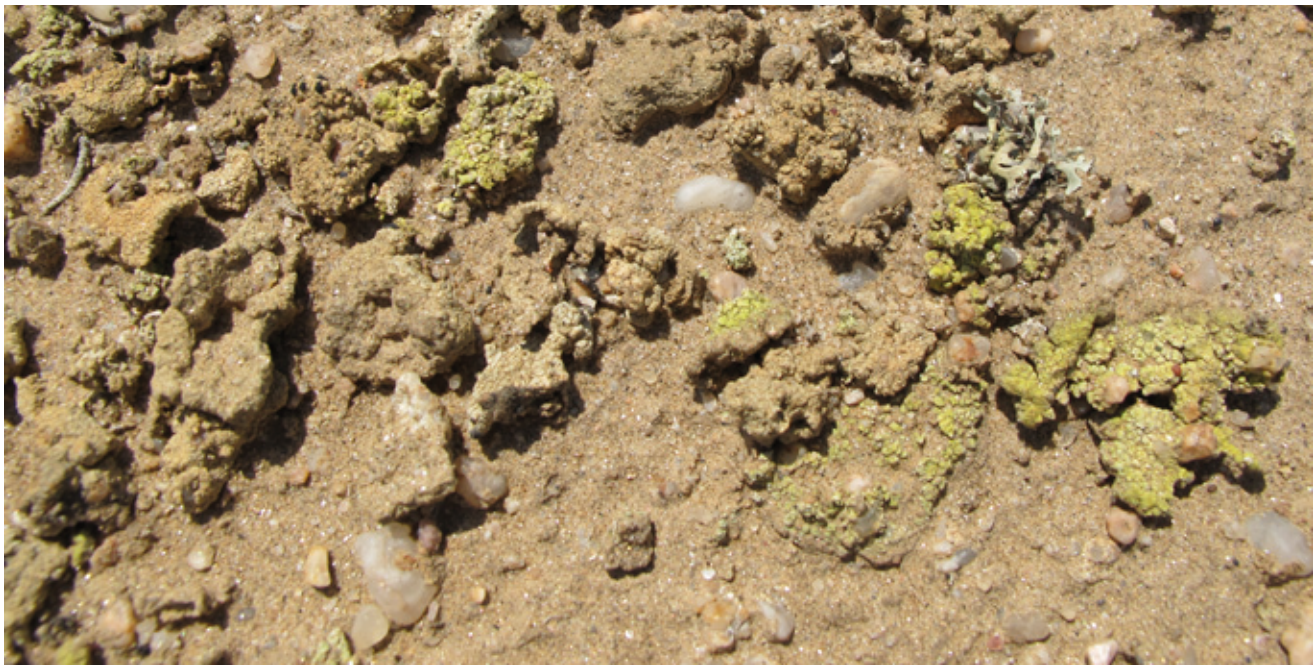
Acarospora sp. 01 (M-0125660)
Caloplaca volkii
Lecidella crystallina

Saxicolous (on rock):

Acarospora sp.
Buellia sp.
Caloplaca sp.
Caloplaca testudinea
Lecidella sp.
Xanthoparmelia dregeana s.l.
Xanthoparmelia walteri s.l.

Epiphytic (on plants):

Arthonia sp.
Xanthoria sp.



Crustous lichens including *Lecidella crystallina* and *Acarospora* cover the soil surface and gypsum crusts. Photo: N. Jürgens.

Crustous lichens including *Lecidella crystallina* and *Acarospora*. Photo: N. Jürgens.

Caloplaca volkii. Photo: M. Schultz, L. Zedda & G. Rambold.

Lecidella crystallina. Photo: M. Schultz, L. Zedda & G. Rambold.

Responsible authors: L. Zedda & G. Rambold

Vascular plants

Sampling period(s)	Hectare plots sampled	Biome
2010	100 (R1−R100)*	Namib Desert/ Succulent Karoo
Vegetation unit (level 1)	**Vegetation unit (level 2)**	**Identification rate**
Central Namib	n.a.	100%
Cumulative family richness	**Dominant families (cover)**	**Dominant families (richness)**
4	Amaranthaceae	Amaranthaceae
Cumulative species richness (1 km²)	**Species richness (1000 m²)**	**Species richness (100 m²)**
4 − 4	n.a.	n.a.
***z*−value**	**Species richness change per year (1000 m²)**	**Evenness (1000 m²)**
n.a.	n.a.	n.a.
Evenness (100 m²)	**Simpson (1000 m²)**	**Simpson (100 m²)**
n.a.	n.a.	n.a.

**Only plot size 10,000 m² sampled*

	0	1	2	3	4	5	6	7	8	9
0	34	52	7	20	20	1	0	0	28	10
1	23	22	3	16	5	0	0	0	5	44
2	14	17	12	14	8	5	0	0	52	20
3	9	11	18	30	7	1	0	1	28	14
4	20	24	22	23	18	0	2	10	2	17
5	30	11	40	20	9	1	3	23	10	16
6	50	13	7	15	9	0	3	5	1	3
7	21	15	25	0	19	0	16	23	1	1
8	2	7	8	3	7	0	2	1	1	9
9	9	24	0	11	7	2	4	1	0	1

	0	1	2	3	4	5	6	7	8	9
0	34	52	7	20	20	1	0	0	28	10
1	23	22	3	16	5	0	0	0	5	44
2	14	17	12	14	8	5	0	0	52	20
3	9	11	18	30	7	1	0	1	28	14
4	20	24	22	23	18	0	2	10	2	17
5	30	11	40	20	9	1	3	23	10	16
6	50	13	7	15	9	0	3	5	1	3
7	21	15	25	0	19	0	16	23	1	1
8	2	7	8	3	7	0	2	1	1	9
9	9	24	0	11	7	2	4	1	0	1

	0	1	2	3	4	5	6	7	8	9
0	34	52	7	20	20	1	0	0	28	10
1	23	22	3	16	5	0	0	0	5	44
2	14	17	12	14	8	5	0	0	52	20
3	9	11	18	30	7	1	0	1	28	14
4	20	24	22	23	18	0	2	10	2	17
5	30	11	40	20	9	1	3	23	10	16
6	50	13	7	15	9	0	3	5	1	3
7	21	15	25	0	19	0	16	23	1	1
8	2	7	8	3	7	0	2	1	1	9
9	9	24	0	11	7	2	4	1	0	1

Number of riverbeds per hectare:
1
2
3
4
5

Largest width of riverbeds per hectare [m]:
0
1
2-5
6-10
10-30
31-100

Dominant aspect of the hectare plot:
NE
SE
SW
NW

Number of individuals of *Arthraerua leubnitziae* per hectare (numbers in the cells) and number of riverbeds per hectare (left), largest width of riverbeds per hectare in meters (centre), dominant aspect of the hectare plot (right).

Kleinberg is by far the most species poor BIOTA Observatory in southern Africa. Only four vascular plant species were recorded during the years 2004 to 2010. It represents a good example of the coastal Namib Desert vegetation in the hinterland of Walvis Bay.

The dominant vascular plant is *Arthraerua leubnitziae* (Penbush) with 1178 individuals recorded in March 2010 (0 to 52 individuals per ha), which has not shown any changes since the first inventory in 2004. There is no simple explanation for the spatial distribution patterns of *Arthraerua leubnitziae*. On the one hand, it is obvious that a large proportion of Arthraerua individuals occur along the riverbeds. Some of the accumulations of *Arthraerua* are mirrored by either the number or the size of riverbeds per hectare. However, many other individuals are not associated with riverbeds at all. It may be that exposure to the fog-carrying south-west winds may explain the occurrence of these *Arthraerua* individuals. *Arthraerua* has often been interpreted as a fog-harvesting plant, or as a companion of riverbeds. However, the remarkable patterns of *Arthraerua* abundance within the 100 hectares is obviously not well correlated with parameters describing the presence and dimension of rivers now parameters reflecting fog exposition. However, no evidence regarding the recruitment of *Arthraerua* can be established before a new cohort of individuals establishes itself at the Observatory.

All other vascular plants on the Observatory play only a minor role. There are two individuals of *Salsola tuberculata*. There were about 80 dead individuals of a grass species, most probably the perennial species *Stipagrostis ciliata*, and about 100 dead individuals of the annual *Zygophyllum spongiosum*, which probably emerged after a good rainfall event between 2004 and 2009. The two latter species were only found in slight depres-

sions of approximately 3 m in diameter or at sites where the homogenous soil surface had been disturbed. These circular areas of soil disturbance often possess small mammal burrows and a higher density of stones at the surface than elsewhere.

The whole surface of the Kleinberg Observatory, exept riverbeds, is covered by crustous lichens at the soil surface. *Arthraerua leubnitziae* is the only important vascular plant growing in direct vicinity of smaller washes or on fog exposed SW hill slopes (in the background). Photo: N. Jürgens.

Bare patches without lichen crust often form slight depressions of a few meters diameter. Probably these are fossil burrow sites of soil digging mammals. Photo: N. Jürgens.

Disturbance and slight depressions caused by soil digging mammals allows penetration of rain water and growth of ephemeral vascular plants (*Stipagrostis ciliata*). Photo: N. Jürgens.

Responsible author: N. Jürgens

Termites

Taxon richness	Abundance index	Dominant (sub-) family
0	0	n.a.

No termites were observed at this Observatory. The harsh environmental conditions here including extremely low annual precipitation, a low mean annual temperature and sparseness of plant material are presumably hard to tolerate even for undemanding species such as *Hodotermes mossambicus* (see Observatory S39/Narais).

Responsible authors: C. Grohmann & K.E. Linsenmair

General data

Number	Name	Alternative name(s)
S35	Gobabeb	n.a.
Implementation	Country	Province/ region
2004	Namibia	Erongo
District/ constituency	Locality	Farm name
Swakopmund	Gobabeb	Gobabeb
Latitude	Longitude	Altitude
23.532409 S	15.046890 E	419 m a.s.l.
Rainfall season	Biome	WWF Ecoregion
Summer	Namib Desert	AT1315 Namib desert
Agro-Ecological Zone	Relative intensity of land use	Tenure
NAM6	None	State
Type and history of landuse	Land owner	
Conservation area	Government of Namibia	

Gobabeb (S35)

The Gobabeb Observatory forms part of the Namib Desert. However, a few dwarf shrubs are found close to rocks and after good rains also the gravel plains are covered with grasses. Photo: N. Jürgens.

The Gobabeb Observatory is located at an altitude of 419 m a.s.l. in the most arid part of the Central Namib Desert, 54 km inland from the Atlantic Ocean coast and 100 km west of the Great Escarpment. The Observatory is situated just 2.1 km north of the Khuiseb River, which forms the boundary between the Great Namib Dunefield (stretching uninterrupted over 340 km from Gobabeb to near Luderitz) and the Central Namib plains.

At the Observatory, the Central Namib plain consists of Damara granite and partly of schist of the Kuiseb formation of the Khomas Complex, and there is also one quartz outcrop. The topography is typical of a windshaped landscape with the formation of yardangs (i.e. wind-abraded ridges) and tafoni (i.e. small cave-like features in granular rocks). There are also drainage channels but without recent dynamics. The soils are shallow and saline. Compared to the Observatories Wlotzkasbaken (S16) and Kleinberg (S34), gypsum crusts are not visible at the soil surface. Fog from the Atlantic Ocean frequently reaches Gobabeb in spite of its distance from the coast (54 km). In contrast to the very saline coastal fog, the inland fog consists of "distilled water". The hyperarid climate at Gobabeb is of clear summer rainfall seasonality. Nevertheless, there may be winter rainfall during one of every four years. The flora consists of 27 species and is typical of the summer rainfall desert flora, with 15 annual species and 7 dwarf shrub species. Only two succulent species were observed to occur

at Gobabeb, compared to the high proportion of succulents at Wlotzkasbaken and Kleinberg.

The vegetation is very sparse and limited to scattered small shrubs at hydrologically favourable sites close to rocky outcrops. During good rainfall years, grasses of the genus *Stipagrostis* cover the plains.

Landuse is of low intensity and limited to grazing by donkeys and horses of the Topnaar communities, which live along the Kuiseb river valley. However, compared to the migratory springbok (*Antidorcas marsupialis*) and ostrich (*Struthio camelus*), the year-round grazing pressure exerted by donkeys and horses has strong negative impacts on the vegetation.

This Observatory forms part of the Namibian west-east transect, which was primarily established in order to monitor and describe the steep climatic coast-inland gradient.

At the Gobabeb Observatory there are two major ecosystem types. There are granite boulders in the more western parts and quartz gravel plains in the more eastern parts. Photo: N. Jürgens.

Within the quartz gravel plains a series of quartz outcrops defines a third habitat type. Note the Namib dunes in the distance. Photo: N. Jürgens.

Responsible authors: N. Jürgens & D.H. Haarmeyer

Remote sensing and landscape

Geomorphology	Geological units	Lithological units
Granit flats, quartz ridges, quartz gravel	Damara granite intrusions	Granites
Mean EVI	**EVI absolute range**	**Mean leaf area index**
0.056 (0.046–0.069)	0.030 (2001)–0.085 (2006)	0.00

Grid map of Observatory

	0	1	2	3	4	5	6	7	8	9
0	50	94	16	57	92	27	71	91	17	61
1	56	86	19	34	84	33	85	25	73	53
2	98	62	59	10	66	90	99	93	26	77
3	3	15	70	54	7	9	35	12	49	37
4	44	82	100	88	42	63	43	45	87	95
5	60	1	80	68	96	58	5	14	23	81
6	28	78	46	40	21	69	8	75	32	52
7	51	74	72	64	38	83	29	89	6	79
8	4	22	30	48	67	2	55	18	39	31
9	13	36	24	76	97	41	47	20	65	11

1	Quartz gravel plains
2	Granite flats
3	Quartz ridges
4	Transition between quartz gravel plains and granite flats

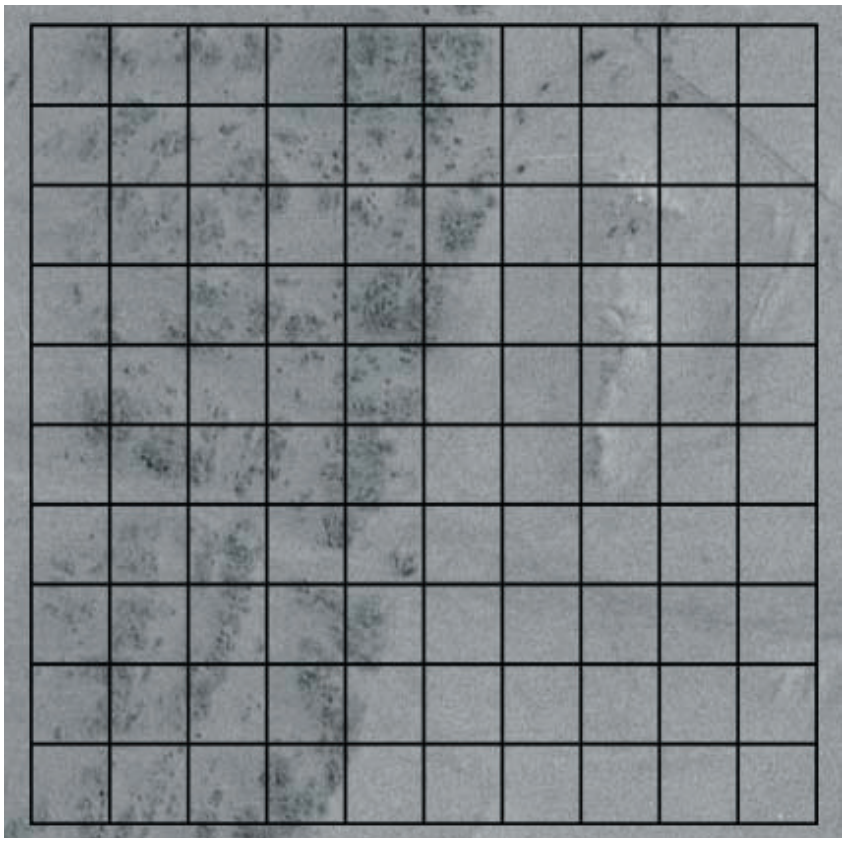
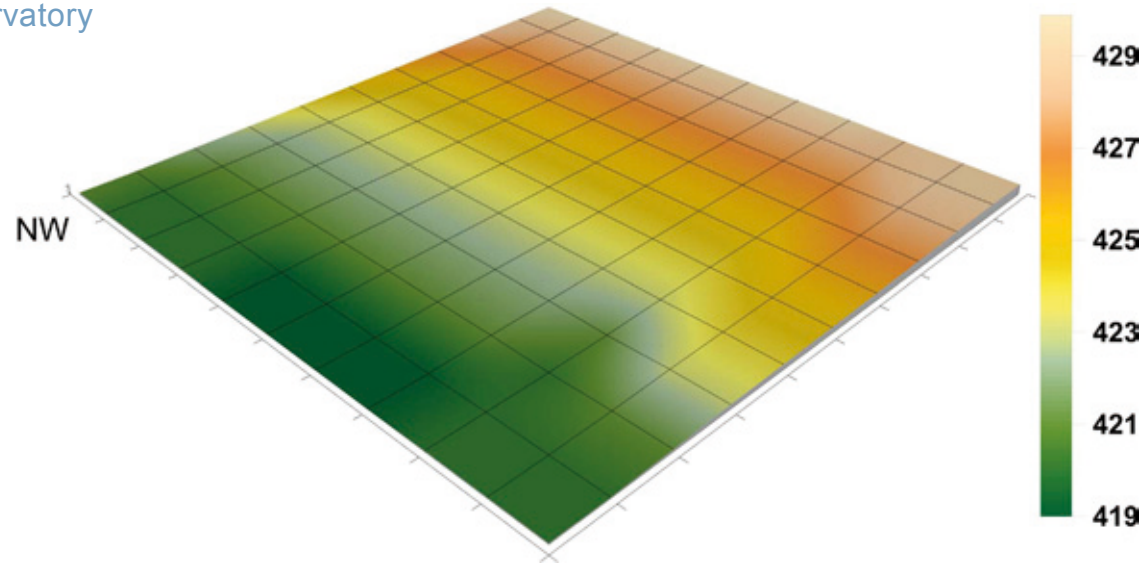


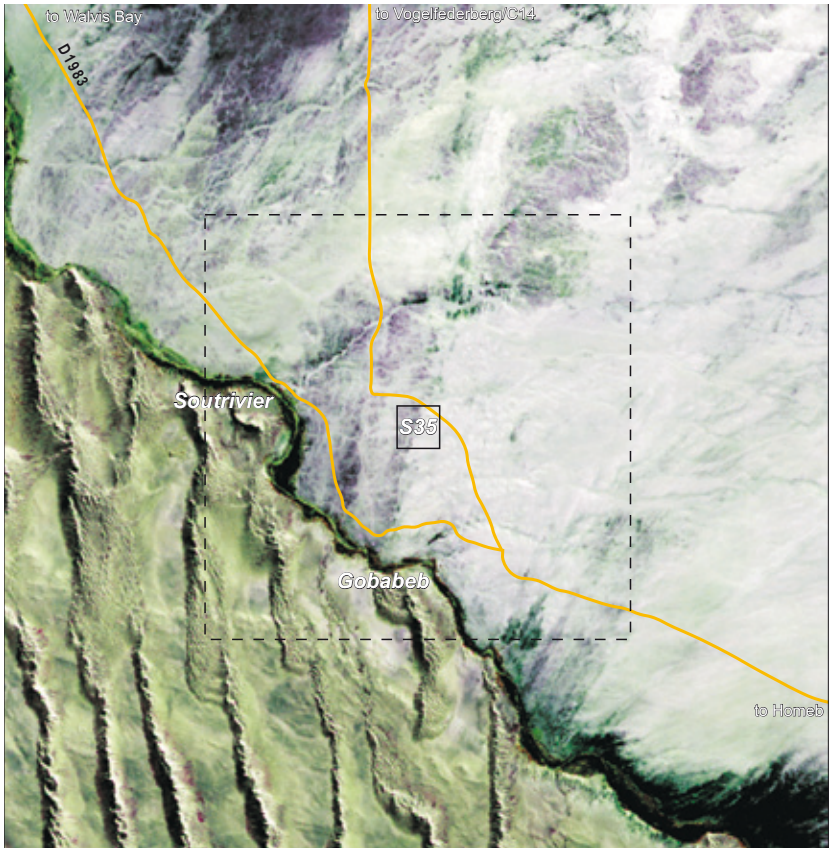
Image: aerial photograph

Elevation model of Observatory



Landsat image

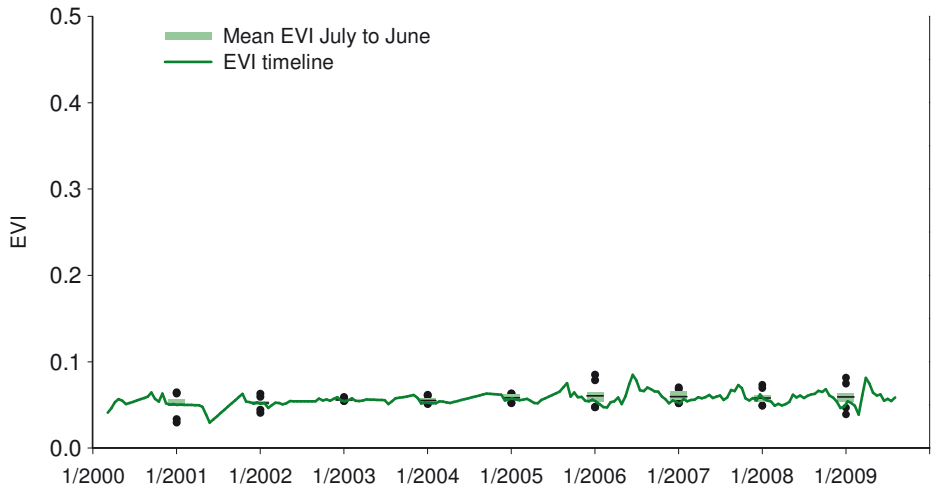
South of the Observatory, the Kuiseb River appears as a dark line draining in a north-westerly direction. The riverbed of the Kuiseb separates the large north-south orientated sand dunes in the south from a sand and gravel desert plain in the north, and shows as blue-grey and bright grey tones. The dark green tones in the Kuiseb River valley correspond to woody vegetation along the dry riverbed.



Scene: 179/76, acquisition date: 01 May 2003

MODIS time series

Temporal patterns of annual rainfall and vegetation cogy



Responsible authors: M. Keil & T. Labitzky

Climate

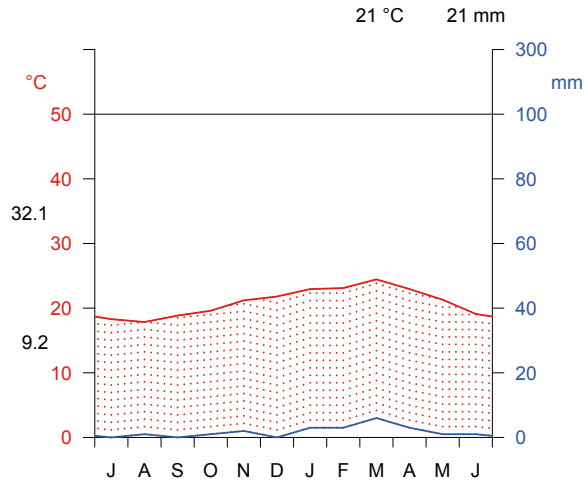
Modelled data

Mean temperature	Mean annual temperature range	Mean diurnal temperature range
21.0 (9.2–32.1) °C	6.6 °C	16.2 °C
Mean annual precipitation	**Precipitation seasonality**	**Percentage winter precipitation**
21 mm	84%	29% (summer)
Climate type	**Length of dry season**	**Aridity index (De Martonne)**
BWh	12 months	0.7 (dry)

Only interpolated data from the WorldClim dataset is available for this Observatory. The climate at the Observatory is characterised by hyper-arid conditions. Rainfall is fairly uniformly distributed throughout the year. The mean annual rainfall was 21 mm, which does not deviate much from the other Observatories within the Namib Desert, but makes it the driest Observatory of the transect. Near-surface air temperatures show a weak seasonal cycle. The mean annual temperature is 21.0°C and is therefore slightly warmer than the mean temperature of the Observatories in this biome.

Climate diagrams

Modelled data (WorldClim)



Responsible authors: K. Berger, A. Haensler & J. Luther-Mosebach

Biological soil crusts

Sampling period(s)	Hectare plots sampled	Types of soil crusts
2004	3 (R1–R2, R4)	6
Crust thickness	**Cover**	**Carbon [weight %]**
n.a.	less than 1%	0.173
Nitrogen [weight %]	**Chlorophyll *a* [mg/m²]**	**Chlorophyll *a+b* [mg/m²]**
0.009	1	2

Due to the extremely low mean annual rainfall of 21 mm (Section on climate) and the almost complete lack of fog (in contrast to Observatory S34/Kleinberg), biological soil crusts in this Observatory only rarely occur as hypolithic crusts underneath quartz pebbles (type 6). The extensive areas of bare soil (see Photo) are consistent with the extremely low chlorophyll, carbon, and nitrogen contents. Cyanobacteria and algae are very rare and not determined yet.

Biological soil crust characteristics

	H51	H80	H85
Soil characteristics	Yellow unweathered sand, rich in minerals (mica, feldspar, quartz)	Yellow unweathered sand, rich in minerals (mica, feldspar, quartz)	Yellow fine sand with quartz and mica, almost no feldspars
Crust characteristics	No BSC	No BSC	Little hypolithic BSC at an early development stage
Chlorophyll a [mg/m²]	0.78	0.28	2.25
Chlorophyll a+b [mg/m²]	1.21	0.57	3.54
Carbon [weight %]	0.19	0.17	0.17
Nitrogen [weight %]	0.01	0.01	0.01

The surface area around the Observatory Gobabeb looks bare. Photo: K. Deutschewitz.

Also during a close observation of the respective sites, no biological soil crusts are found. Photo: K. Deutschewitz.

Responsible authors: B. Weber, K. Deutschewitz, S. Dojani, T. Friedl, T. Darienko, K. Mohr & B. Büdel

Lichens

Sampling period(s)	Hectare plots sampled	Cover
2005	n.a.	n.a.
Total species richness	**Species richness on soil [1 km²]**	**Species richness on rock [1 km²]**
5	0	5 (100%)
Species richness on plants [1 km²]	**Species richness on soil [1000 cm²]**	
0	n.a.	

This Observatory is relatively poor in lichen richness in comparison with the other Observatories in the Namib Desert. Only a few crustose lichen species occur on granite and on quartz pebbles, while unstable sandy soils, which are probably lacking gypsum, do not allow growth of terricolous lichens. Epiphytic species are also absent as no woody plants that could serve as substrates occur here. A general survey of lichen richness was carried out at this Observatory and no sampling of lichen crusts was carried out at the hectare plot level.

List of Taxa

Terricolous (on soil):

No records

Saxicolous (on rock):

Acarospora sp.
Caloplaca sp.
Caloplaca testudinea
Lecanora sp.
Xanthoparmelia dregeana s.l.

Epiphytic (on plants):

No records

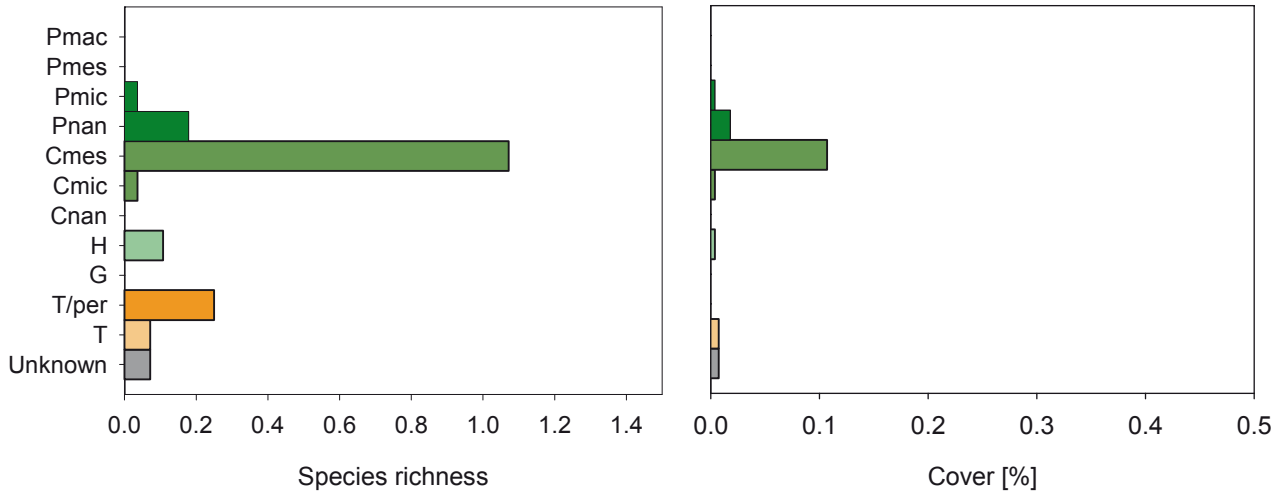
Acarospora sp. Photo: M. Schultz, L. Zedda & G. Rambold.

Responsible authors: L. Zedda & G. Rambold

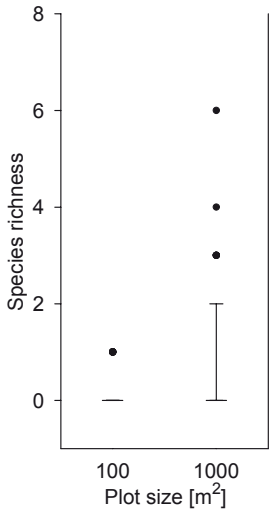
Vascular plants

Sampling period(s)	Hectare plots sampled	Biome
2004	20 (R1–R20)	Namib Desert
Vegetation unit (level 1)	**Vegetation unit (level 2)**	**Identification rate**
Central Namib	n.a.	33% – 46% – 50%
Cumulative family richness	**Dominant families (cover)**	**Dominant families (richness)**
10	n.a.	Fabaceae, Poaceae, Aizoaceae
Cumulative species richness (1 km²)	**Species richness (1000 m²)**	**Species richness (100 m²)**
33 – 33	0.6 (0–6)	0.1 (0–1)
***z*-value**	**Species richness change per year (1000 m²)**	**Evenness (1000 m²)**
0.837	n.a.	n.a.
Evenness (100 m²)	**Simpson (1000 m²)**	**Simpson (100 m²)**
n.a.	n.a.	n.a.

Life forms



Species richness

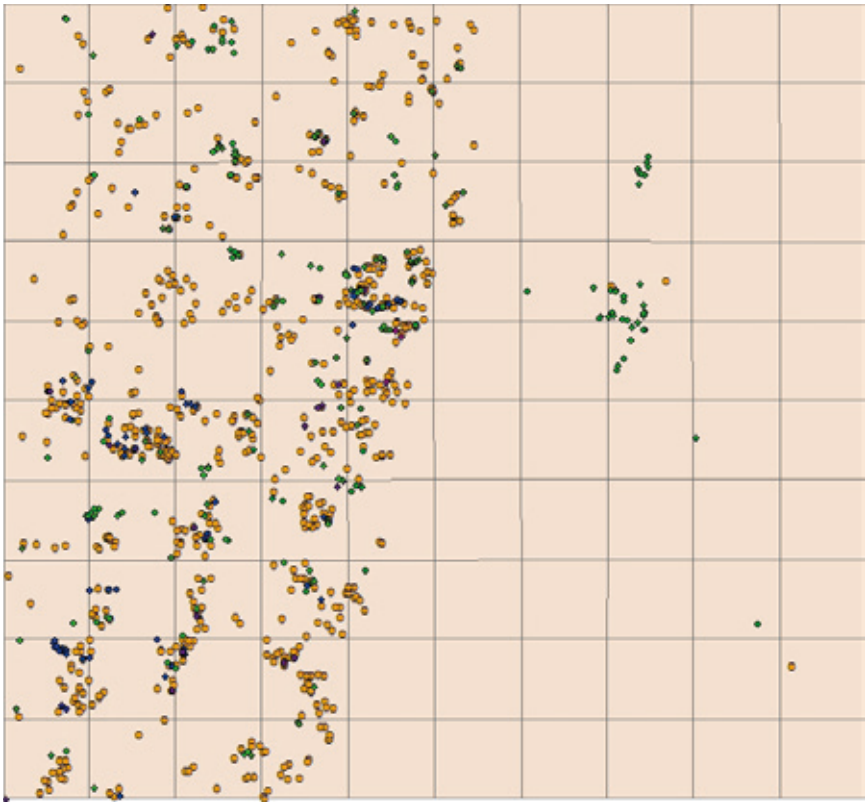


The vegetation of the Gobabeb Observatory is typical of the southern parts of the Central Namib Desert. While at a first glance there seems to be nearly no vegetation at all, the total species richness of the Gobabeb Observatory is in fact 10 times higher than at the Kleinberg Observatory (S34) close to Walvis Bay.

Dwarf shrubs (C mes) possess the highest species richness and highest cover values, whereas all other life forms occur only with very low species richness and low cover values. The families with highest cover values are Fabaceae and Poaceae. The family richness is the second-lowest amongst the Observatories along the BIOTA transects. The diversity of the Observatory is generally low, and species richness at small scales (100 m²–1 ha) is the lowest of all BIOTA Observatories. Only the species richness of the entire Observatory (1 km²) is comparable with the less arid Ganab Observatory (S36). The very low species richness up to the hectare scale and the comparably high species richness at the Observatory scale indicate a high species turnover. This is also reflected in a very high β-diversity, as expressed by high *z*-values at all transitions (i.e. 100 m²–1000 m², 1000 m²–1 km),

Species list (2004)

Column		Cover	All
Number of relevés			**28**
Mean cover [%]			0.2
Mean species richness (1000 m²)			1.9
Cmes	Calicorema capitata	0.10	68
T/Hper	Tephrosia dregeana	0.10	25
Cmes	Blepharis obmitrata	0.10	21
Cmes	Salsola tuberculata	0.10	18
Pnan	Asparagus pearsonii	0.10	11
Hper	Heliotropium tubulosum	0.10	11
T	Stipagrostis namibensis	0.10	7
Pnan	Orthanthera albida	0.10	7
n.a.	Stipagrostis gonatostachys	0.10	7
Pmic	Adenolobus pechuelii	0.10	4
H	Stipagrostis ciliata var. capensis	0.10	4
Cmic	Euphorbia phylloclada	0.10	4
T/Hper	Indigofera auricoma	0.10	4



Distribution of vascular plant individuals on the Gobabeb Observatory. Brown circles: *Calicorema capitata*. Blue circles: *Bleparis obmitrata*, mainly on the granite boulders in the western part. Green circles: *Salsola tuberculata*, mainly occurring on the quartz hills in the eastern part of the Observatory.

which are the highest amongst all southern African Observatories.

Vegetation distribution is extremely patchy. There are three strikingly different habitat types.

The vast plains that are covered by white, fine quartz gravel are devoid of vegetation. Only after good rainfall events masses of the leaf-succulent annual *Zygophyllum spongiosum* and the perennial grass *Stipagrostis gonatostachys* (Rough-Leaved Bushman Grass) germinate. Within the quartz gravel plains there are quartz veins, which are nearly exclusively inhabited by *Salsola tuberculata* plants. The majority of the plants occur in the habitat characterised by granite boulders, roughly covering the western half of the Observatory.

The most important species on the granite boulders is the broom-like dwarf shrub *Calicorema capitata*. It is accompanied by *Tephrosia dregeana*, *Salsola tuberculata*, *Hoodia pedicellata*, *Heliotropium tubulosum*, *Blepharis obmitrata*, *Aristida parvula*, and *Asparagus pearsonii*. All these plants grow in the immediate vicinity of granite boulders, where soil moisture is higher due to water run-off from the rocks.

Many small-scale patterns occur besides these three most important habitat types. Within the quartz gravel plains, for instance, soil polygons develop after good rains, which are mirrored by the emergence of *Stipagrostis gonatostachys* only.

Zygophyllum spongiosum is a frequent leaf succulent annual. Photo: N. Jürgens.

Salsola tuberculata is able to survive high salinity and aridity. “Stem splitting” allows survival of certain branches only, a drastic survival measure in periods of extreme drought. Photo: N. Jürgens.

Stipagrostis gonatostachys. Photo: N. Jürgens.

The flowers and fruits of *Calicorema* are often camouflaged by long white hairs. Photo: N. Jürgens.

Soil salinity is probably the main driver causing polygon structures especially with regard to the patterns of *Stipagrostis gonatostachys*. Photo: N. Jürgens.

The western part of the Observatory is dominated by granite boulders which redistribute water to certain favoured places. These are inhabitated by *Calicorema capitata* (five plants are shown in the image) and many other perennial dwarf shrubs. Photo: N. Jürgens.

Responsible authors: N. Jürgens, U. Schmiedel & J. Luther-Mosebach

Termites

Taxon richness	Abundance index	Dominant (sub-) family
1	3	Rhinotermitidae

The "sand termite" *Psammotermes allocerus* (see Observatory S11/Nabaos) was the only species encountered at this Observatory. It was collected from baits and by direct sampling. However, *Hodotermes mossambicus* (see Observatory S39/Narais) is not scarce in the vicinity of the research station Gobabeb. This species was collected at the station, at a distance of 2 km from the Observatory.

List of taxa

Taxon	(Sub-)family	Frequency Index	Feeding substrate
Psammotermes allocerus	Rhinotermitidae	0.22	w, d

Soil dumps of *Hodotermes mossambicus* close to the Observatory; the darker parts on top are fresh parts which still possess high moisture contents. Photo: C. Grohmann.

Wood baits showing different degrees of decomposition due to *Psammotermes allocerus* attacks. Photo: C. Grohmann.

Responsible authors: C. Grohmann & K.E. Linsenmair

Butterflies and moths

Sampling period(s)	Number of samples (moths)	Species richness (total)
2007/I; 2008/IV; 2009/I	3	45
Species richness (butterflies)	**Species richness (all moths)**	**Species richness (Microlepidoptera)**
2	43	10
Species richness (Pyraloidea)	**Species richness (Macrolepidoptera)**	**Species richness (Noctuidae)**
16	4	13
Individuals sampled (moths)	**Fisher's alpha diversity (moths)**	
306	10.4	

Butterflies

Chilades trochylus was the only species observed to occur at the Observatory. The butterflies were seen flying over patches of flowering *Zygophyllum* sp. This butterfly species also occurs in the valley of the nearby Kuiseb River.

Moths

Nearly all moth species collected at the lights on the Observatory were found to also live on the banks of the Kuiseb River. The species disperse from there into the Namib plains and reach the Observatory in small numbers, e.g. *Ctenusa varians* (Noctuidae) (see Photo). A distinction between autochthonous and Kuiseb born specimens is impossible in most cases. The abundant endemic species of S16 (Wlotzkasbaken) were not encountered at Gobabeb. However, a new and most likely endemic species of the Namib Desert (*Ephysteris* sp., Gelechiidae) was discovered and will be described in the near future (Mey 2010).

Taxonomic spectrum of moths

Family	S	N
Tineidae	1	1
Coleophoridae	1	1
Ethmiidae	1	7
Scythrididae	2	3
Gelechiidae	5	205
Microlepidoptera	**10**	**217**
Pyralidae: Phycitinae	5	15
Pyralidae: Pyralinae	3	17
Crambidae	8	14
Pyraloidea	**16**	**46**
Sphingidae	1	4
Geometridae	2	2
Arctiidae	1	6
Noctuidae	13	31
Macrolepidoptera	**17**	**43**
Total	**43**	**306**

Male of *Ctenusa varians*. Photo: W. Mey.

Responsible author: W. Mey

General data

Number	Name	Alternative name(s)
S36	Ganab	n.a.
Implementation	**Country**	**Province/ region**
2004	Namibia	Erongo
District/ constituency	**Locality**	**Farm name**
Swakopmund	Namib-Naukluft Park	Ganab
Latitude	**Longitude**	**Altitude**
23.121820 S	15.538440 E	995 m a.s.l.
Rainfall season	**Biome**	**WWF Ecoregion**
Summer	Namib Desert	AT1316 Namibian savanna woodlands
Agro-Ecological Zone	**Relative intensity of land use**	**Tenure**
NAM6	None	State
Type and history of landuse	**Land owner**	
Conservation area	Government of Namibia	

Ganab (S36)

The pediments of the mighty inselberg Ganab are mainly characterised by vast grasslands. Only along small rivers linear oases of *Acacia erioloba* and *Adenolobus gariepensis* are found. Photo: N. Jürgens.

The Ganab Observatory is located at 995 m a.s.l., 108 km east of the Atlantic Ocean coastline and some 30 km west of the first major steps of the Great Escapment which leads up to the African Plateau. The geology is partly characterised by Damaran granite, partly by schist of the Khomas Complex, and is mostly covered by younger sediments. These sediments are predominantly characterised by a finely layered calcrete, which is either directly at the surface (denudated by erosion) or covered with a shallow layer of fine material and gravel. Topographically, the Observatory forms part of a tilted plain, which is a pediment of the Ganab granite inselberg. There are a few rivers, which are either eroded down to a flat granite surface, or, if larger, covered by sandy river sediments.

Peculiar patterns of circular stone accumulations 2 to 3 m in diameter and mostly composed of calcrete fragments, but also including granite and schist elements, occur on parts of the Observatory. These stone circles are spaced at an average distance of ca. 30 m from each other. In good rainfall years, these stone circles are densely covered with grasses and are easily visible in the landscape due to the luxurious grass growth.

The sparse vegetation is a transition from semidesert grassland to savanna. Trees occur along linear oases, controlled by perennial water presence in the soils of drainage lines, while grasses dominate the calcrete plains. The smaller and very shallow dry rivers are characterised by an accumulation of dwarf shrubs. At

regular intervals along rivers flowing over exposed bedrock, larger shrubs and small trees form dam structures, which accumulate sediments and seeds. Larger river beds are accompanied by a gallery of trees and shrubs.

Being part of the Namib Naukluft National Park, there are no farming activities on the Observatory. Accumulations of Zebra (*Equus zebra*), Gemsbok (*Oryx gazella*), Springbok (*Antidorcas marsupialis*) and Ostrich (*Struthio camelus*) occur in the area depending on rainfall patterns.

This Observatory forms part of the Namibian west-east transect, which was mainly established to describe and monitor the steep climatic coast-inland gradient.

The vast grasslands covering the pediments of the Ganab inselberg in good rain years attract large numbers of Zebra and Ostrich. Photo: J. Beaumont.

Linear tree oases along riverbeds are characteristic for the transition between Namib and Savanna. Photo: J. Deckert.

A few weeks after a good rain, a riverbed is covered by germinating grasses and fringed by woody plants, in this case *Adenolobus gariepensis*. Photo: N. Jürgens.

At regular intervals along rivers flowing over exposed bedrock, larger shrubs and small trees form dam structures, which accumulate sediments and seeds. Photo: N. Jürgens.

Responsible authors: N. Jürgens & D.H. Haarmeyer

Remote sensing and landscape

Geomorphology	Geological units	Lithological units
n.a.	Damara granite intrusions, Khomas Group in Damara Supergroup and Gariep Complex	Granites, Schists
Mean EVI	**EVI absolute range**	**Mean leaf area index**
0.088 (0.071–0.128)	0.063 (2008)–0.222 (2006)	0.00

Grid map of Observatory

	0	1	2	3	4	5	6	7	8	9
0			14			18			10	
1	21	16	20		5					
2		22								
3		8						12	2	
4										
5		9				1		11		7
6	6									
7			15						17	
8		4		19						
9							13		3	

1 Grassland on rocky plain with variable denudated calcrete cover

2 Tree- and bush-lines along dry river beds (linear oases)

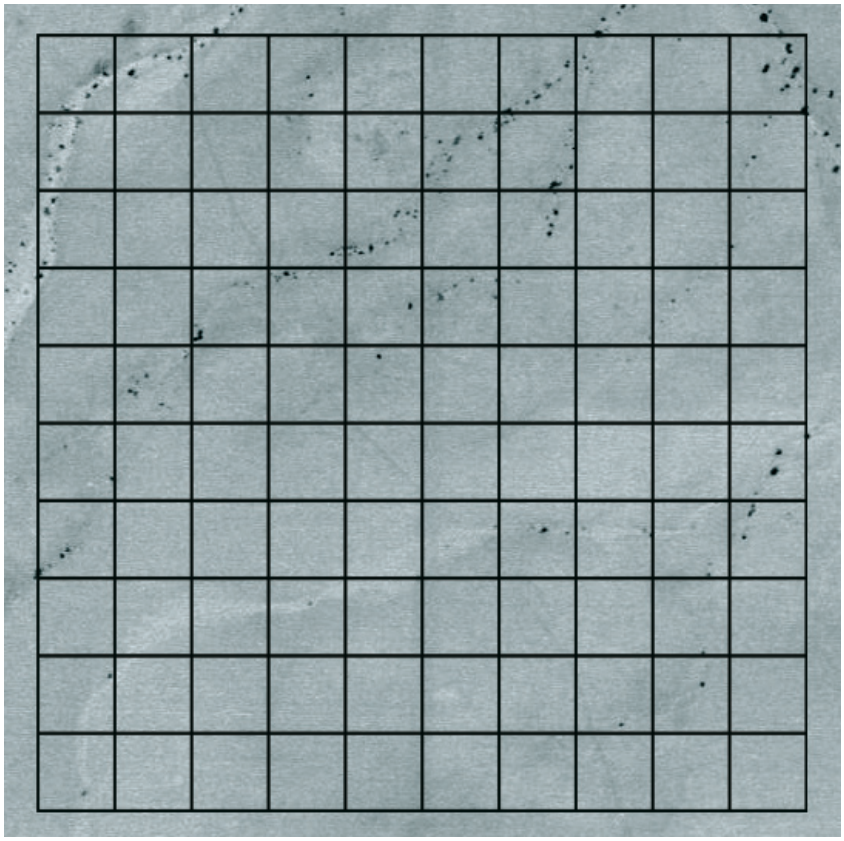
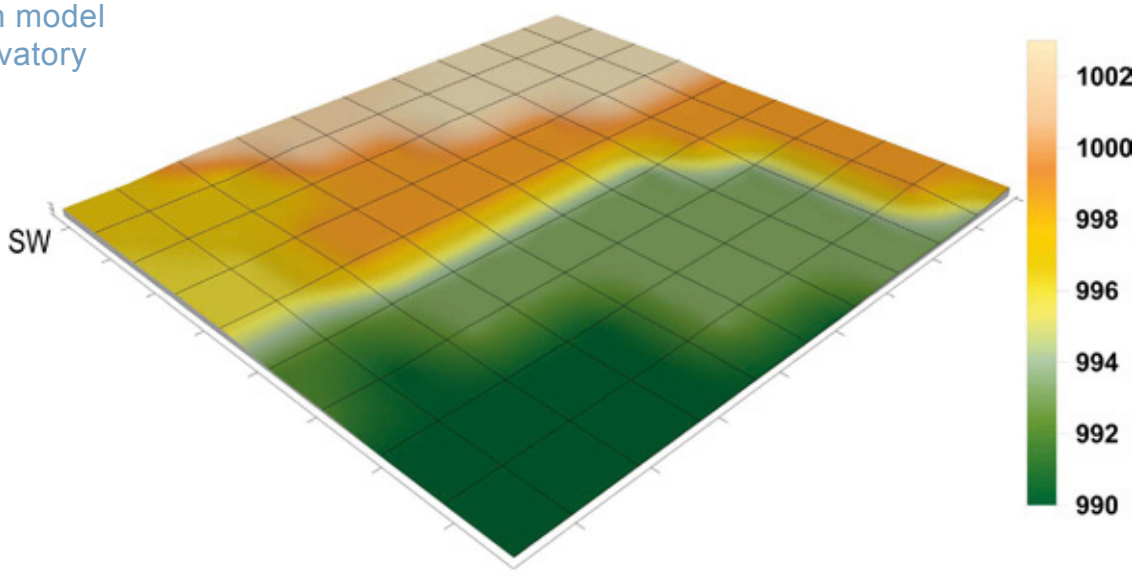


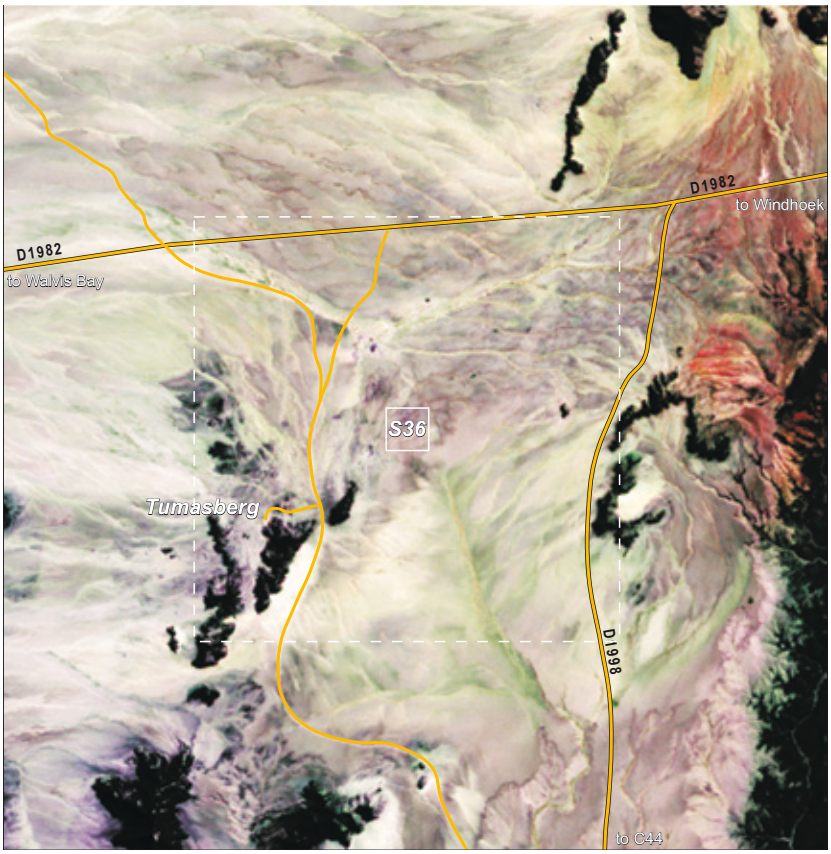
Image: aerial photograph

Elevation model of Observatory



Landsat image

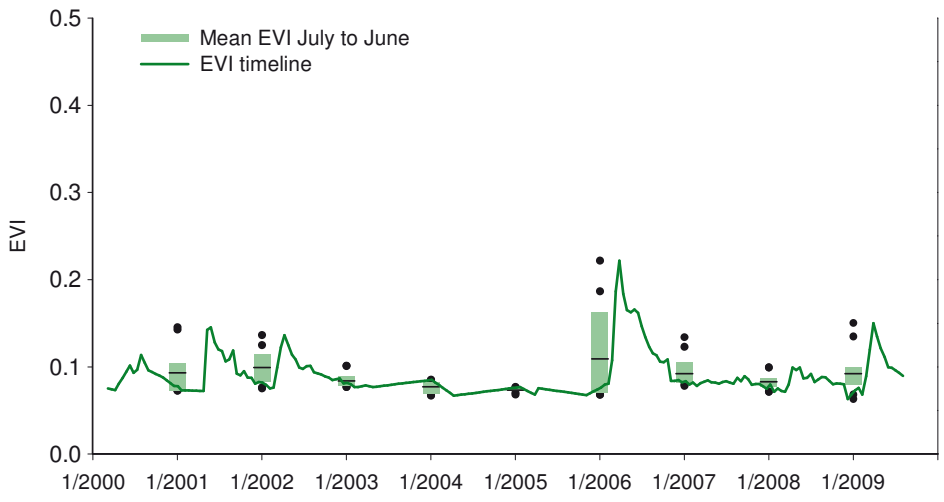
The pale colours (mainly light blue-grey to whitish tones) indicate a very sparse vegetation cover. Rocky cover (dark grey tones) is also sparse. Dark patterns also result from shadows cast by rocky hills because of the low angle of the sun at the time of image acquisition. Several drainage lines cross the desert landscape, with some draining to the west and some to the south. Scattered grass and shrub development is evident along several drainage lines, and is indicated by light green tones.



Scene: 179/76, acquisition date: 01 May 2003

MODIS time series

Temporal patterns of vegetation cover, and phenology



Responsible authors: M. Keil & T. Labitzky

Climate

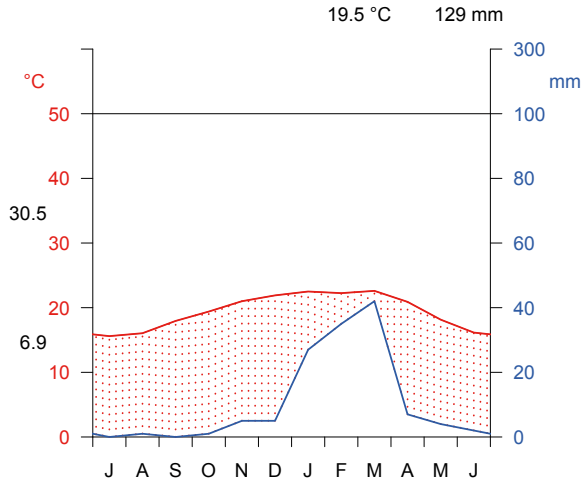
Modelled data

Mean temperature	Mean annual temperature range	Mean diurnal temperature range
19.5 (6.9–30.5) °C	7.0 °C	16.7 °C
Mean annual precipitation	**Precipitation seasonality**	**Percentage winter precipitation**
129 mm	130%	11% (strong summer)
Climate type	**Length of dry season**	**Aridity index (De Martonne)**
BWh	12 months	4.4 (dry)

Only interpolated data from the WorldClim dataset is available for this Observatory. The climate at the Observatory is characterised by semi-arid conditions. Rainfall shows a moderate seasonality with the major portion of rain falling during the summer season, peaking in March. The mean annual rainfall is 129 mm, which is fairly dry in comparison to the mean rainfall recorded at the Observatories along the entire transect, but makes it the wettest of all Observatories within the Namib Desert. Near-surface air temperatures show a weak seasonal cycle. The mean annual temperature is 19.5°C, which approximates the average for this biome.

Climate diagrams

Modelled data (WorldClim)



Responsible authors: K. Berger, A. Haensler & J. Luther-Mosebach

Lichens

Sampling period(s)	Hectare plots sampled	Cover
2006	n.a.	n.a.
Total species richness	**Species richness on soil [1 km²]**	**Species richness on rock [1 km²]**
1	0	1 (100%)
Species richness on plants [1 km²]	**Species richness on soil [1000 cm²]**	
0	n.a.	

This Observatory is relatively poor in lichens due to the higher aridity in comparison to other sites of the Namib Desert. Only one cyanolichen species was found on rock, and no lichens were observed growing on soil. Epiphytic lichens were absent mainly due to the lack of suitable phorophytes. No sampling of soil-inhabiting lichens was carried out at the hectare plot level.

List of Taxa

Terricolous (on soil):

No records

Saxicolous (on rock):

Phloeopeccania sp.

Epiphytic (on plants):

No records

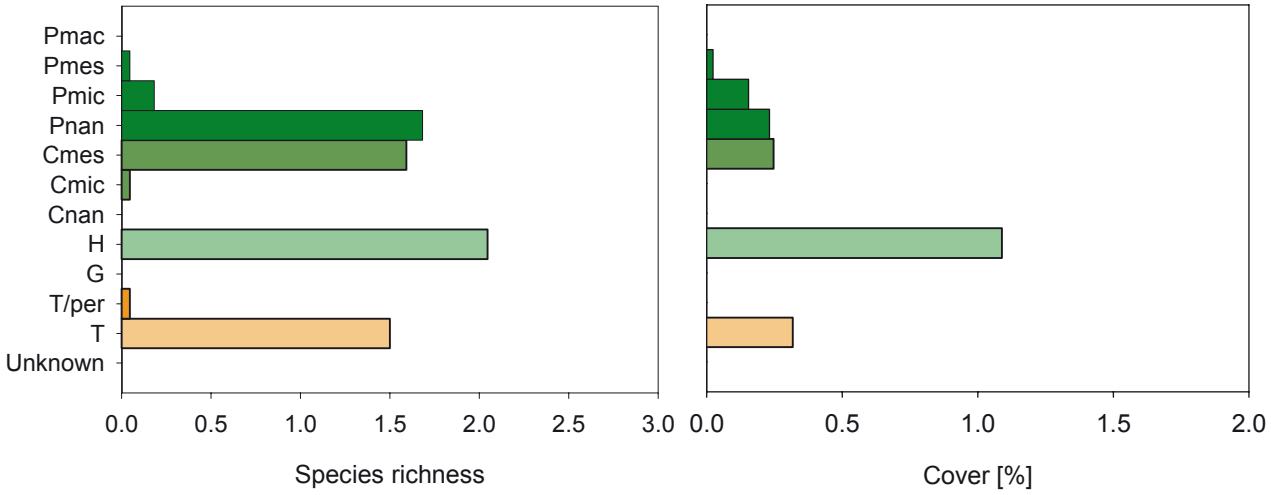
Phloeopeccania sp. Photo: M. Schultz, L. Zedda & G. Rambold.

Responsible authors: L. Zedda & G. Rambold

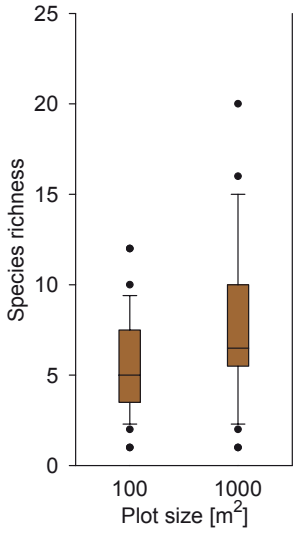
Vascular plants

Sampling period(s)	Hectare plots sampled	Biome
2010	20 (R1–R20)	Namib Desert
Vegetation unit (level 1)	**Vegetation unit (level 2)**	**Identification rate**
Central Namib	n.a.	98% – 98% – 97%
Cumulative family richness	**Dominant families (cover)**	**Dominant families (richness)**
28	Poaceae, Zygophyllaceae, Acanthaceae	Poaceae, Fabaceae, Acanthaceae
Cumulative species richness (1 km²)	**Species richness (1000 m²)**	**Species richness (100 m²)**
53 – 46	7.9 (1–20)	5.4 (1–12)
***z*-value**	**Species richness change per year (1000 m²)**	**Evenness (1000 m²)**
0.168 (0.000–0.301)	n.a.	0.666 (0.101–0.935)
Evenness (100 m²)	**Simpson (1000 m²)**	**Simpson (100 m²)**
0.545 (0.023–0.862)	0.602 (0.000–0.875)	0.489 (0.000–0.814)

Life forms



Species richness

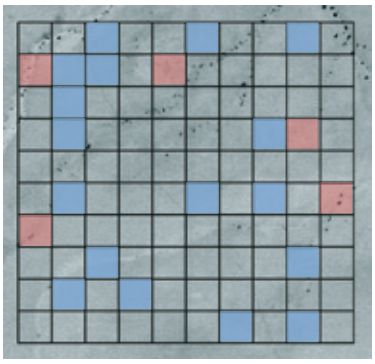


The vegetation of Ganab falls into the transition from savanna to the Namib Desert, often referred to as Pro-Namib. The savanna elements are restricted to the beds of ephemeral rivers, which are aptly described as linear oases, i.e. tree lines along the riverbeds. In addition, the plains are abundantly covered by grasses during good rainfall years. Comparable only to Karios (Observatory S12 at Gondwana Canyon Park), this Observatory is characterised by the sometimes extreme dominance of grasses in terms of cover, but with low species numbers ($N = 8$: *Enneapogon desvauxii*, *Eragrostis nindensis*, *E. porosa*, *Schmidtia pappophoroides*, *Stipagrostis ciliata*, *S. hirtigluma*, *S. hochstetteriana*, *S. obtusa*). Such semidesert-grasslands are known to occur at desert margins where there is a transition to higher summer rainfall ar-

Classification table (2010)

Column		Cover	All	1	2
Number of relevés			**22**	**5**	**17**
Mean cover [%]			2.2	3.5	1.8
Mean species richness (1000 m²)			8.1	13.4	6.5
Unit 1: Blepharis obmitrata-Monechma cleomoides community					
Cmes	Blepharis obmitrata	0.11	27	100	6
Cmes	Monechma cleomoides	0.32	45	100	29
Cmes	Phaeoptilum spinosum	0.30	9	40	.
Pnan	Commiphora saxicola	0.55	9	40	.
n.a.	Amphiasma merenskyanum	0.06	9	40	.
n.a.	Maerua parvifolia	0.16	9	40	.
Unit 2: Eragrostis nindensis-Zygophyllum cylindrifolium community					
Most frequent companions					
T	Eragrostis nindensis	0.39	91	60	100
H	Stipagrostis ciliata var. capensis	0.77	91	100	88
T	Cleome suffruticosa	0.09	82	100	76
Pnan	Zygophyllum cylindrifolium	0.12	68	80	65
H	Stipagrostis hirtigluma	0.44	59	40	65
T	Zygophyllum simplex	0.04	50	20	59
Cmes	Salsola tuberculata	0.08	50	40	53
Pnan	Petalidium setosum	0.22	32	60	24
n.a.	Hermannia affinis	0.03	27	60	18
T	Eragrostis porosa	0.23	23	40	18
Pnan	Calicorema capitata	0.26	23	60	12
Cmes	Blepharis grossa	0.07	14	40	6
n.a.	Indigastrum argyraeum	0.01	14	20	12
H	Stipagrostis hochstetteriana	0.34	14	40	6
Cmes	Cryptolepis decidua	0.10	9	20	6
Pnan	Asparagus pearsonii	0.01	5	20	.
n.a.	Citrullus ecirrhosus	0.10	5	20	.
Pmic	Boscia albitrunca	3.00	5	20	.
Cnan	Aptosimum spinescens	0.01	5	.	6
Pmic	Grewia tenax	0.50	5	20	.
Pmes	Euclea pseudebenus	0.50	5	20	.
Pnan	Gymnosporia senegalensis	0.30	5	20	.
T	Tephrosia dregeana	0.10	5	20	.
H	Stipagrostis obtusa	0.01	5	.	6
Cmes	Otoptera burchellii	0.10	5	20	.
Pmic	Boscia foetida	0.10	5	20	.
H	Schmidtia pappophoroides	0.01	5	20	.

Map of vegetation units



The semidesert plains of Ganab do not show much diversity. Therefore, in the vegetation classification, they are all grouped into one community (unit 2, see below). The vegetation of the drainage lines is very clearly separated from the plains, forming the *Blepharis obmitrata-Monechma cleomoides* community (unit 1). This community always possesses the non-succulent desert dwarf shrubs *Blepharis obmitrata* and *Monechma cleomoides*, which are accompanied by a number of shrubs, small trees, and climbers that are only found in unit 1, and never in unit 2.

This extreme divergence is due to the fact that the Observatory is located at the tilted pediment plain of the Ganab Inselberg. A large proportion of the water that moves either aboveground after good rains or belowground along the drainage lines, is to a large extent not generated by precipitation at the Observatory, but comes from upstream in the rocky landscape of the granite inselbergs. Therefore, the riverbed habitat has an azonal character, comparable to the Gariep and the Kunene Rivers flowing through the Namib Desert. Seven small tree species occur along the drainage lines: *Acacia erioloba* (Camelthorn), *Euclea pseudebenus* (Black Ebony), *Sterculia africana*, *Boscia foetida* (Noeniebos), *B. albitrunca*, *Maerua parvifolia*, *Ziziphus mucronata*. The following eight shrub species occur along the drainage lines: *Adenolobus garipensis*, *Commiphora glaucescens*, *C. pyracanthoides*, *C. saxicola*, *Grewia tenax*, *Gymnosporia senegalensis*, *Phaeoptilum spinosum*,

eas. However, in dry years, only certain desert shrubs survive.

Shrubs (P nan) and dwarf shrubs (C mes), perennial grasses (hemicryptophytes, H), and annuals (T) are the most species-rich life forms at Ganab. Hemicryptophytes (H, perennial grasses) are the life form that occurs with the highest cover values. The family Poaceae is also the most diverse and abundant floral element, indicating the importance of grasses at this Observatory. The family-richness is the highest amongst the Namib Desert Observatories but lies far below the transect-wide mean value. The species richness and Simpson index at all plot sizes is very low compared to most of the other Observatories along the BIOTA transects, but is the highest amongst the Observatories in the Namib Desert. The species turnover at small plot sizes (transition 100 m²–1000 m²) is amongst the lowest of all Observatories. However, the *z*-values for the transition 1000 m²–1 km² is high, even when compared to the other Observatories along the BIOTA transects.

Rhus marlothii. Besides the usual pattern of scattered trees and shrubs along drainage lines, a peculiar biogenic structure sometimes occurs on very rocky ground. Trees and shrubs create dams with their root systems and litter, which accumulate and store water after rains for prolonged time periods. This promotes the survival of trees and shrubs, which further strengthens the dam, thereby creating a positive feedback loop.

The plains are far more homogeneous in comparison to the riverbeds. The *Eragrostis nindensis-Zygophyllum cylindrifolium* community (unit 2) that occurs on the plains is characterised by the grasses *Eragrostis nindensis* (Agtdaepluimgras) and *Stipagrostis ciliata* (Langbeenboesmangras), the leaf-succulent dwarf shrub *Zygophyllum cylindrifolium* and the annual to perennial shoot-shedding herb *Cleome suffruticosa*. The dwarf shrubs *Petalidium setosum* and *Calicorema capitata* grow in the vicinity of riverbeds. However, they also occur on open plains, while the *Salsola tuberculata* (Gannabos) prefers the plains to the riverbeds.

The only heterogeneity within the plains is related to burrowing animals. There are many burrows created by small mammals, which form large gaps (of 3–5 m diameter) in the vegetation due to the excavated sand and stones. Abandoned burrows increase the diversity of herbaceous plants by providing pioneer sites and possibly improving infiltration of the rainwater into the soil. In many cases, ants colonise these burrows and contribute to spatial heterogeneity by their harvesting activities. Increased plant diversity is also found around stone circles as described in the introduction section.

Zygophyllum cylindrifolium is a characteristic plant of the plains of the Pro-Namib. Photo: N. Jürgens.

Petalidium setosum is a dwarf shrub frequently found in riverbeds. Photo: N. Jürgens.

Eragrostis nindensis is the most frequent grass species of the Pro-Namib. Photo: N. Jürgens.

Within river beds, *Monechma cleomoides* and *Petalidium setosum* may be the dominant plant species (unit 1). Photo: N. Jürgens.

In the plain habitats grasses are dominant, growing more abundantly on the stone circles (unit 2). Photo: N. Jürgens.

Responsible authors: N. Jürgens, U. Schmiedel & J. Luther-Mosebach

Termites

Taxon richness	Abundance index	Dominant (sub-) family
4	4	Hodotermitidae

Four taxa were encountered at this Observatory. Besides *Psammotermes allocerus* (see Observatory S11/Nabaos) and *Hodotermes mossambicus* (see Observatory S39/Narais), which also occur in the westward parts of the Namib Desert, *Amitermes* sp. and *Trinervitermes* sp. were collected.

List of taxa

Taxon	(Sub-)family	Frequency Index	Feeding substrate
Hodotermes mossambicus	Hodotermitidae	0.22	g
Psammotermes allocerus	Rhinotermitidae	0.11	w, d
Amitermes	Termitidae (Termitinae)	0.11	s, w, g
Trinervitermes	Termitidae (Nasutitermitinae)	0.11	s, w, g, l, m

Responsible authors: C. Grohmann & K.E. Linsenmair

True bugs

Sampling period(s)	Methods	Family richness
2007/I; 2008/IV	Trapping (light)	10
Species richness	**Individuals sampled**	**Fisher's alpha diversity**
18	35	14.88

At the BIOTA Observatory Ganab (S36) Heteroptera species from five families (Miridae, Rhyparochromidae, Alydidae, Stenocephalidae, and Rhopalidae) were most common at light traps (72%). The most common species were *Dicranocephalus schmitzi* (Stenocephalidae), *Euthetus leucostictus* (Alydidae) and *Dieuches herero* (Rhyparochromidae). All species are restricted to southern Africa. *Dieuches herero* is endemic to western Namibia and the Northern Cape.

Species richness in families

Family	*S*
Miridae	4
Rhyparochromidae	3
Alydidae	2
Rhopalidae	2
Stenocephalidae	2
Coreidae	1
Cydnidae	1
Micronectidae	1
Pentatomidae	1
Reduviidae	1
Total	**18**

Species abundances

Light traps

Species	Family	*N*	%
Dicranocephalus spec.	Stenocephalidae	8	23
Euthetus leucostictus	Alydidae	3	9
Miridae spec.	Miridae	3	9
Dieuches herero	Rhyparochromidae	3	9
Cydnidae spec.	Cydnidae	2	6
Piezodorus purus	Pentatomidae	2	6
Liorhyssus spec.	Rhopalidae	2	6
Hyalochilus scudderi	Rhyparochromidae	2	6
Others (10)		10	29
Total		**35**	**100**

Responsible author: J. Deckert

Butterflies and moths

Sampling period(s)	Number of samples (moths)	Species richness (total)
2007/I; 2008/IV	2	149
Species richness (butterflies)	**Species richness (all moths)**	**Species richness (Microlepidoptera)**
8	141	47
Species richness (Pyraloidea)	**Species richness (Macrolepidoptera)**	**Species richness (Noctuidae)**
30	20	44
Individuals sampled (moths)	**Fisher's alpha diversity (moths)**	
1034	29.8	

Butterflies

Being situated at the edge of the Namib Desert, the vegetation cover at this Observatory is sparse and a scattered shrubs and small trees only grow in the dry riverbeds. The climatic and biological conditions are not favourable for supporting the presence of a diverse fauna. However, the few observations made during 2007 and 2008 accumulated a list of 10 species. All of them have wide ranges in Namibia. Butterflies are absent from the area for most of the year.

Transect analysis

Sampling period: 08 April 2008. After a long rainy season with much rain in Namibia, many butterflies were observed. The number of specimens on the wing was high enough to perform a transect analysis.

Description of transect: the 1000 m transect starts on the north-western border of the Observatory and crosses the Observatory parallel to its western limit. The transect crosses several dry river beds with shrubby vegetation and small trees.

Species richness: 6; **number of individuals:** 82

Abundances

Species	*N*	Proportion
Belenois aurota aurota	64	78.1%
Vanessa cardui	11	13.4%
Hypolimnas misippus	3	3.6%
Chilades trochylus	2	2.4%

Moths

The moth fauna of this Observatory is diverse in Microlepidoptera, Pyraloidea, and Noctuidae but poor in Macrolepidoptera. Among the latter group, several specimens of *Salagena* sp. (Metarbelidae) and *Aethalopteryx dictyotephra* (Cossidae) were collected. Both species are endemic to Namibia. The micromoths are dominated by the ubiquitous *Ochrodia subdiminutella* (Gelechiidae) and *Ectoedemia vannifera* (Nepticulidae). *Spodoptera exigua*, *Eublemma* sp., and *Pseudozarba schencki* (see Photo) were the most abundant noctuids, while the Pyraloidea are represented by *Epicrosis nigrinella* (Pyralidae: Phycitinae) and two *Hypotia* species (see Photo) (Pyralidae: Pyralinae). The overall composition of the moth fauna is typical of the Nama-Karoo Biome.

Butterfly species and main food plants

Nymphalidae

Danaus chrysippus aegyptius	Asclepias, Stapelia, Cynanchum (Asclepiadaceae)
Hypolimnas misippus	Portulaca, Talinum (Portulacaceae)
Junonia hierta cebrene	Asystasia, Adhatoda, Barleria, Ruellia (Acanthaceae)
Vanessa cardui	Carduus, Arctotis, Berkheya (Asteraceae)

Lycaenidae

Iolaus subinfuscata subinfuscata	Tapinanthus (Loranthaceae)
Azanus ubaldus	Acacia (Fabaceae)
Chilades trochylus	Indigofera (Fabaceae), Heliotropium (Boraginaceae)

Pieridae

Belenois aurota aurota	Boscia, Capparis, Maerua (Capparaceae)

Female of *Pseudozarba schencki.* Photo: J. Deckert.

Female of *Hypotia* sp. Photo: W. Mey.

Taxonomic spectrum of moths

Family	S	N
Nepticulidae	3	32
Tischeriidae	1	1
Tineidae	5	8
Psychidae	1	1
Bucculatricidae	3	5
Yponomeutidae	2	3
Plutellidae	1	22
Lyonetiidae	1	1
Coleophoridae	3	11
Scythrididae	5	11
Oecophoridae	1	1
Autostichidae	1	4
Chrysopeleidae	2	8
Cosmopterigidae	2	2
Gelechiidae	12	530
Tortricidae	4	8
Microlepidoptera	**47**	**648**
Pyralidae: Phycitinae	10	36
Pyralidae: Pyralinae	6	16
Crambidae	14	45
Pyraloidea	**30**	**97**
Metarbelidae	1	8
Cossidae	1	4
Lasiocampidae	1	1
Sphingidae	2	10
Geometridae	14	31
Arctiidae	1	2
Noctuidae	44	233
Macrolepidoptera	**64**	**289**
Total	**141**	**1034**

Responsible author: W. Mey

Vertebrates

Total species richness	Reptile species richness	Bird species richness
2	n.a.	2
Large mammal species richness	**Small mammal species richness**	
n.a.	n.a.	

Birds

Passeriformes	Perching birds
Ammomanes grayi	Gray's Lark
Cinnyris fuscus	Dusky Sunbird

Photo: J. Dengler

Succulent Karoo

Boundaries

- International Boundary
- Provincial Border

Hydrography

- River
- Periodical River
- Salt Pan
- Lake
- Wetland

Contour Levels

- up to 300 m
- up to 600 m
- up to 900 m
- up to 1200 m
- up to 1500 m
- up to 1800 m
- more than 1800 m

Communications

- Motorway
- Road
- Railway

Populated Places

- City
- Provincial Capital
- Capital

- Transect
- S32 Elandsberg — BIOTA Observatory

0 250 500 km

Uwe Ulrich Jäschke & Karen Langner • HTW - University of Applied Sciences Dresden

Flowering succulent shrubs and daisies during spring in Namaqualand. Photo: J. Dengler.

Succulent Karoo

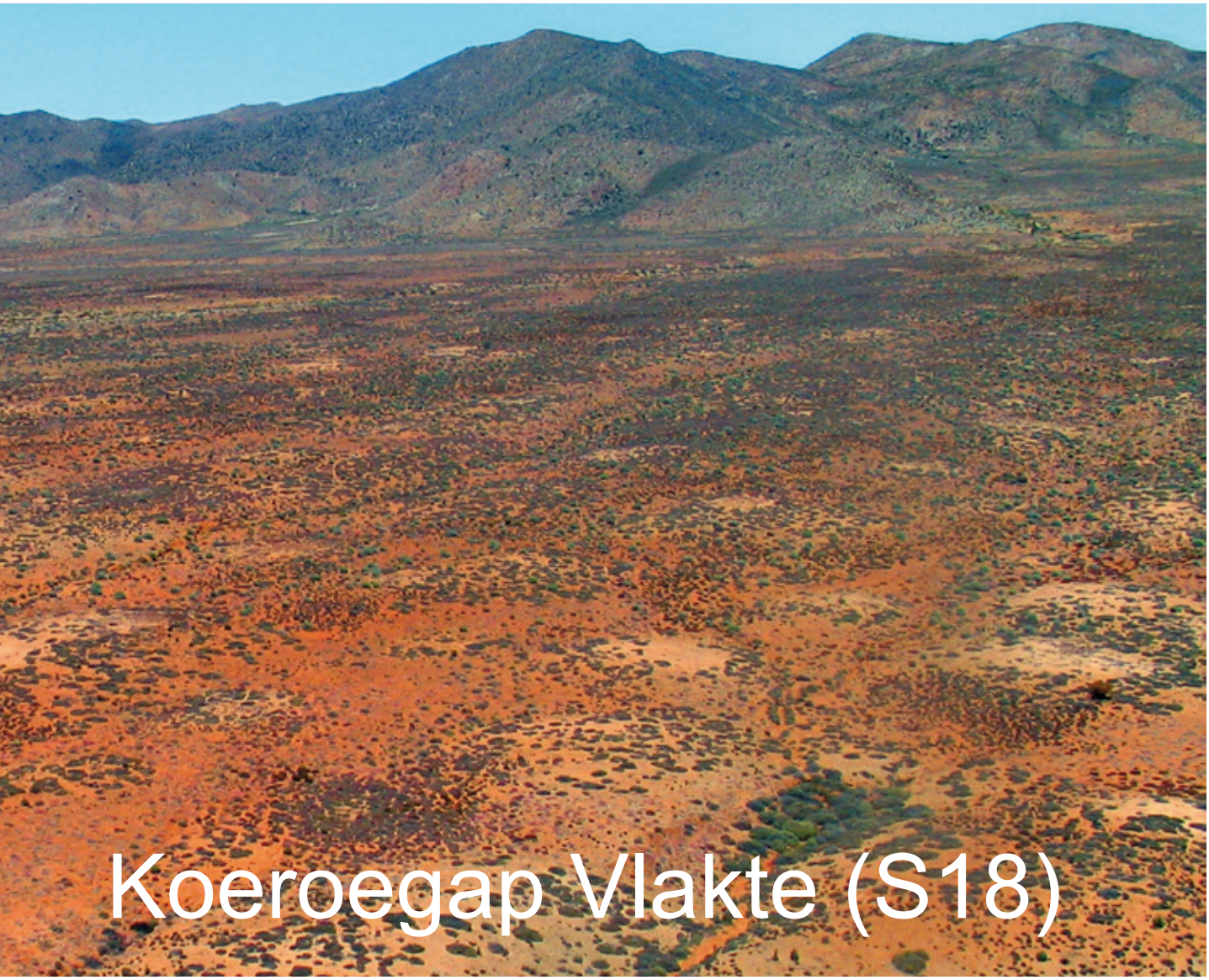
II.6.1 Koeroegap Vlakte (S18) 550
II.6.2 Numees (S20) 572
II.6.3 Groot Derm (S21) 594
II.6.4 Soebatsfontein (S22) 614
II.6.5 Paulshoek (S24) 644
II.6.6 Remhoogte (S25) 662
II.6.7 Goedehoop (S26) 680
II.6.8 Ratelgat (S27) 698
II.6.9 Moedverloren (S28) 716

The Succulent Karoo Biome of southern Africa is renowned as one of the world centres of endemism and biodiversity. The biodiversity of the Succulent Karoo Biome is primarily driven by mild climatic conditions (winter rainfall with mild temperatures during the growing season, and additional water supply from fog and dew), and small-scale patterns in pedodiversity that are driven by abiotic (geology, soils) and biotic (bioturbation by termites and small mammals) factors. This results in typically patchy habitat conditions and related small-scale patterns of vegetation and phytodiversity. Due to the low annual rainfall, the carrying capacity of the rangelands is very low and the very rich biodiversity is threatened by habitat transformation and subsequent species loss due to unsustainable landuse (overgrazing, ploughing, and mining) as well as projected climate change.

The BIOTA Observatories cover the major parts of the western Succulent Karoo (i.e. Namaqualand), from the very arid Richtersveld in the north (S18 Koeroegap Vlakte, S20 Numees, S21 Groot Derm) to the Knersvlakte in the south (S26 Goedehoop, S27 Ratelgat, S28 Moedverloren) and from the lowland Namaqualand near the coast (S22 Soebatsfontein) to the high mountains (S24 Paulshoek and S25 Remhoogte) in the east. The latter Observatory pair represents a strong fence-line contrast between the Paulshoek commonage, a homeland during the apartheid era, which is an important component of the economy and subsistence activities of a large number of poor people, and the privately owned neighbouring commercial farm. [U. Schmiedel]

General data

Number	Name	Alternative name(s)
S18	Koeroegap Vlakte	n.a.
Implementation	Country	Province/ region
2001	South Africa	Northern Cape
District/ constituency	Locality	Farm name
Namakwa	Sendelingsdrif	Koeroegap Vlakte
Latitude	Longitude	Altitude
28.226646 S	17.025668 E	635 m a.s.l.
Rainfall season	Biome	WWF Ecoregion
Winter	Succulent Karoo	AT1322 Succulent Karoo
Agro-Ecological Zone	Relative intensity of land use	Tenure
n.a.	Medium	Communal
Type and history of landuse	Land owner	
Semi-nomadic farming with goats and sheep (and cattle)	Richtersfeld Community / SANParks	



Koeroegap Vlakte (S18)

The Koeroegap Vlakte Observatory forms a tilted plain, structured by a number of smaller and one large riverbed. Circular vegetation patterns in the 5 to 10 m range are visible all over the square kilometer, most of them related to termitaria (heuweltjies).
Photo: N. Jürgens.

The Koeroegap Vlakte Observatory is located at an altitude of 635 m a.s.l. in the Richtersveld National Park, 70 km north-east of the Atlantic Ocean. It is surrounded to the west, north, and east by a loop of the Gariep River, which lies 17 km away, and is only 22 km east of the dune fields (Obib Dune) situated in the Namibian Sperrgebiet of the Namib Desert.

The Koeroegap Vlakte (or Koeroegabvlakte) forms a system of tilted plains (Northern Koeroegab, Upper Koeroegab, Southern Koeroegab, Lower Koeroegab), dissected by smaller mountain chains (gneissic granites of the Vioolsdrif Suite, 1.7–1.8 Ga), which are connected by plains and river courses.

Altitude decreases constantly over a distance of 13 km, from the highest parts of the plain in the south-west at 720 m a.s.l. to the lowest part at 260 m a.s.l. in the north-east, just before the plain narrows to the gorge of the lower Kookrivier, near De Hoop. A sharp decrease in winter rainfall is associated with this altitudinal gradient. A mean annual rainfall of 138 mm was recorded at the Observatory weather station from 2001 to 2009. The probability of winter rainfall generally decreases from the south-west to the north-east, while the probability of summer rainfalls increases.

The soil surface and the vegetation display a regular pattern caused by so called "heuweltjies" (old termitaria, which form large flat mounds). These termitaria are frequently inhabitated by the termite *Microhodotermes viator*, and

burrowing small mammals may also inhabit the central parts of these structures. Zoogenic disturbance, high salt, calcrete accumulations, and silcrete rings at the centre of the termitaria facilitate the establishment of distinct vegetation patches on these structures. Short-lived annuals and opportunistic life forms dominate on the centre of heuweltjies, while the margins accommodate more luxurious vegetation than the surrounding matrix vegetation.

Landuse is limited to pastoral smallstock farming. Stock rates have been fixed to a limited number of livestock since the proclamation of the Richtersveld National Park in 1991. However, this has not resulted in any significant changes to the vegetation in the Koeroegap Vlakte area. During the last decade, the pastoralists have created new roads within the Observatory, which lead to their stockpost. Gemsboks (*Oryx gazella*) have been observed at the Observatory since 2008, following their re-introduction to the area by South African National Parks.

The Koeroegap Vlakte Observatory and a few additional experimental monitoring plots were established in order to observe whether a trend of increasing erosion is taking place in the area. In addition, together with the Observatories Numees (S20) and Groot Derm (S21), the Koeroegap Vlakte Observatory allows monitoring of the boundary and steep gradient between the winter rainfall and the summer rainfall regimes. Ecophysiological measurements and climate change experiments are conducted within a fenced experimental plot of 1 ha located east of the Observatory (see for instance Article III.6.1).

Erosion and sedimentation, both triggered by overgrazing and trampling and by extreme rainfall events, cause disturbance along linear systems. Photo: N. Jürgens.

One large central riverbed expanded its sedimentation fan to almost one fifth of a square kilometer, during the last 70 years. Photo: N. Jürgens.

Responsible authors: N. Jürgens & D.H. Haarmeyer

Remote sensing and landscape

Geomorphology	Geological units	Lithological units
Flat valley, rivier	Namaqua and Natal Metamorphic Provinces	Migmatite, gneiss, ultrametamorphic rocks
Mean EVI	**EVI absolute range**	**Mean leaf area index**
0.121 (0.098–0.167)	0.091 (2005)–0.284 (2006)	0.39

Grid map of Observatory

	0	1	2	3	4	5	6	7	8	9
0	86	100	5	52	51	59	41	10	13	85
1	61	94	79	62	35	98	31	47	80	84
2	15	28	16	60	54	48	4	82	91	27
3	68	21	96	42	17	81	75	76	66	97
4	26	90	2	77	45	29	20	74	89	14
5	12	88	83	38	58	95	19	37	63	9
6	78	33	3	72	67	36	39	44	92	56
7	69	24	64	93	53	32	25	50	23	87
8	6	70	57	55	73	7	1	30	18	49
9	11	8	22	65	34	99	71	43	46	40

1 Plain with heuweltjies

2 Rivier with tall shrubs

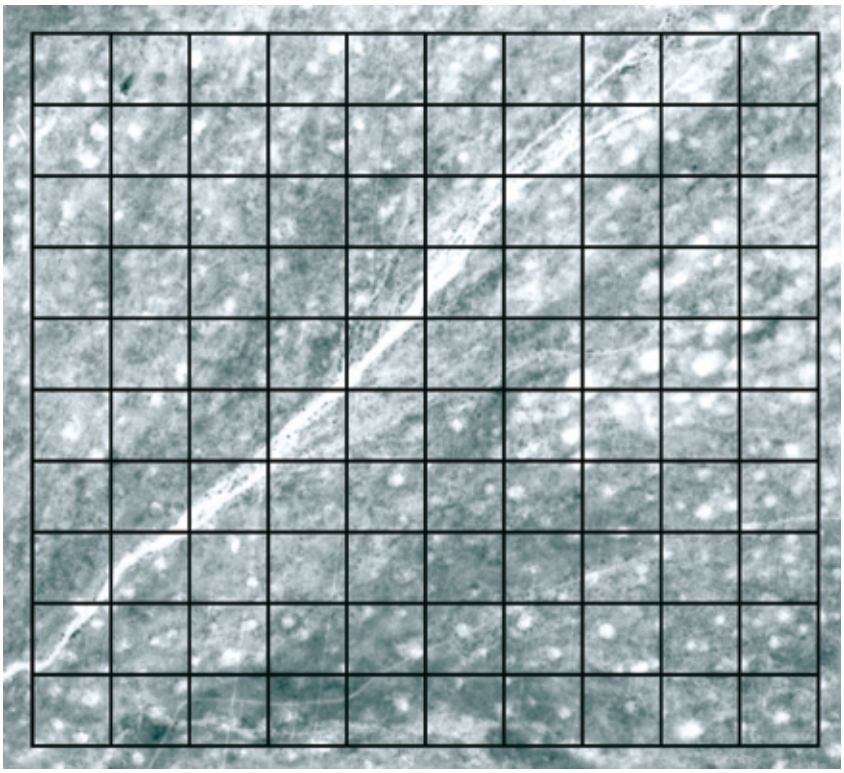
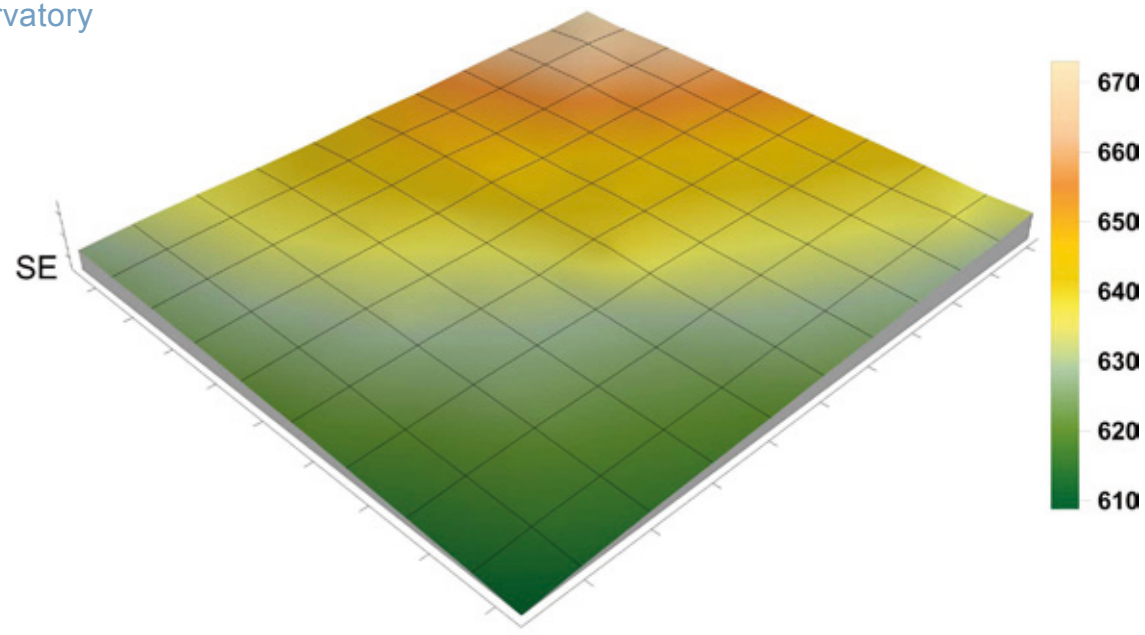


Image: aerial photograph

Elevation model of Observatory



Landsat image

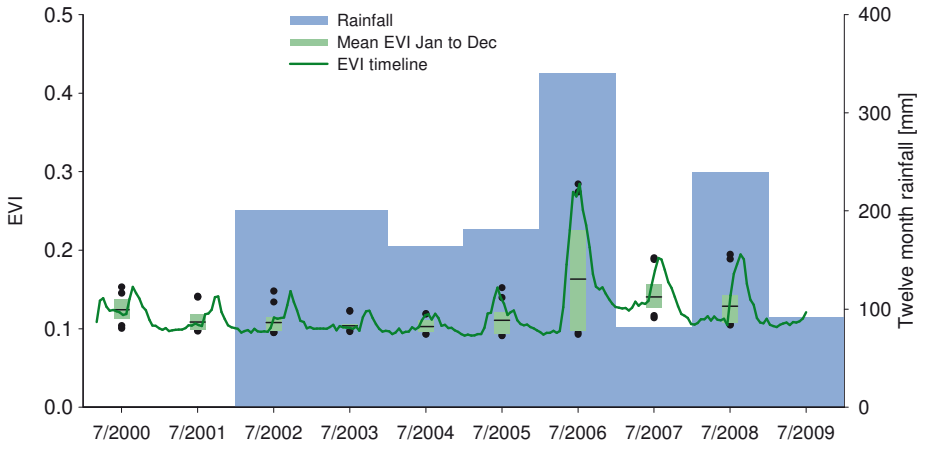
Geology and topography are highly diverse, which can be seen in the Landsat data of 30 m resolution, especially concerning topography. The plains drain to the north-east into the Gariep River (outside the image).

The rugged Richtersveld Mountains form a mountainous desert with highly diverse vegetation dominated by succulent plants. The plains possess a continuous sparse vegetation cover of succulent shrubs (light blue-grey to green-grey tones), interrupted by washes and areas of little or no vegetation (brighter colours). The vegetation cover on the mountain slopes shows as light green tones.

Scene: 177/80, acquisition date: 08 February 2003

MODIS time series

Temporal patterns of annual rainfall, vegetation cover, and phenology



Responsible authors: M. Keil & T. Labitzky

Climate

Data from BIOTA weather station

Location	Recorded period	Mean temperature
Koeroegap Vlakte (S18)	2001–2009	20.6 (4.6–42.3) °C
Mean solar radiation	**Mean wind speed**	**Mean annual precipitation**
605 (346–908) MJ·m^{-2}·month^{-1}	3.5 (11.2) m·s^{-1}	138 (11–265) mm
Mean annual potential evapotranspiration	**Interannual precipitation variability**	**Mean relative humidity**
1348 mm	160%	51% (26–70%)
Aridity index (UNEP)		
0.10 (arid)		

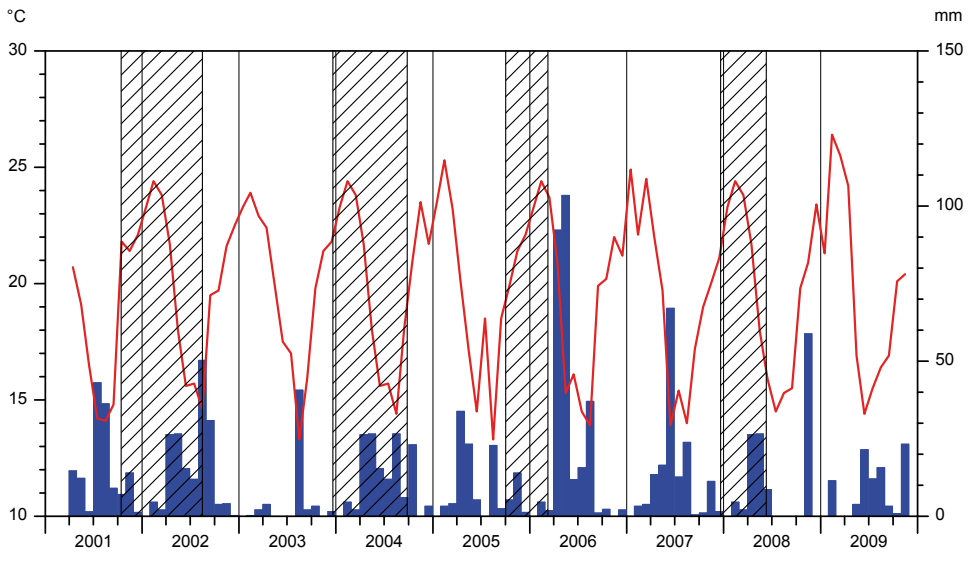
Modelled data

Mean temperature	Mean annual temperature range	Mean diurnal temperature range
16.9 (5.8–27.2) °C	8.8 °C	12.6 °C
Mean annual precipitation	**Precipitation seasonality**	**Percentage winter precipitation**
73 mm	29%	58% (even)
Climate type	**Length of dry season**	**Aridity index (De Martonne)**
BWh	12 months	2.7 (dry)

The climate at the Observatory is characterised by arid conditions. Rainfall shows a weak seasonality with the major portion of rain falling between April and August. The mean annual rainfall over the observation period was 138 mm, which is fairly dry in comparison to the average rainfall recorded over the entire transect, but is intermediate for the Succulent Karoo. However, substantial interannual variability is evident. Observed near-surface air temperatures show a weak seasonal cycle. The mean annual temperature is 20.6°C, which is slightly warmer than the average for this biome. Compared to the interpolated long-term data taken from the WorldClim dataset, a markedly warmer mean annual temperature is observed at the BIOTA weather station. Furthermore, the station records of temperature extremes deviate substantially from the interpolated data, showing warmer maximum and minimum temperatures. For precipitation, mean annual rainfall observed at the BIOTA weather station is almost twice the amount of the WorldClim dataset.

The observed near-surface winds at the Observatory are fairly variable. The major portion of wind originates from a westerly direction, but a southerly and south-westerly component are also apparent. Mean wind speed shows a moderate annual cycle in the mornings and a pronounced annual cycle in the evenings, with reversed amplitudes. However, winds during the early afternoon stay fairly constant throughout the year, reaching about 15 km/h.

Time series: rainfall and temperature

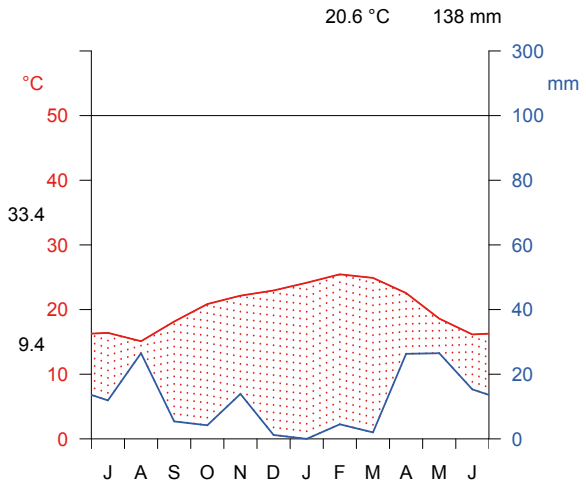


Humidity is mainly transported into the Koeroegap Vlakte from southwestern direction. Turbulences caused by the passage over the highest ridges of the Vandersterrberge defines the pathways of humidity. Photo: N. Jürgens.

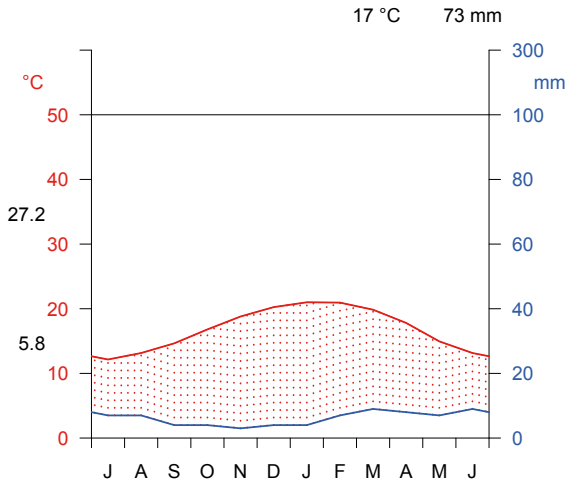
Fog is creeping into the Koeroegap Vlakte behind the weather station. Photo: N. Jürgens.

Climate diagrams

Recorded data (BIOTA)

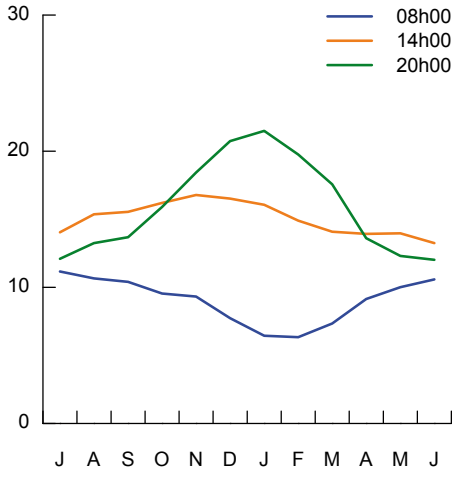


Modelled data (WorldClim)

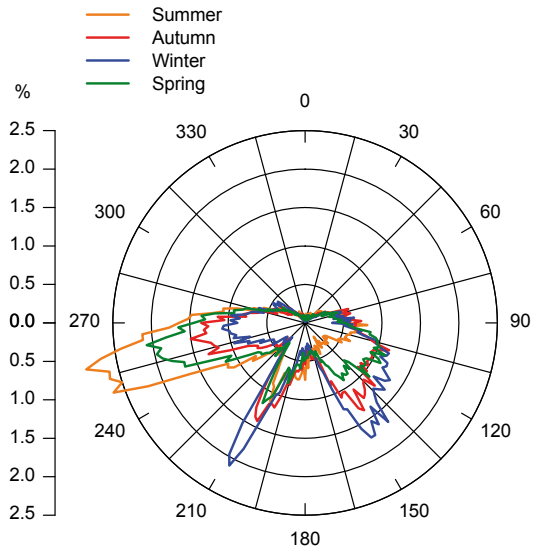


Wind diagrams

Speed



Directions



Responsible authors: K. Berger, A. Haensler & J. Luther-Mosebach

Soils

Year of sampling	Hectare plots sampled	SOTER unit
2002	25 (R1–25)	ZA1237
Soilscape	**Dominant soil group(s)**	**Reference group richness**
Solonchak	Durisol	4
Soil unit richness	**Soil unit evenness**	**Soil ecotype richness**
11	0.674	14
Parametric space	**pH**	**Electrical conductivity**
3.44	8.8 (7.9–9.8)	83 (31–542) $\mu S \cdot cm^{-1}$
Organic carbon		
0.31% (0.10–1.65%)		

On this Observatory, a relatively high number of soil units occur, of which Durisols are dominant, followed by Cambisols. Only two profiles along the dry river exhibited fluvic properties and are thus classified as Fluvisols. One profile on a heuweltjie was strongly salt-affected, resulting in a Hypersalic Duric Solonchak. The depth of the duripan, the intensity of the reddish colour and the substrate qualifiers mainly justify the distinction between the Durisols and Cambisols. Durisols are associated with the heuweltjies (fossile termitaria) and their surrounding rings of silcretes. The proportion of Cambisols is higher in the south-eastern part of the Observatory where most likely larger amounts of non-duric soil material accumulated after the establishment of the heuweltjies and covered older duripans. Common features on the Observatory are the calcareous fine earth and concretions in the heuweltjie structures, which are most likely of biogenic origin, as the soils have developed in relatively base-poor, granite-derived substrates.

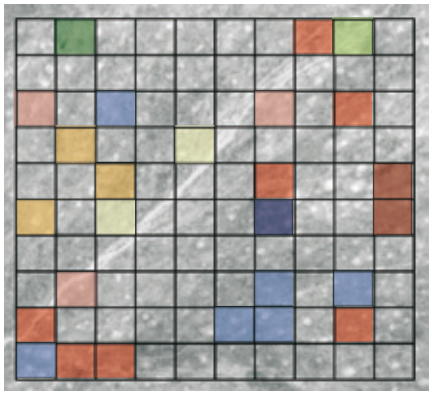
Two features of the landscape are conspicuous regarding the soils. Most evident is gully erosion, which has affected large areas of the Observatory and other parts of Koeroegabvlakte (see also Gotzmann 2002). It is not clear whether these erosion processes are favoured (i) by stronger rainfall intensities due to an intensification of summer rainfall, (ii) by reduced vegetation cover from overgrazing, or (iii) by a combination of both.

Another feature is the vegetation pattern on the heuweltjies, which show bare or only sparsely vegetated patches. An analysis of five aerial photographs spanning from 1938 to 2004 showed that no turnover in the pattern of bare and vegetated heuweltjies occurred within the last 70 years. This corroborates the theory that bare patches are a result of soil features (salt and carbonate accumulation), which did not change over this period, rather than caused by disturbance processes. The analysis of the aerial photographs further revealed an increase in size and visibility of the dry river structure in the Observatory. This is interpreted as further proof for the increasing pressure on soil resources by erosion processes.

Pattern analogies in the soil and vegetation distribution are obvious. Regarding soil features, this is most evident on a small scale in the concentric pattern of different species communities on and around heuweltjies. Except for sand, many soil properties show a strong increase towards the centre of the heuweltjie. The accompanying change in plant species is a result of both soil chemical properties and soil physical effects caused by duripans. These silica-cemented horizons are found around heuweltjies and are believed to be a result of silica precipitation caused by drying processes or lower pH values outside the termite-influenced heuweltjie.

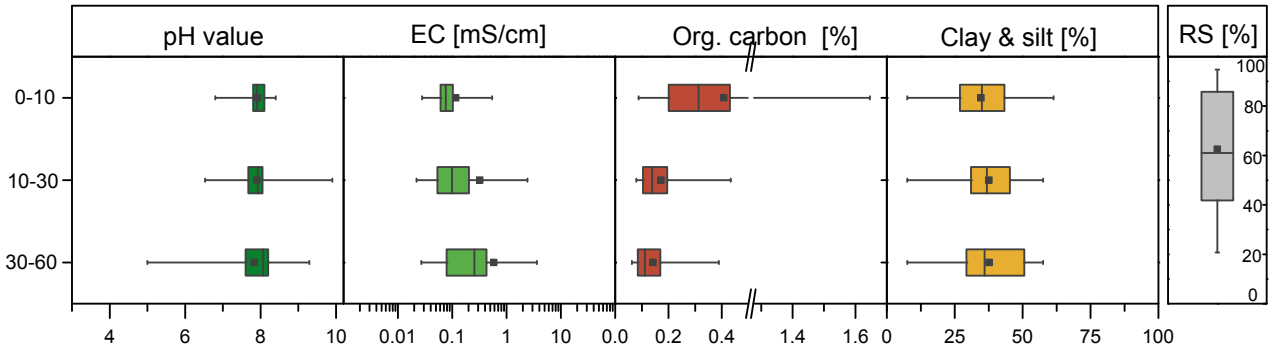
A prominent micro-feature of the landscape, which is apparent in the steep profiles aside dry rivers at many places, is a small (0.5 cm) greyish to black band or soil horizon. It has been found on several occasions throughout the Richtersveld at a depth of 30–120 cm. Laboratory analyses revealed that the blackish colour is a result of manganese coatings on the grain surfaces and that this feature is regularly found as a border between calcareous and non-calcareous material. This often goes along with a strong change in pH values and soluble salts. The process behind this accumulation is most likely a dissolution and precipitation process at the substrate boundary. A possible explanation for the calcareous top-layer could be mass movements of former erosion, caused by irregular, strong precipitation events. The origin of the calcium carbonate is

Map of soil profiles

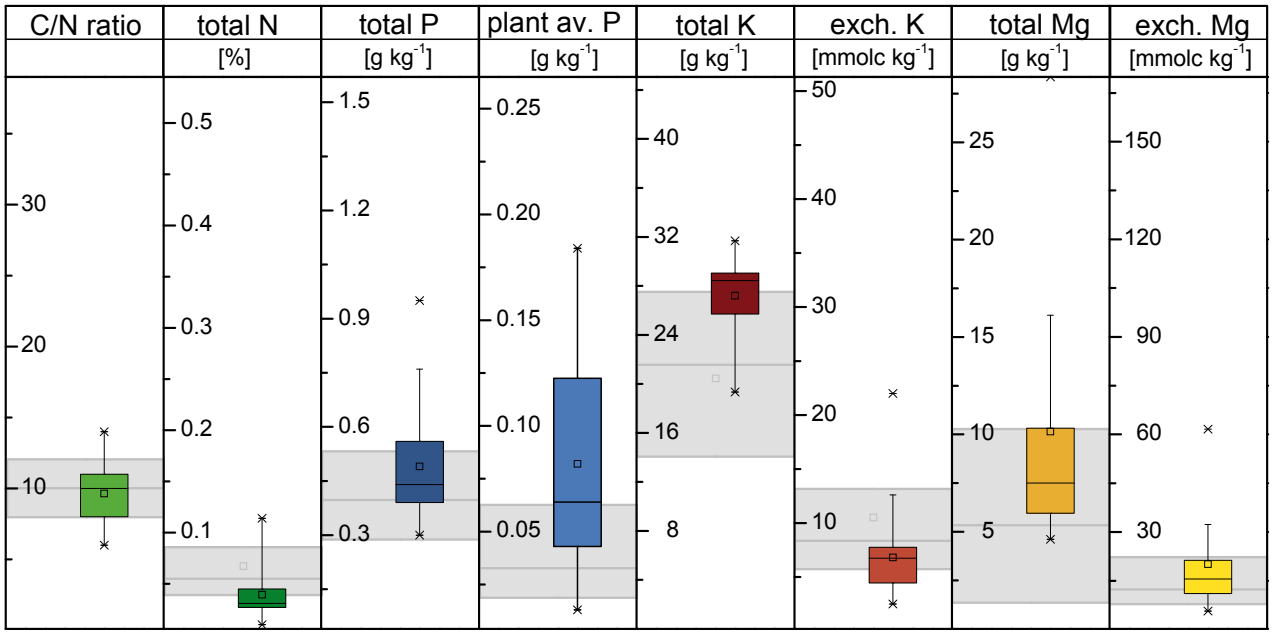


- Haplic Durisol
- Endopetric Durisol
- Epipetric Durisol
- Hypocalcic Durisol
- Haplic Cambisol
- Endoleptic Cambisol
- Duric Solonchak
- Hypocalcic Solonchak
- Haplic Fluvisol

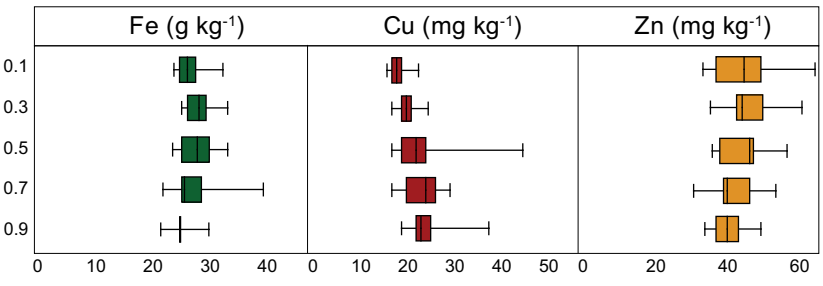
Soil characteristics



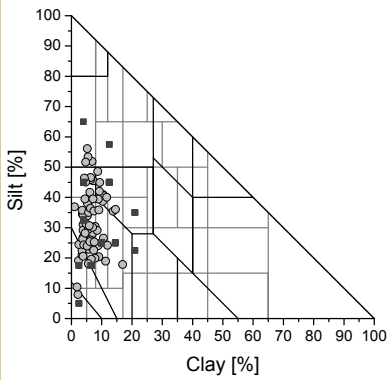
Soil nutrients



Soil micronutrients



Soil texture triangle



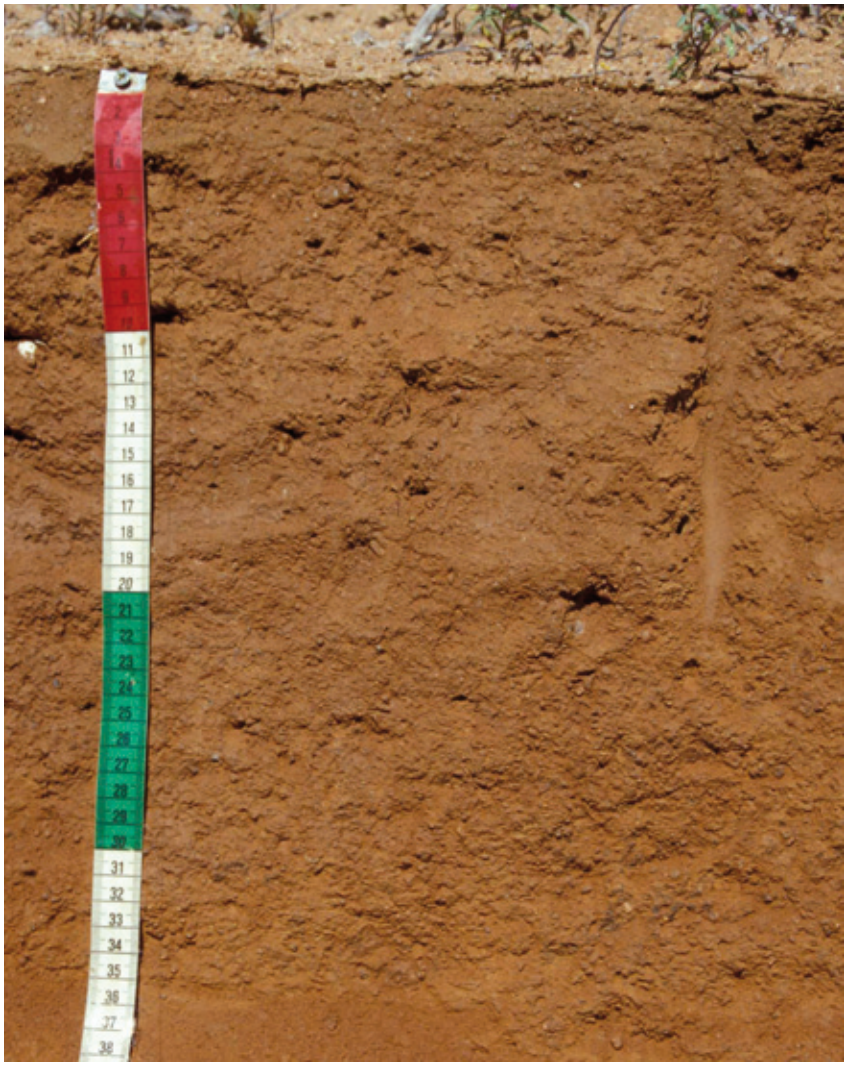
thus most likely derived from eroded termite mounds in the upper part of adjacent slopes of the Koeroegabvlakte, where heuweltijes are missing to date. The hypothesis of strong mass movement also explains the relatively small elevation of the heuweltjies above the surrounding area, which is much stronger in other regions.

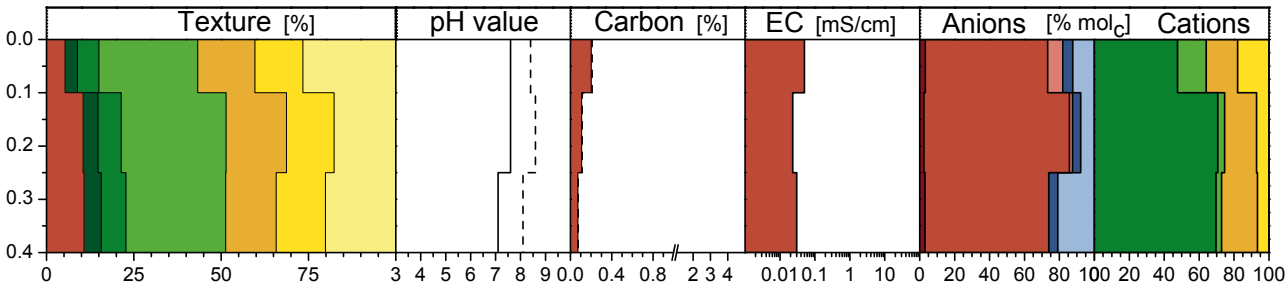
Due to the dominant ions in the soil solution (Na^+ and HCO_3^-), the pH values show a concentration of values around pH 8.0 but with a wide variation, in particular in the subsoil. Electrical conductivity also exhibits a wide range of values, especially in the subsoil, but the median values indicate a generally low content of soluble salts that increases with depth. Increased mean values and strong salinity occur in the heuweltjie centres, which are always nutrient- (and carbonate-) enriched. Thus, total nutrient content in the topsoil is in general in the upper intermediate levels despite the relatively nutrient poor bedrock. The fine particle percentage (clay and silt) varies across all depths due to a combination of pure sand substrate in the dry river and more silty sands in the heuweltjies. The rooting space fluctuates for both the coarse fragment proportions (durinodes and fine and medium gravel from granitic substrates) and the depth of duripans, which are regarded as root restricting.

A possible explanation for the calcareous top-layer could be mass movements of former erosion, caused by irregular, strong precipitation events. Photo: N. Jürgens.

Reference profile (H20)

The **Epipetric Durisol (Chromic)** is positioned in the matrix between the heuweltjies and has a strong reddish, non-calcareous and non-salty character. The occurrence of a duripan below the depth of 40 cm restricts the available rooting space. Soil texture (silty to loamy sand) is homogenous with depth. The non-saline character is expressed by very low electrical conductivity values of 20–50 µS cm^{-1}. The pH value is moderately high and constant with depth. Carbon content was very low, and the constancy of the total element concentration indicates the homogenous parent material of weathered granites. Both electrical conductivity and the amount of water-soluble salts are very low. Nevertheless, the content of exchangeable cations with up to 110 $mmol_c\ kg^{-1}$ was fairly high.





Texture

- Fine silt
- Medium silt
- Coarse silt
- Clay
- Fine sand
- Medium sand
- Coarse sand

- pH ($CaCl_2$)
- pH (H_2O)
- Organic carbon
- Inorganic carbon
- Electrical conductivity

Water soluble ions

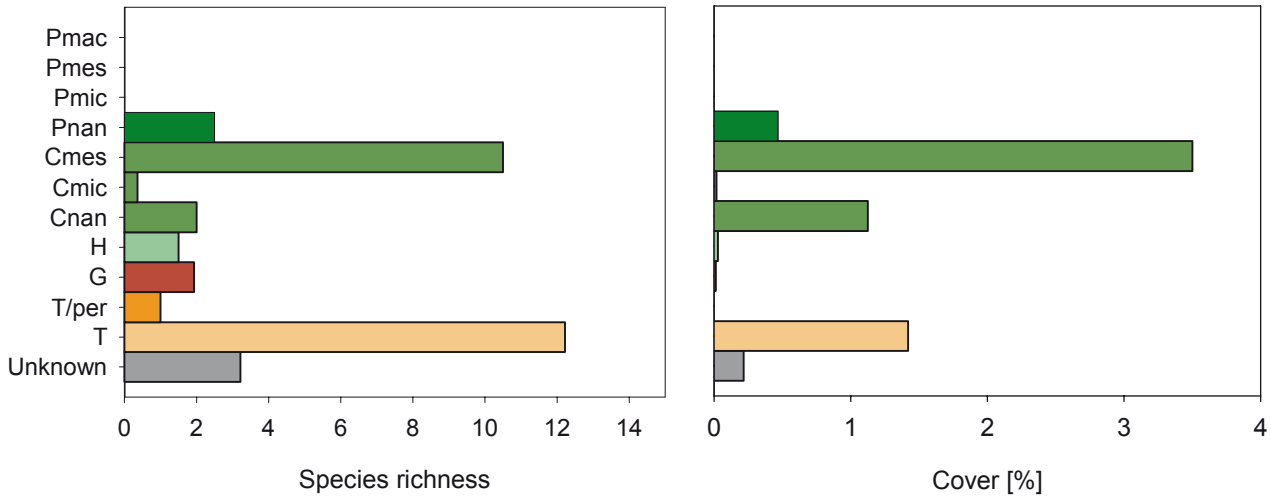
- Cloride
- Sulfate
- Nitrate
- Hydrocarbonate
- Fluoride, Bromide, Nitrite
- Calcium
- Magnesium
- Potassium
- Sodium

Responsible authors: U. Wisch, A. Petersen, A. Gröngröft & D. Mager

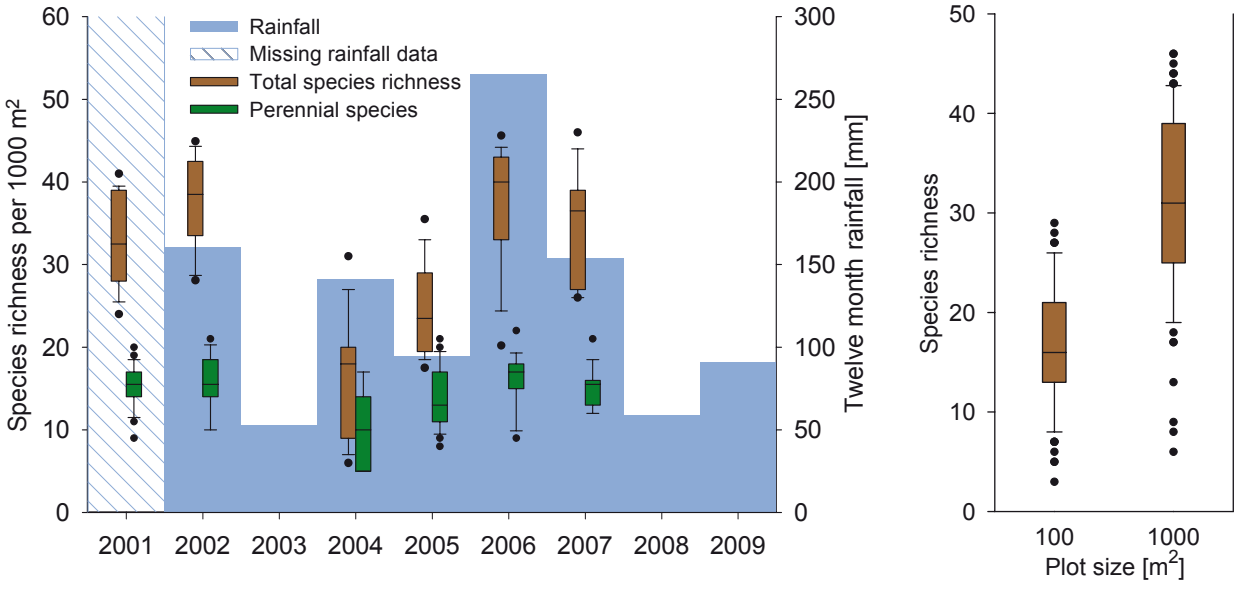
Vascular plants

Sampling period(s)	Hectare plots sampled	Biome
2001–2009	20 (R1–R20)	Succulent Karoo
Vegetation unit (level 1)	**Vegetation unit (level 2)**	**Identification rate**
Richtersveld Bioregion	SKr 7 Northern Richtersveld Scorpionstailveld	44% – 76% – 78%
Cumulative family richness	**Dominant families (cover)**	**Dominant families (richness)**
34	Aizoaceae, Asteraceae, Euphorbiaceae	Aizoaceae, Asteraceae, Poaceae
Cumulative species richness (1 km²)	**Species richness (1000 m²)**	**Species richness (100 m²)**
345 – 121	30.6 (6–46)	16.8 (3–29)
***z*-value**	**Species richness change per year (1000 m²)**	**Evenness (1000 m²)**
0.261 (0.000–0.615)	2.21	0.586 (0.262–0.987)
Evenness (100 m²)	**Simpson (1000 m²)**	**Simpson (100 m²)**
0.515 (0.180–0.872)	0.775 (0.347–0.974)	0.640 (0.178–0.929)

Life forms



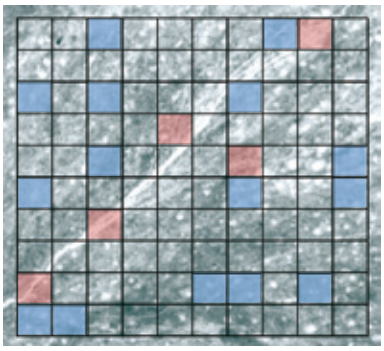
Species richness



Classification table (2005)

Column		Cover	All	1	2
Number of relevés			**20**	**5**	**15**
Mean cover [%]			14.66	9.5	16.38
Mean species richness (1000 m²)			23.05	28.8	22.67
Mean soil pH			7.90	7.80	7.93
Mean electrical conductivity [µS·cm^{-1}]			119.7	117.8	120.3
Organic carbon [%]			0.35	0.30	0.37
Nitrogen [%]			0.04	0.03	0.04
Unit 1: Psilocaulon subnodosum-Zygophyllum retrofractum community					
Hper	Forsskaolea candida	0.10	30	100	7
T	Codon royenii	0.10	20	80	.
Cmes	Monechma spartioides	0.10	20	80	.
Pnan	Hermbstaedtia glauca	0.33	20	80	.
Cmes	Zygophyllum retrofractum	0.50	35	100	13
Cmes	Psilocaulon subnodosum	0.91	35	100	13
T	Trichodesma africanum	0.10	25	80	7
T	Tripteris microcarpa	0.45	40	100	20
T	Oncosiphon suffruticosum	0.33	40	100	20
Cmes	Berkheya canescens	0.10	20	60	7
Cmes	Solanum giftbergense	0.10	10	40	.
Unit 2: Brownanthus pseudoschlichtianus-Lampranthus otzenianus community					
Cmic	Aptosimum spinescens	0.24	30	.	40
Pnan	Asparagus capensis	0.10	25	.	33
Most frequent companions					
Cmes	Galenia crystallina	0.54	95	100	93
Cmes	Brownanthus pseudoschlichtianus	4.91	85	60	93
Cmes	Lampranthus otzenianus	2.76	85	80	87
T/Hper	Mesembryanthemum barkleyi	0.88	85	100	80
Pnan	Aridaria noctiflora ssp. noctiflora	0.44	85	60	93
T	Enneapogon desvauxii	0.10	85	60	93
T	Didelta carnosa ssp. carnosa	0.10	85	80	87
T/Hper	Leysera tenella	0.34	80	60	87
T/Hper	Acanthopsis disperma	0.13	80	80	80
Cnan	Prenia sladeniana	1.66	75	80	73
Pnan	Euphorbia mauritanica var. mauritanica	1.19	75	100	67
Cnan	Hypertelis salsoloides var. salsoloides	0.16	75	60	80
H	Stipagrostis obtusa	0.17	65	80	60
Cmes	Euphorbia ephedroides	0.33	60	60	60
T	Foveolina dichotoma	0.10	60	40	67
G	Phyllobolus oculatus	0.26	55	40	60
T	Aristida adscensionis	0.09	55	40	60
Cmes	Drosanthemum inornatum	0.37	50	60	47
Cmes	Tetragonia reduplicata	0.32	50	40	53
Hper	Lotononis falcata	0.28	50	60	47
Cmic	Drosanthemum hispidum	1.08	45	20	53
Cnan	Helichrysum obtusum	0.20	45	60	40
T	Gorteria diffusa ssp. diffusa	0.10	45	60	40
T	Amellus nanus	0.10	40	20	47
Cmes	Eberlanzia ebracteata	0.64	35	20	40
Cmes	Psilocaulon dinteri	0.10	35	40	33
G	Trachyandra bulbinifolia	0.10	25	20	27
Cmes	Salsola zeyheri	0.10	25	40	20
Cmes	Zygophyllum prismatocarpum	0.10	25	60	13
Cmes	Ceraria fruticulosa	0.10	20	.	27
Cmes	Pteronia glabrata	0.10	20	20	20
Cmes	Euphorbia mauritanica var. namaquensis	0.73	15	.	20
T	Helichrysum alsinoides	0.40	15	20	13
H	Stipagrostis ciliata var. capensis	0.10	15	20	13
Cmes	Blepharis furcata	0.10	15	20	13

Map of vegetation units



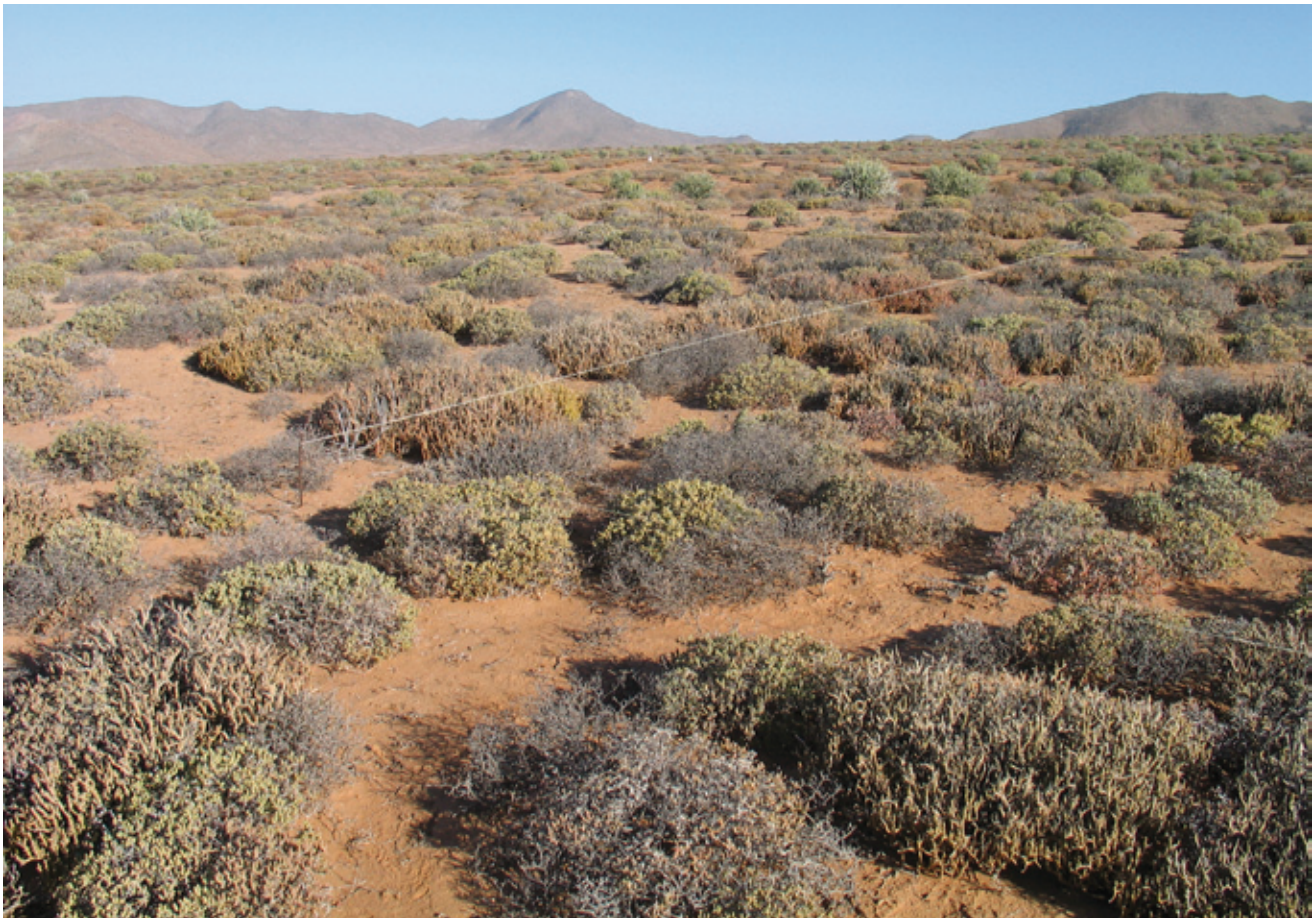
The vegetation of the Koeroegap Vlakte falls into the Northern Richtersveld Scorpionstailveld (SKr 7, Mucina et al. 2006), which is characterised by the dominance of the succulent shrub *Brownanthus pseudoschlichtianus* (Scorpionstail). The homogenous plain is characterised by a dense pattern of fossil termitaria (heuweltjies), which harbour a unique vegetation of opportunistic shrubs and annuals of the Aizoaceae or Asteraceae. *Brownanthus pseudoschlichtianus* and *Lampranthus otzenianus* are most common at the margins of heuweltjies. Both species are also well represented in the matrix between heuweltjies. They are replaced by *Galenia crystallina* (C mes) in the southern parts of the Observatory perhaps due to disturbance by overgrazing and trampling.

The vegetation is dominated by stem- and leaf-succulent dwarf shrubs (C mes), small shrubs (P nan) and, after sufficient seasonal rainfall, succulent or non-succulent annuals (T). Mean species richness per plot (1000 m²) is highest for dwarf shrubs (C mes) and annuals (T), whereas the other life-form types have comparatively low species numbers. Aizoaceae and Asteraceae are the most important plant families in terms of cover and species richness.

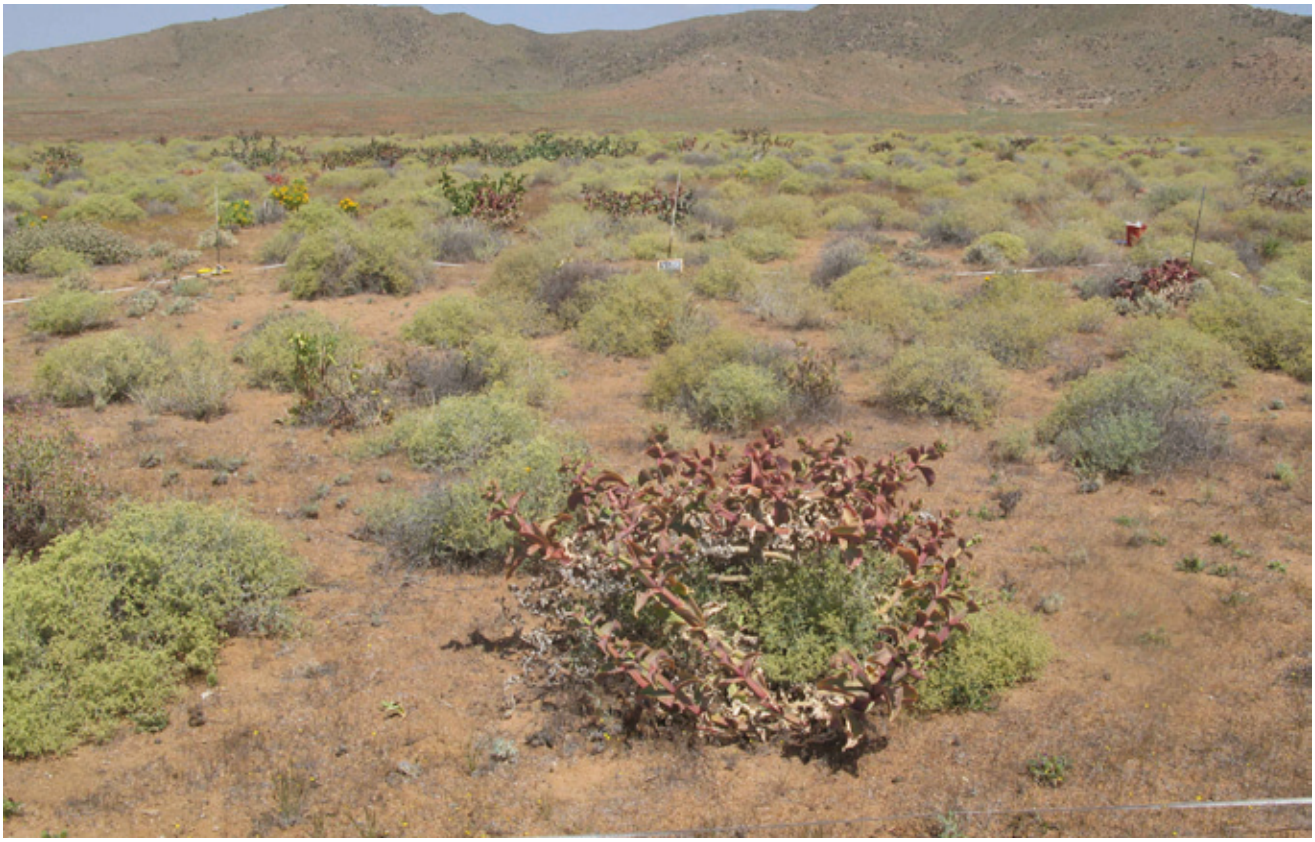
This is the least diverse Observatory in the Succulent Karoo, together with the Observatory Groot Derm (S21) in the yellow dunes of the northwestern Richtersveld. Particularly low values are evident for the mean Simpson diversity index, evenness on 100 m²-plots, and total species richness and plant family richness at

Along the margin of the river larger bushes of up to nearly 2 m size are frequent. The image shows *Hermbstaedtia glauca* (center), *Berkheya spinosissima* (yellow flowers) and a lot of *Monechma spartioides* in the background. Photo: N. Jürgens.

After good winter rains the bare centers of the heuweltjies are covered with various short-lived plants; the center of the image shows the bluish-green leaf masses of *Mesembryanthemum barklyi*. Also the margin of the heuweltjie is denseley covered by vegetation, the bluish-green plants are *Lampranthus otzenianus*, the yellow wilting plants are *Prenia sladeniana* and the many yellow flowers are produced by *Didelta carnosa*. Photo: N. Jürgens.



Brownanthus pseudoschlichtianus forms cushion-like plants in the matrix vegetation, however stronger so at the margin of heuweltjies. Photo: N. Jürgens.



In the southern part of the Observatory large areas are covered by a community dominated by *Galenia crystallina* (yellowish green shrubs). In the foreground a single plant of *Mesembryanthemum barklyi*. Photo: N. Jürgens.

the 1 km² scale. The comparatively low diversity of this Observatory may be explained by its dry climate and its position in the transition zone between the winter and summer rainfall regions. The homogeneous topography, which is only diversified by the heuweltjies and one rivier, also contributes to the low species richness at the Observatory. The Observatory receives slightly higher annual rainfall than the other two Richtersveld Observatories, namely Numees (S20) and Groot Derm (S21), which both lie west of the main mountain ranges of the Richtersveld and benefit from coastal fog. Fog does occur at Koeroegap Vlakte but less frequently than at the other two Richtersveld Observatories. However, the much higher altitude of this Observatory allows for more frequent dewfall. While the majority of the species occurring at Koeroegap Vlakte also occur at Numees, the much more diverse vegetation of the Observatory Numees, only 10 km southwest of the Koeroegap Vlakte, is also driven by extraordinarily high habitat and geological diversity. The location of the Koeroegap Vlakte in a climatic transition zone is also reflected in the very high variance in interannual rainfall, which is also responsible for the strong variance in interannual species richness.

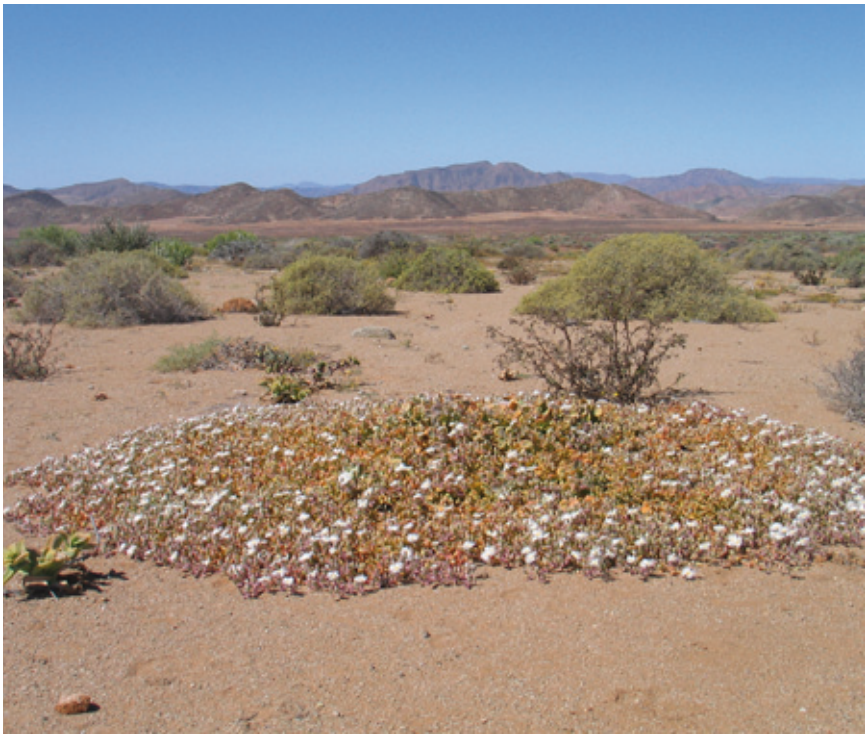
The vegetation unit at the 1000 m²-plot scale represents the two major geomorphological component of the landscape the plains, which consist of heuweltjies and inter-heuweltjie habitats (unit 1); and the community associated with dry riverbeds (unit 2). These two main vegetation units differ in species and life-form composition, due to differences in water supply and disturbance regime. The longitudinal nature of the riverbeds and the standardised selection of the position of sample plots in the landscape make the subdivision of the two units less distinct.

The *Psilocaulon subnodosum-Zygophyllum retrofractum* community (unit 1) occurs along the dry riverbeds that dissect the Koeroegap Vlakte. It is characterised by two succulent shrubs with small succulent leaves, namely *Psilocaulon subnodosum* (Asbos) and *Zygophyllum retrofractum*. These two shrubs and most of the other species that are typically found

Stapelia hirsuta var. *gariepensis* with its fleshy colour and odour of decaying meat attracts flies as pollinators. Photo: N. Jürgens.

Prenia sladeniana is developing the young leaf pairs within a bud-like structure, which allows long survival during dry periods. Photo: N. Jürgens.

Brownanthus pseudoschlichtianus survives the dry season with succulent stem internodes. Photo: N. Jürgens.



Prenia sladeniana is forming mat-like plants with a fringe of flowering branches. Photo: N. Jürgens.

Responsible authors: N. Jürgens, U. Schmiedel & J. Luther-Mosebach

in this community are indicators of disturbance and are typically found in dry riverbeds elsewhere in Namaqualand. Examples are the non-succulent, thorny annuals *Codon royenii* (Soetdoringbos) and *Trichodesma africana*.

The *Aptosimum spinescens-Brownanthus pseudoschlichtianus* community (unit 2) is characterised by the occurrence of succulent Aizoaceae shrubs such as *Brownanthus pseudoschlichtianus* (Scorpionstail), as well as *Lampranthus otzenianus*, *Galenia crystallina*, and *Aridaria noctiflora* ssp. *noctiflora* (Vleisbos). The non-succulent shrubs *Aptosimum spinescens* (Doringviooltjie) and *Asparagus capensis*, occur with low cover values. This unit is characteristic of the mosaic of heuweltjies and matrix vegetation on the plains. If smaller plot-sizes (e.g. 10 m x 10 m or 5 m x 5 m) were used to sample the vegetation, the vegetation unit 2 would have been subdivided according to the following heuweltjie-related habitat types: (a) heuweltjie centres, (b) heuweltjie margins, and (c) the matrix (between heuweltjies).

(a) The heuweltjie centres are typically either bare or covered by the leaf-succulent biennial plant *Mesembryanthemum barkleyi* (Olifantsoutslaai). *Pentzia suffruticosa*, *Didelta carnosa* and *Foveolina dichotoma* can reach high cover values during good rainfall years. During drought periods, *Mesembryanthemum barkleyi*-dominated heuweltjie-centres may be completely bare of vegetation.

(b) The opportunistic leaf-succulent shrubs *Lampranthus otzenianus*, *Prenia sladeniana*, and *Aridaria noctiflora* subsp. *noctiflora* occur at the margins of heuweltjies.

(c) The plain is dominated by a wide range of species in the matrix between heuweltjies. *Brownanthus pseudoschlichtianus* typically plays an important role and is often accompanied by the tall poisonous stem succulent *Euphorbia mauritanica* subsp. *mauritanica* and *E. mauritanica* subsp. *namaquensis* (Gifmelkbos). During years with sufficient seasonal rainfall, the yellow flowers of *Didelta carnosa* subsp. *carnosa* (Perdeblom) may be conspicuous.

Millipedes

Sampling period(s)	Species richness
2003/X	1

Parts of the soil at this Observatory were covered by small, light brown earth-balls, which are the faeces of millipedes belonging to the family Harpagophoridae. Although no adults were found, many juveniles were encountered buried in the soil below trees at a depth of 5–10 cm. This behaviour might reduce the risk of desiccation.

Millipede species

Species	Family	Relative frequency	Feeding group
Harpagophoridae sp. (juveniles)	Harpagophoridae	n.a.	Litter

Responsible author: K. Vohland

Termites

Taxon richness	Abundance index	Dominant (sub-) family
1	n.a.	n.a.

Microhodotermes viator (see Photo) was the only termite species encountered at this Observatory (Vohland & Deckert 2005). This species is distributed in the south-western parts of South Africa and the southernmost region of Namibia. It was also collected from the Observatories S20 (Numees) and S22 (Soebatsfontein). *M. viator* is closely related to *Hodotermes mossambicus* (see Observatory S39/Narais) and forages mainly on small sticks and twigs.

List of taxa

Taxon	(Sub-)family
Microhodotermes viator	Hodotermitidae

Worker of *Microhodotermes viator*; the picture was taken near Ratelgat. Photo: C. Grohmann.

Responsible authors: C. Grohmann & K.E. Linsenmair

True bugs

Sampling period(s)	Methods	Family richness
2001/IX, X; 2002/X; 2003/X	Trapping (light, pitfall traps, Malaise); hand collecting	15
Species richness	**Individuals sampled**	**Fisher's alpha diversity**
50	274	17.91

More than 50% of all species collected at the Observatory Koeroegap Vlakte (S18) belong to the family Miridae. Apart from the Miridae, only the Pentatomidae, Rhyparochromidae, and Oxycarenidae consisted of more than one species.

Dicranocephalus schmitzi (Stenocephalidae), *Eurystylus* sp. (Miridae), and *Leptodemus irroratus* (Oxycarenidae) represented nearly 50% of all collected specimens. All these species are widely distributed in south-western Africa.

Saxicoris verrucosus (Piesmatidae) was collected in a pitfall trap as a single specimen. This species was known only from its type locality in the Western Cape. The same species was recorded at the Soebatsfontein Observatory (S22).

A single specimen of *Barberocoris myrmecoides* (Oxycarenidae) was also collected at Gellap Ost (S10). *Migdylibs furcifer* (Rhyparochromidae) was collected exclusively at Koeroegap Vlakte (S18). Both species are distributed throughout southern African but are rarely collected. *Euthetus leucostictus* was the only species of Broad-headed bugs (Alydidae) recorded. This family (Alydidae) is adapted to living on *Acacia* species or other Fabaceae species. They are more common in the Savanna Biome than in the Succulent Karoo.

Species richness in families

Family	S
Miridae	26
Pentatomidae	7
Rhyparochromidae	4
Oxycarenidae	2
Alydidae	1
Anthocoridae	1
Blissidae	1
Cydnidae	1
Geocoridae	1
Lygaeidae	1
Reduviidae	1
Rhopalidae	1
Stenocephalidae	1
Piesmatidae	1
Tingidae	1
Total	**50**

Species abundances

Light and pitfall traps

Species	Family	N	%
Dicranocephalus schmitzi	Stenocephalidae	60	22
Eurystylus spec.	Miridae	39	14
Leptodemus irroratus	Oxycarenidae	28	10
Miridae spec. 1	Miridae	22	8
Nysius ericae	Lygaeidae	12	4
Geocoris phaeopterus	Geocoridae	9	3
Phytocoris spec.	Miridae	9	3
Euthetus leucostictus	Alydidae	7	3
Elasmolomus transversus	Rhyparochromidae	7	3
Miridae spec. 2	Miridae	6	2
Miridae spec. 3	Miridae	6	2
Others (39)		69	25
Total		**274**	**100**

Responsible author: J. Deckert

Butterflies and moths

Sampling period(s)	Number of samples (moths)	Species richness (total)
2001/X; 2002/XI	2	113
Species richness (butterflies)	**Species richness (all moths)**	**Species richness (Microlepidoptera)**
10	103	45
Species richness (Pyraloidea)	**Species richness (Macrolepidoptera)**	**Species richness (Noctuidae)**
25	8	25
Individuals sampled (moths)	**Fisher's alpha diversity (moths)**	
1917	23.3	

Butterflies

The abundance of butterflies was very low at this Observatory during the planned transect sampling periods, which were in October 2001 and October 2002. No transect analysis was conducted. Data shown below are derived from observations of flying individuals while camping for 3–4 days close to the Observatory which allowed the permanent observation of flying individuals.

Moths

Moth species richness at this Observatory was exceptionally high in October 2001. Microlepidopterans of the family Gelechiidae, especially *Ochrodia subdiminutella* and *O. pentamacula* were the most common taxa. The Succulent Karoo is known to be home to many plume-moths (Pterophoridae). The most abundant species of this family at the Observatory was recently described as *Agdistis eberti* by Arenberger (2009). Among the Pyraloidea, eight species of *Hypotia* sp. (Pyralidae) were registered to occur syntopically. The most common species of this family were *Staudingeria mimeugraphella* and *Epizophorodes capicola* (both Phycitinae). Dominant species of the numerous Noctuidae were *Cardephia definiens* and *Ozarba hemisarca,* which are common all over southern Africa. The co-occurrence of 11 small *Eublemma* species (Noctuidae) is a characteristic feature of the fauna of the Succulent Karoo. Unfortunately, the species cannot be identified correctly as long as the genus remains unrevised.

Butterfly species and main food plants

Hesperiidae	
Alenia namaqua	Blepharis (Acanthaceae)
Lycaenidae	
Aloeides barklyi	n.a.
Spindasis namaqua	Zygophyllum (Zygophyllaceae)
Leptomyria lara	Kalanchore, Cotyledon (Crassulaceae)
Brephidium metophis	Exomis (Chenopodiaceae)
Leptotes pirithous pirithous	Plumbago (Plumbaginaceae), Indigofera (Fabaceae), Burkea (Fabaceae)
Pieridae	
Colotis agoye bowkeri	Boscia, Cadaba (Capparaceae)
Colotis evenina evenina	Boscia, Capparis (Capparaceae)
Pontia helice helice	Heliophila, Lobularia (Brassicaceae), Rheseda (Rhesedaceae)
Satyridae	
Tarsocera imitator	n.a.

Taxonomic spectrum of moths

Collection period: X/2001

Family	*S*	*N*
Tineidae	7	31
Plutellidae	1	2
Lyonetiidae	1	1
Coleophoridae	6	19
Scythrididae	6	49
Batrachedridae	1	14
Oecophoridae	1	15
Cosmopterigidae	2	2
Gelechiidae	16	1282
Pterophoridae	3	69
Tortricidae	1	2
Microlepidoptera	**45**	**1486**
Pyralidae	22	108
Crambidae	3	8
Pyraloidea	**25**	**116**
Geometridae	8	16
Noctuidae	25	299
Macrolepidoptera	**33**	**315**
Total	**103**	**1917**

Responsible author: W. Mey

Vertebrates

Total species richness	Reptile species richness	Bird species richness
14	n.a.	14
Large mammal species richness	Small mammal species richness	
n.a.	n.a.	

Birds

Passeriformes	**Perching birds**
Certhilauda albescens	Karoo Lark
Corvus capensis	Cape Crow
Pycnonotus nigricans	Black-fronted Bulbul
Cercomela schlegelii	Karoo Chat
Galerida magnirostris	Large-billed Lark
Parisoma layardi	Layard's Tit-Babbler
Serinus albogularis	White-throaded Canary
Telophorus zeylonus	Bokmakierie
Emberiza capensis	Cape Bunting
Passer melanurus	Cape Sparrow
Cinnyris fuscus	Dusky Sunbird
Piciformes	**Woodpeckers and relatives**
Tricholaema leucomelas	Acacia Pied Barbet
Coraciiformes	**Kingfishers and relatives**
Ceryle rudis	Pied Kingfisher
Pelecaniformes	**Pelicans, cormorants, and relatives**
Anhinga melanogaster rufa	African Darter

Responsible authors: J. Deckert, A. Hoffmann & A. Mills

Site-specific studies

Significance of the lithology on the soil genesis and variability in the Richtersveld (S18.01)

[A. Gröngröft & J. Willer]

The soils of the Richtersveld have been developed from a variety of different rocks, are predominantly shallow and rich in coarse fragments. According to the WRB soil classification, most of the soils are Leptosols, Regosols, and Calcisols with only few signs of actual pedogenesis.

This study conducted on the Observatories S18 (Koeroegap Vlakte) and S20 (Numees) tested the hypothesis that the properties of shallow mountainous soils are strongly controlled by the type of underlying bedrock. Therefore, analyses of the grain size distribution and the geochemical composition were conducted to qualify and quantify the origin of soil material. By the comparison of the elemental composition of bedrock, subsoil, and topsoil samples it could be shown that within the soils considerable amounts (40–50%) of airborne material in the grain size of silt and fine-sand were present. In some locations another 20–30% were classified as eroded material from upslope origin. The even depth distribution of the airborne material and the lack of actual deposits indicated that the aeolian deposition took place in the past and was followed by intensive mixing processes. Air-transported fine earth particles therefore have a strong impact on the development and the properties of the soils of this region.

Willer, J. (2004): Einfluss von unterschiedlichen lithologischen Einheiten auf die Bodenbildung und Bodenvariabilität im Richtersveld, Südafrika. – Diplom thesis in Soil Science. Hamburg: University of Hamburg.

Further studies

Petersen, A., Gröngröft, A., Miehlich, G. (2003): Einfluss der Termiten auf die Pedodiversität südafrikanischer Trockengebiete. – Mitteilungen der Deutschen Bodenkundlichen Gesellschaft **102**: 313–314.

General data

Number	Name	Alternative name(s)
S20	Numees	n.a.
Implementation	**Country**	**Province/ region**
2001	South Africa	Northern Cape
District/ constituency	**Locality**	**Farm name**
Namakwa	Sendelingsdrif	Numees
Latitude	**Longitude**	**Altitude**
28.293087 S	16.953805 E	362 m a.s.l.
Rainfall season	**Biome**	**WWF Ecoregion**
Winter	Succulent Karoo	AT1322 Succulent Karoo
Agro-Ecological Zone	**Relative intensity of land use**	**Tenure**
n.a.	Medium	Communal
Type and history of landuse	**Land owner**	
Semi-nomadic farming with goats and sheep (and cattle)	Richtersveld Community / SANPark	

Numees (S20)

The Numees Observatory combines a mountainous part and a valley bottom with terraces and riverbeds. Photo: N. Jürgens.

The Numees Observatory is located in the northern Richtersveld, 13 km southeast of the Gariep River, and 61 km east of the Atlantic Ocean coastline. Topographically, the Observatory includes the transition from a valley bottom to the slopes of the Escarpment, which is dissected and mainly represented by the north-south oriented Stinkfontein-Vandersterrberg Range (reaching > 1300 m altitude) in the Richtersveld. The altitude rises from the sandy Grasvlakte plain (just above 350 m a.s.l.) to mountain slopes at 550 m a.s.l. within the space of the 1 km² Observatory, which is the largest vertical gradient within all the BIOTA Observatories. The topographical diversity is accompanied by extraordinary geological diversity, which is mirrored by a diversity of soil types and soil parameters (see Section on soils). There are gneissic granites and mylonites of the Vioolsdrif Suite (1.7–1.8 Ga), Diamictites of the Orange River Group (1.9–2.0 Ga) and Arkose, Quarzite, and calcareous micaschist of the Stinkfontein SubGroup (0.7–0.8 Ga) of the Gariep Belt.

An additional environmental parameter supporting biological diversity is the overlap of the winter rainfall climate with frequent fog events, which are enhanced by the topographical position directly in front of the Vandersterrberg Range, with elements of the tropical (summer rainfall) desert climate, especially occasional intense summer rains as well as periods of extremely hot temperatures caused by bergwinds.

The Numees Observatory therefore combines floristic elements of the Succulent Karoo, Desert, Nama Karoo and even possesses some Cape affinities. This explains the very high species numbers in such an arid environment (114 mm mean annual precipitation during 2001–2009, compared to 57 mm, as interpolated by global models).

Landuse is limited to pastoral small stock farming. Stocking rates have been fixed to a limited number of livestock since the proclamation of the Richtersveld National Park in 1991. However, this has not resulted in any significant changes to the vegetation of the Numees area. For most months of the year, approximately 600 small stock units utilise the Numees valley and surrounds, and stockposts have even been established within the Observatory.

With regard to changes in biodiversity, there has been an overall increase of plant biomass and species richness since 1981 following an extreme drought experienced from 1978 to 1980. Parts of the valley bottom are invaded by grasses and the native legume shrub *Lebeckia multiflora* (Fluitjiesbos).

This Observatory was established to continue the research, which has been conducted on the site since the 1970s. Besides early ecophysiological research (summarised in von Willert et al. 1991), monitoring activities were also initiated in 1980 (Jürgens 1986, Jürgens et al. 1999). Ecophysiological measurements and climate change experiments are conducted within these plots (see Article III.6.1). Together with the Observatories Koeroegap Vlakte (S18) and Groot Derm (S21), the Numees Observatory allows monitoring of the boundary and steep gradient between the winter rainfall and the summer rainfall regimes.

The mountainous parts of the Numees Observatory offer a great diversity of microhabitats defined by differing shares of rock, blocks, stones and fine material soil ”Numees 01”. Photo: N. Jürgens.

The plains within the Numees Observatory are mostly ancient river terraces with denuded calcretes, intersected by riverbeds with blocks and gravel. Photo: N. Jürgens.

Responsible authors: N. Jürgens & D.H. Haarmeyer

Remote sensing and landscape

Geomorphology	Geological units	Lithological units
Slopes and plain valleys	Gariep Supergroup	Sedimentary and volcanic rocks
Mean EVI	**EVI absolute range**	**Mean leaf area index**
0.093 (0.077–0.121)	0.071 (2003)–0.162 (2006)	0.33

Grid map of Observatory

	0	1	2	3	4	5	6	7	8	9
0	53	87	69	81	60	95	52	66	20	13
1	90	84	18	40	93	57	72	65	77	47
2	79	99	24	10	100	7	58	97	1	75
3	15	74	39	51	22	50	11	42	62	30
4	94	55	48	88	92	56	28	8	71	33
5	68	78	38	85	41	80	46	98	54	23
6	73	89	9	35	45	31	3	6	86	21
7	16	63	4	83	37	76	59	82	25	27
8	67	19	91	29	12	70	64	2	32	96
9	61	34	14	44	36	43	49	26	17	5

1 Open *Zygophyllum patenticaule-Mesembryanthemum pellitum*-dominated dwarf shrubland on valley

2 Open *Z. patenticaule-M. pellitum*-dominated dwarf shrubland with road on valley

3 *M. pellitum* and *Z. prismatocarpum*-dominated dwarf shrubland, *Brownantus pseudoschlichtianus*-dominated rivier

4 *Othonna opima-Galenia dregeana*-dominated dwarf shrubland on montainous highlands

5 Dense *Didelta spinosa-Tylecodon paniculatum*-dominated shrubland on E-exposed slopes of mountainous highlands

6 *M. pellitum* and *Z. prismatocarpum*-dominated plain to medium gradient valley, *B. pseudoschlichtianus*-dominated rivier

7 M.pellitum and Z. prismatocarpum-dominated vegetation in valley

8 *Trianthema triquetra*-dominated dwarf shrubland on mountainous highlands

9 *Ruschia senaria*-dominated dwarf shrubland in valley

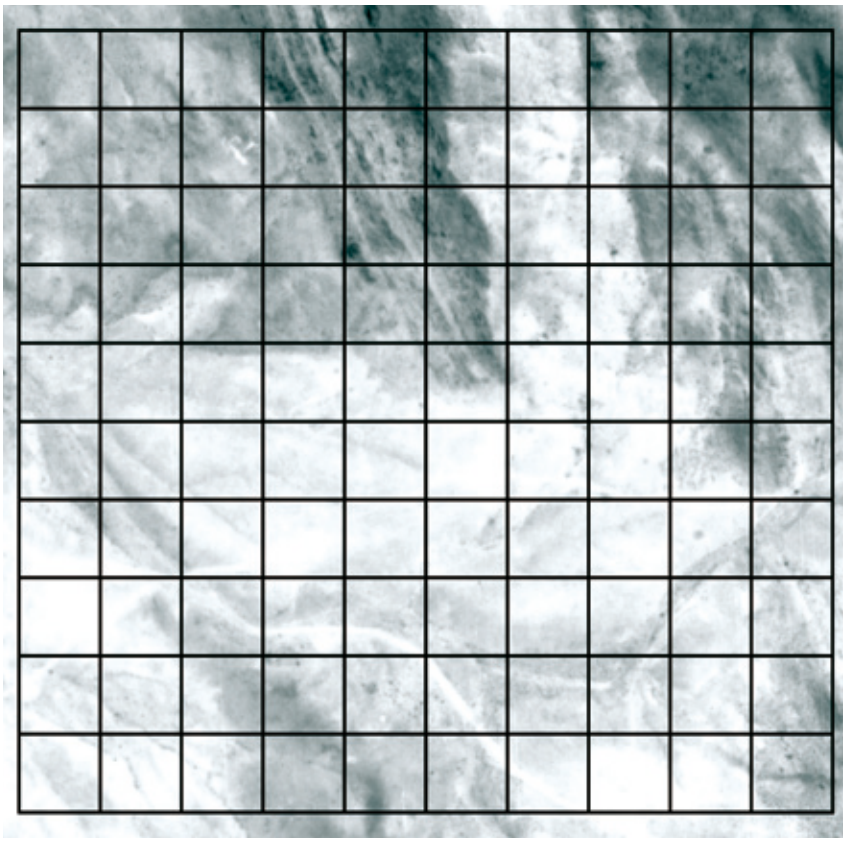
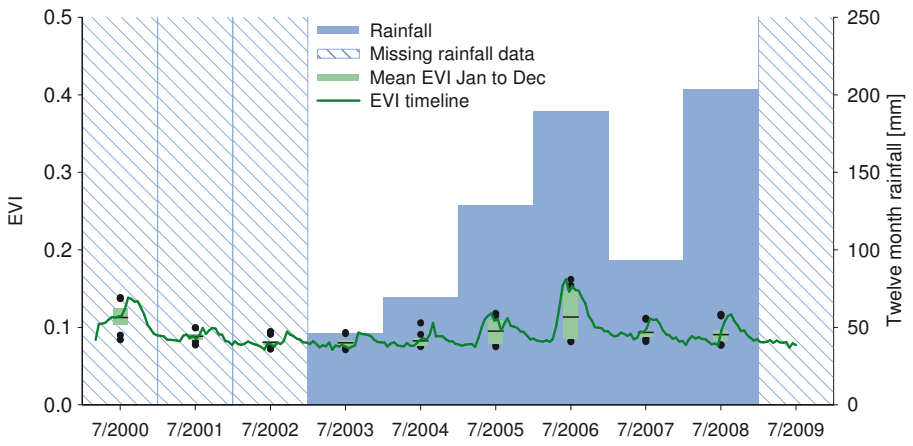


Image: aerial photograph

MODIS time series

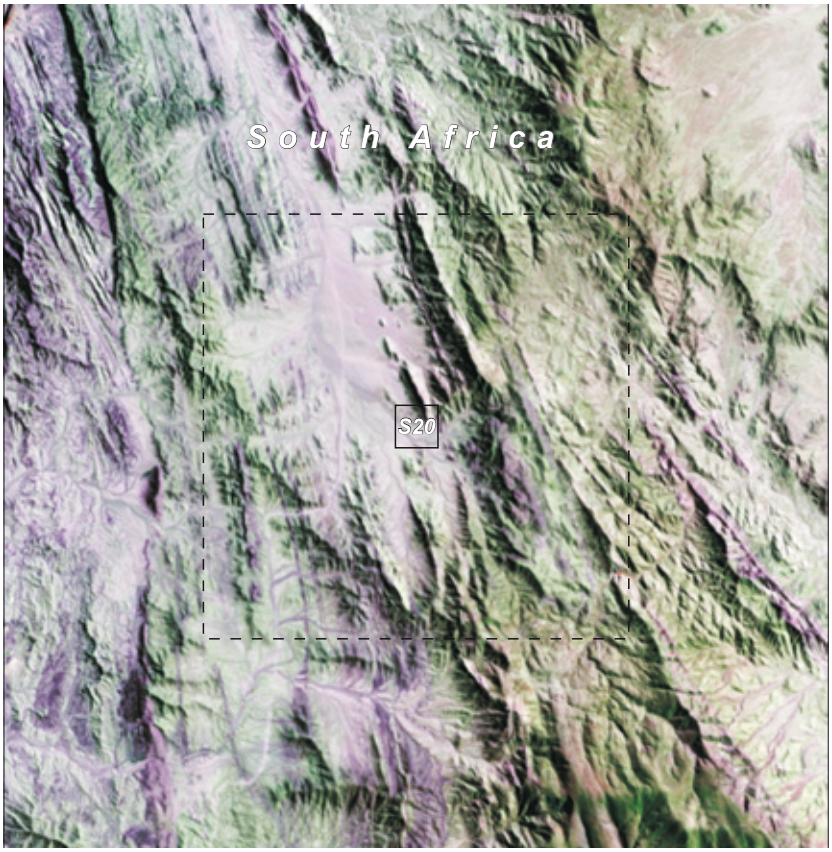
Temporal patterns of annual rainfall, vegetation cover, and phenology



Landsat image

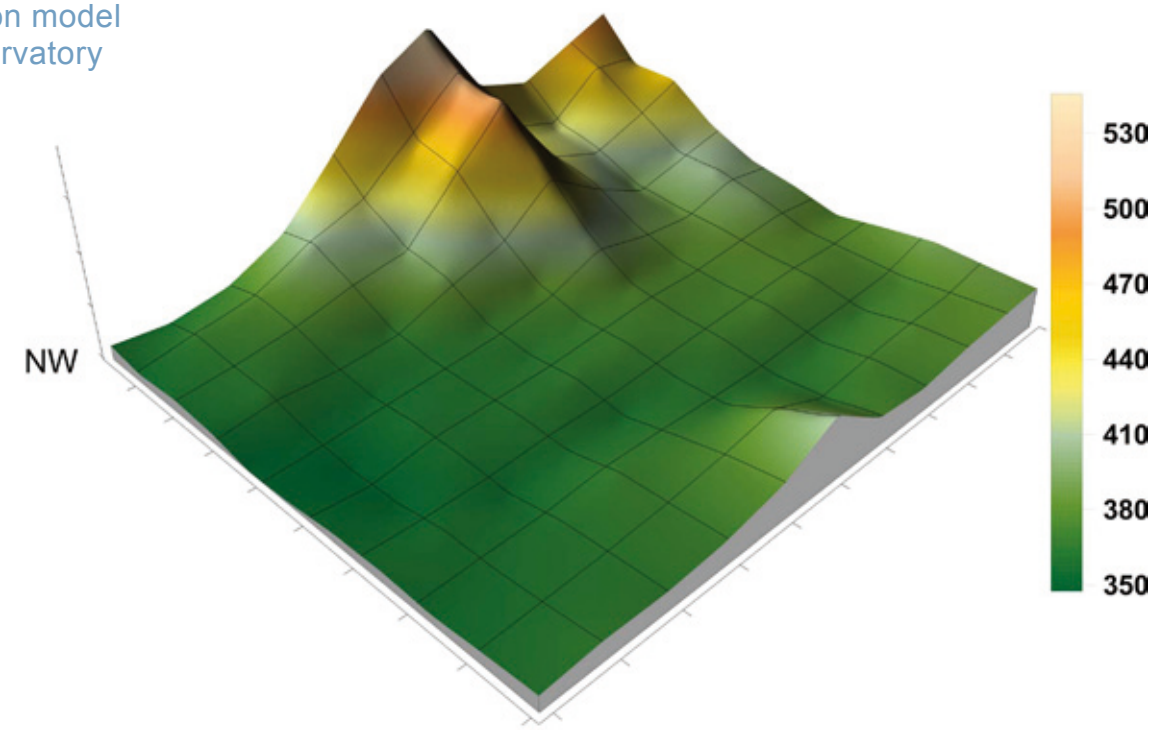
The Observatory covers an area consisting of a plain and a few mountainous slopes. Geology and topography are highly diverse, which can be seen in the Landsat data of 30 m resolution, especially concerning topography. The plain drains northwards into the Gariep River, which lies outside the image.

The rugged Richtersveld Mountains form a mountainous desert with species-rich succulent vegetation. The plain possesses a sparse but continuous vegetation cover of succulent shrubs (light blue tones). The vegetation on the slopes shows as light green tones.



Scene: 177/80, acquisition date: 08 February 2003

Elevation model of Observatory



Responsible authors: M. Keil & T. Labitzky

Climate

Data from BIOTA weather station

Location	Recorded period	Mean temperature
Numees (S20)	2003–2009	20.6 (5.7–43.7) °C
Mean solar radiation	**Mean wind speed**	**Mean annual precipitation**
582 (319–904) MJ·m^{-2}·month^{-1}	2.8 (9.4) m·s^{-1}	114 (11–204) mm
Mean annual potential evapotranspiration	**Interannual precipitation variability**	**Mean relative humidity**
1391 mm	160%	53% (30–66%)
Aridity index (UNEP)		
0.08 (arid)		

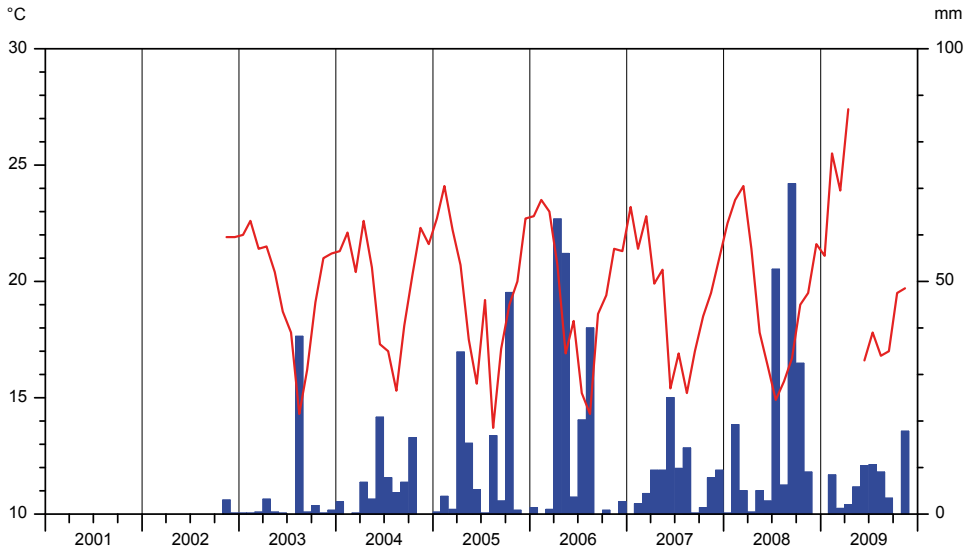
Modelled data

Mean temperature	Mean annual temperature range	Mean diurnal temperature range
17.6 (7.0–27.0) °C	7.9 °C	12.1 °C
Mean annual precipitation	**Precipitation seasonality**	**Percentage winter precipitation**
57 mm	39%	61% (winter)
Climate type	**Length of dry season**	**Aridity index (De Martonne)**
BWk	12 months	2.1 (dry)

The climate at the Observatory is characterised by arid conditions. Rainfall shows a weak seasonality with the major portion of rain falling between April and October. The mean annual rainfall was 114 mm, which is fairly dry in comparison to the average rainfall recorded over the entire transect, and within the Succulent Karoo. However, substantial interannual variability is evident. The observed near-surface air temperatures show a weak seasonal cycle. The mean annual temperature is 20.6°C, which is slightly warmer than the average for this biome. Compared to the interpolated long-term data taken from the WorldClim dataset, a markedly warmer mean annual temperature is observed at the BIOTA weather station. Furthermore, the station records of temperature extremes deviate substantially from the interpolated data, showing warmer maximum and minimum temperatures than the WorldClim dataset. For precipitation, mean annual rainfall observed at the station is about twice the amount of the WorldClim dataset.

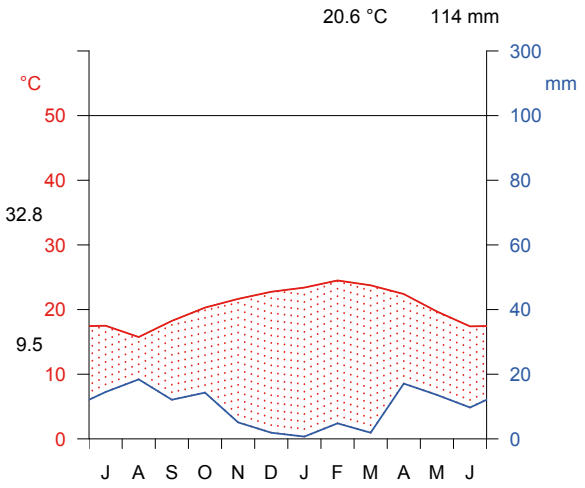
The observed near-surface winds at the Observatory are predominantly constituted of north-westerly flows throughout the year. Mean wind speed shows a moderate annual cycle in the mornings and evenings, with reversed amplitudes. However, winds during the early afternoon remain fairly constant throughout the year, reaching about 15 km/h.

Time series: rainfall and temperature

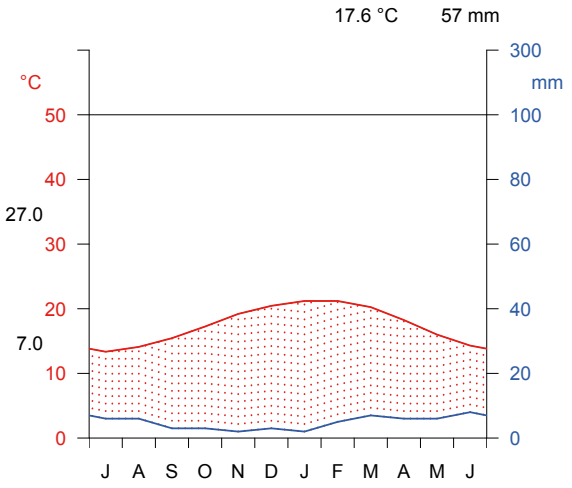


Climate diagrams

Recorded data (BIOTA)

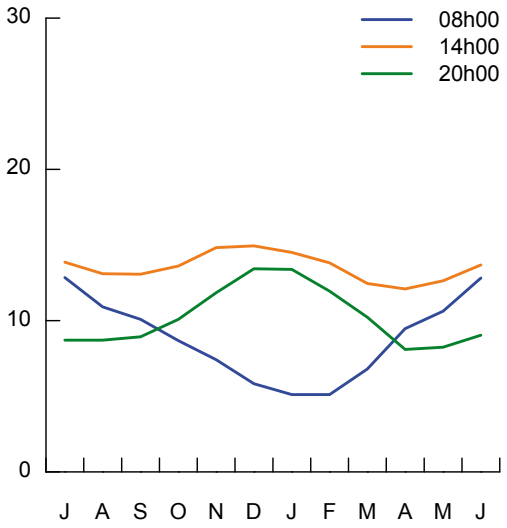


Modelled data (WorldClim)

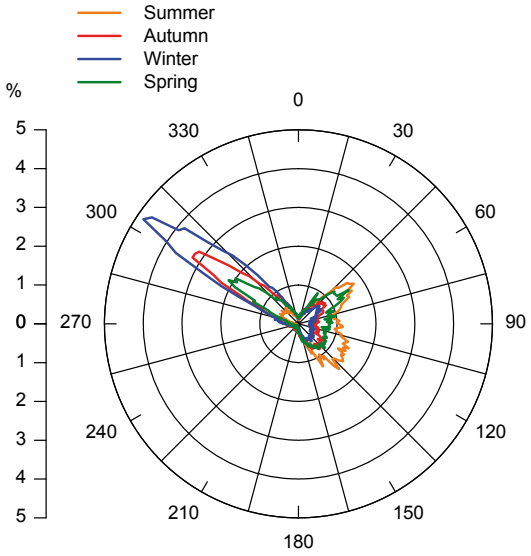


Wind diagrams

Speed



Directions



Responsible authors: K. Berger, A. Haensler & J. Luther-Mosebach

Soils

Year of sampling	Hectare plots sampled	SOTER unit
2002	26 (R1–25, R65)	ZA1317
Soilscape	**Dominant soil group(s)**	**Reference group richness**
Leptosols	Leptosol, Solonchak	5
Soil unit richness	**Soil unit evenness**	**Soil ecotype richness**
14	0.727	19
Parametric space	**pH**	**Electrical conductivity**
4.61	8.4 (4.8–10.2)	227 (48–9100) $\mu S \cdot cm^{-1}$
Organic carbon		
0.69% (0.13–9.82%)		

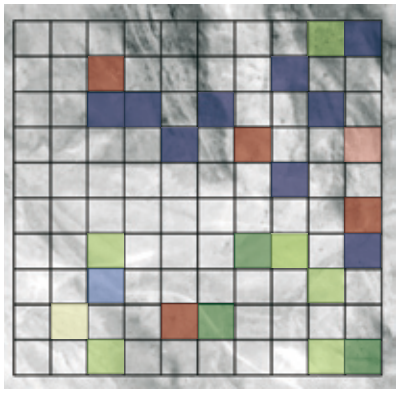
Leptosols are the most common group on this Observatory and predominantly found on steeper positions, followed by Calcisols and Regosols in the footslopes and valleys, occasionally accompanied by Solonchaks and Durisols.

The pH values show relatively wide ranges except for the subsoil, which is mainly represented by deeper, calcareous soils. The same is true for the electrical conductivity, which reaches its highest values in the saline Solonchaks. These high concentrations would also cause the high mean values of electrical conductivity, while the median in the upper horizons represents the non-saline character of the majority of profiles. Organic carbon is enriched in the topsoil and its content widely varies with depth. The fine particle percentage (clay and silt) shows similar wide ranges with depth. This is due to the different parent material, ranging from silty sand to sandy silt in the southwest-exposed accumulation areas on the footslopes. The variability of the rooting space caused by different depths of the bedrock and contents of coarse rock fragments is moderate. The rooting space median of 15% underlines the shallow, rocky character of the soils.

Textures range from silty-loamy sand to sandy silt and silty loam. With regard to the sand fractions, the samples cover a range from coarse to fine sands. This uneven distribution is a result of both, different parent materials and weathering behaviour as well as an aeolian input of fine sand. Willer (2004) showed a strong influence of aeolian sediments (silt and fine sand) in the soils of the region. This has an enormous impact on the differences in geochemical composition of the soils as it reduces the original differences from the bedrock as parent material. However, large differences in the soil units are still evident with respect to their physical properties and dynamic parameters such as salinity, pH values, and nutrient availability.

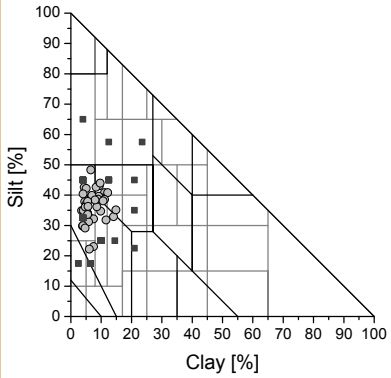
The trend of increasing small-scale heterogeneity from the hilly habitats to the steep slopes causes a strong variability of soil physical conditions on the steep slopes within a distance of few centimetres. The pattern of soil pockets combined with run-off and run-on effects by exposed bedrock and stone cover provides a wide range of micro-habitats with varying water availability. This 'flowerpot' environment enables the remarkably high vascular plant species richness. Additionally, small-scale changes in the parent material such as calcareous layers in the arkoses amplify the abiotic diversity. A microtransect from east to west on a hill slope revealed a pH-gradient from pH 4.8 to pH 9.1 within a distance of 10 m, caused by low contents of calcium carbonate in the parent material on the western site. The vertical orientation of bedrocks in the area enhances these effects by a high variation of the sedimentary bedrock units. As a result, the variability of total content of potassium, magnesium, and phosphorus is high. Nitrogen mainly originates from the atmosphere or decayed organic matter and its concentration is thus independent of the variable bedrock.

Map of soil profiles



Haplic Leptosol
Lithic Leptosol
Calcic Solonchak
Hypersalic Solonchak
Epipetric Calcisol
Epipetric Durisol
Epileptic Regosol

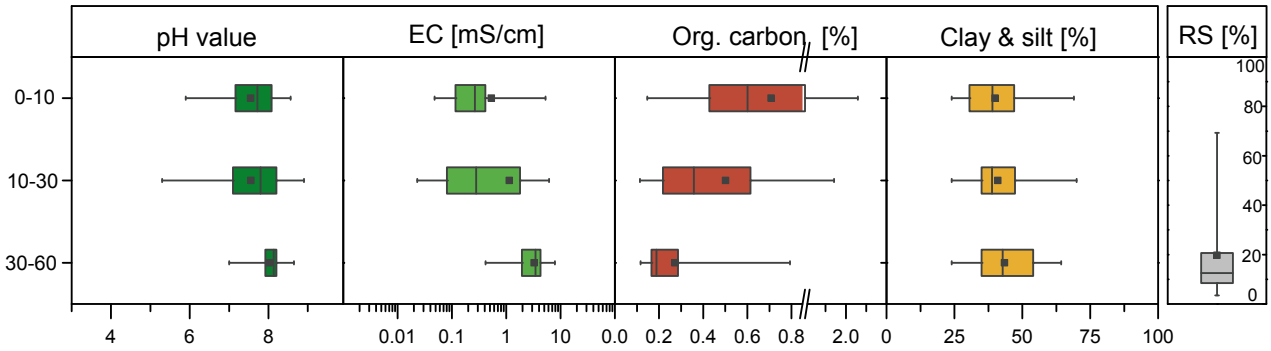
Soil texture triangle



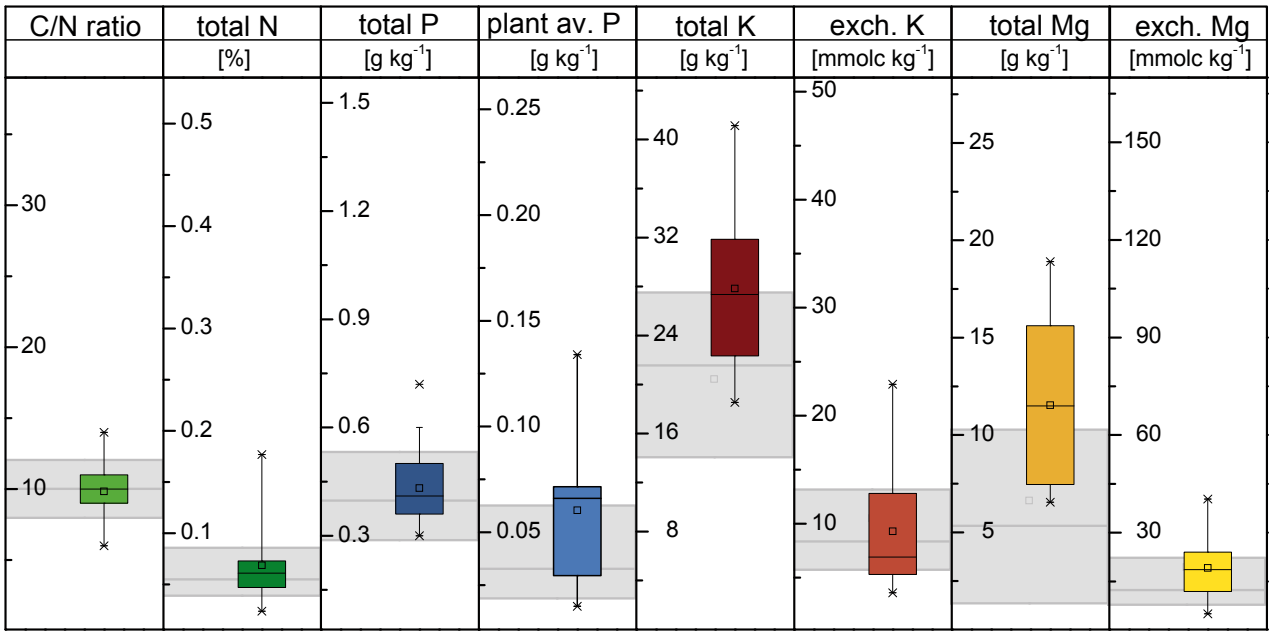
Besides the parent material and the small-scale structures, the exposition and inclination of the slopes influence soil properties. Even slight variations in these factors can result in different temperature regimes and wind exposure, which again leads to differing amounts of rainfall, fog, and dew, and therefore different soil moisture conditions and weathering conditions of the bedrock.

Finally, the impact of termites should not be underestimated. Although not a common feature in this Observatory, few remnants of termite mounds (heuweltjies) exist on the slopes. They are easily detectable by changes in vegetation patterns, presumably due to changes in nutrient patterns since no major differences were evident in the soil depth and texture except for positions near the centre of the structures.

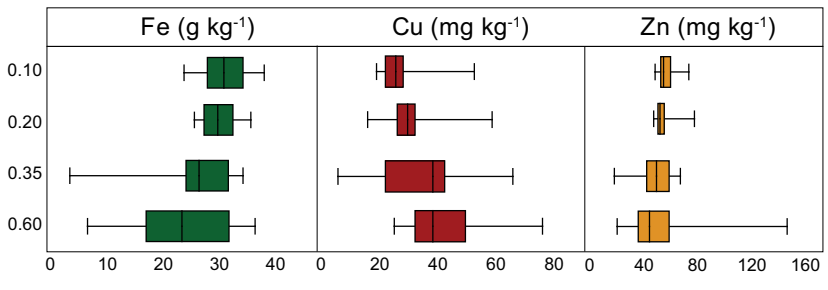
Soil characteristics



Soil nutrients



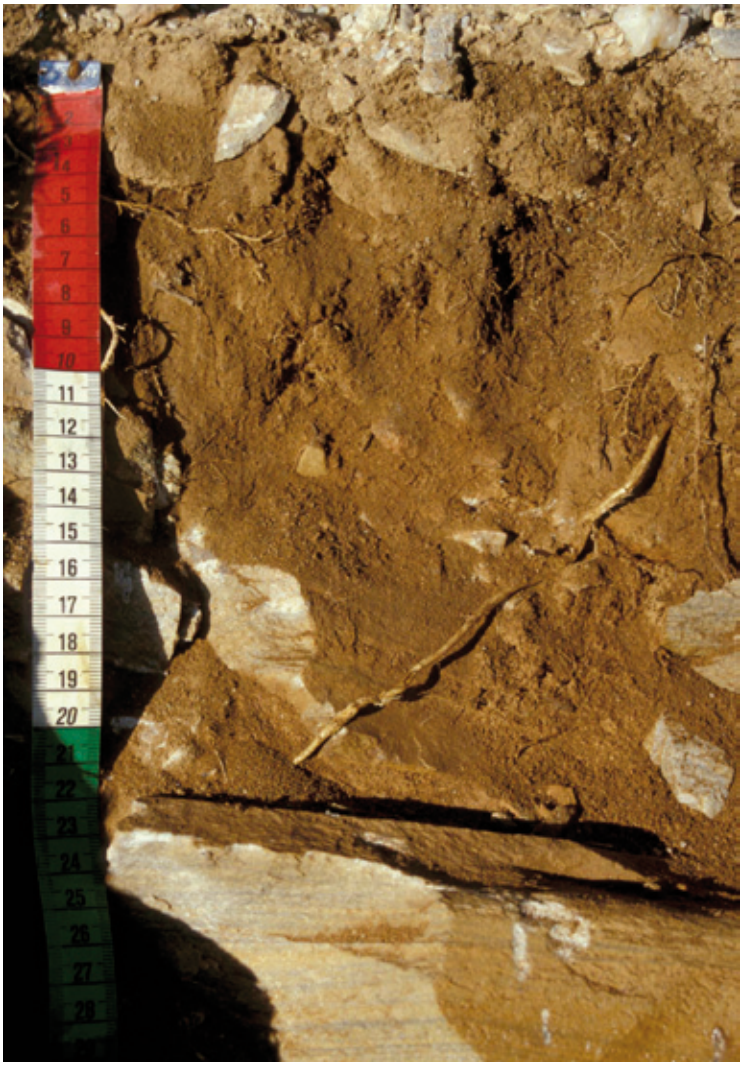
Soil micronutrients

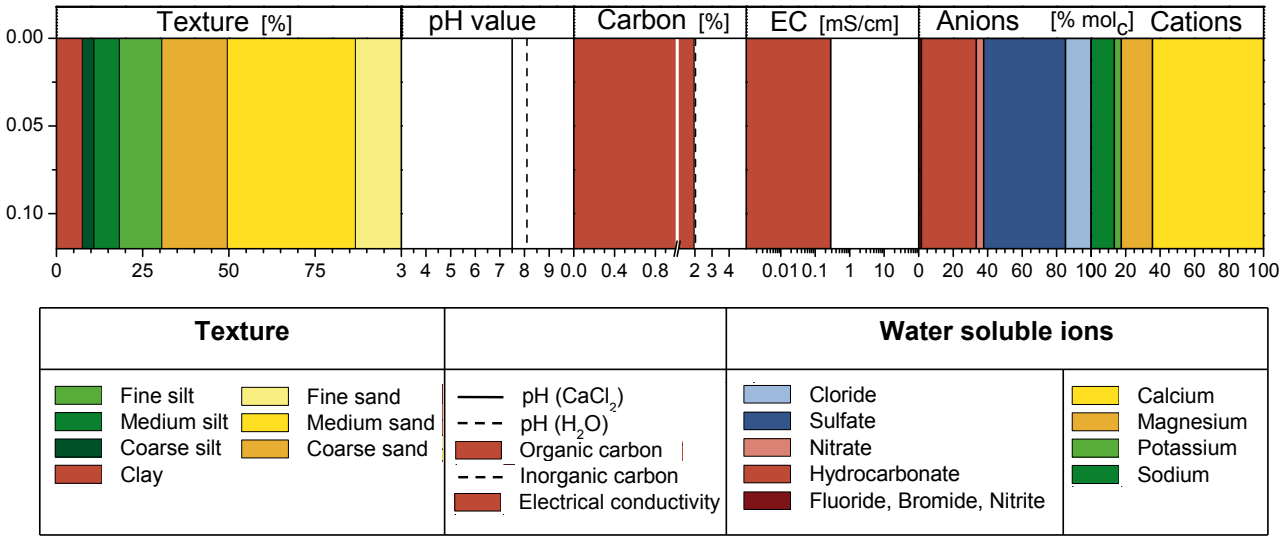


Reference profile (H25)

The **Leptosol** is a typical example of a shallow soil developed on the steep slopes of the Observatory. This profile was formed on the weathering resistant arkoses of the Stinkfontein Formation. The westerly exposed slope has approx. 60% inclination. Additionally, the bedrock layers have an inclination of 75% towards the slope, which results in a 'flowerpot'-like substrate structure typical for the region, which is one important aspect for the wide range of microhabitats. Run-on of rainwater from surrounding stone covered areas (up to 90%), variability in depth of the cover layer and root penetration in bedrock fissures and pockets enhances the small-scale heterogeneity of water resources in this system.

The electrical conductivity was moderate (280 µS cm^{-1}) and the soil reaction was moderately alkaline (pH 7.5). Deviating from the general decrease of organic carbon content from south to north along the winter-rainfall section of the BIOTA Southern Africa transect (see also Article III.3.3), the values in this profile are unusually high for its northern location. This might be a result of the high fine-root density in the soil sample. Resulting from the former input of wind-blown material, the total element contents are elevated with respect to the underlying arkose bedrock, with highest values for potassium and iron resulting in a mean total soil base content of 220 $cmol_c$ kg^{-1}.



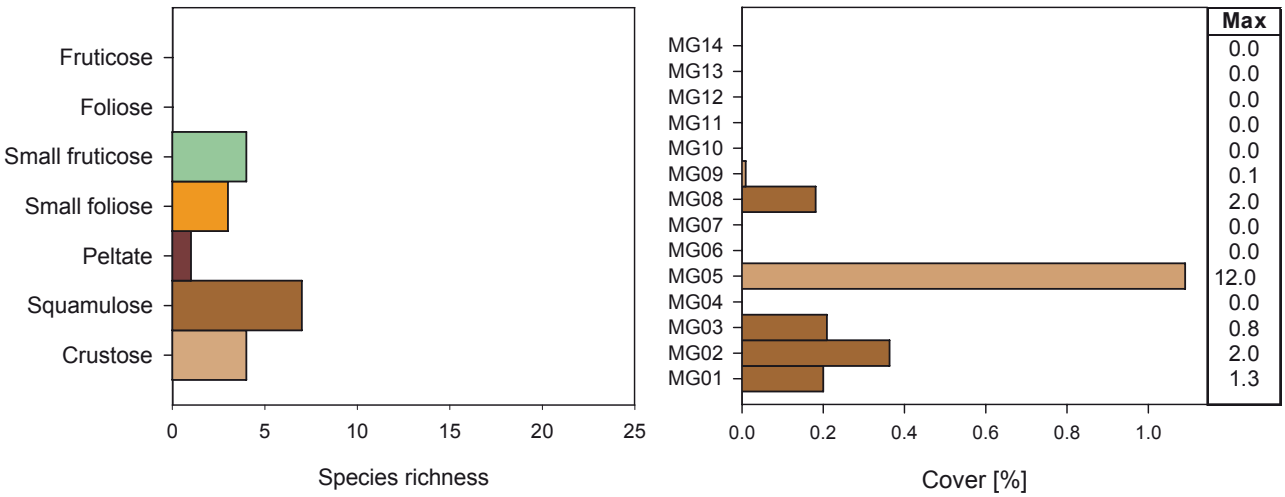


Responsible authors: U. Wisch, A. Petersen, A. Gröngröft & D. Mager

Lichens

Sampling period(s)	Hectare plots sampled	Cover
2001, 2002	11 (R1−R10, R31)	2% (0−15%)
Total species richness	**Species richness on soil [1 km²]**	**Species richness on rock [1 km²]**
53	19 (36%)	21 (40%)
Species richness on plants [1 km²]	**Species richness on soil [1000 cm²]**	
13 (24%)	2 (0−6)	

Life forms



List of Taxa

Terricolous (on soil):

Acarospora sp. 01 (M-0038552)
Buellia sp. 01 (M-0038995)
Collema coccophorum
Collema texanum
Diploschistes aeneus
Diploschistes cf. thelenelloides
Lichinaceae sp.
Peccania arabica
Peccania font-queriana
Peccania subnigra
Peltula coriacea
Placidium semaforonense
Placidium squamulosum
Placidium tenellum
Protoparmelia sp. 01 (M-0038411)
Psora crenata
Psora sp. 01 (M-0038999)
Toninia aff. lutosa
Toninia lutosa

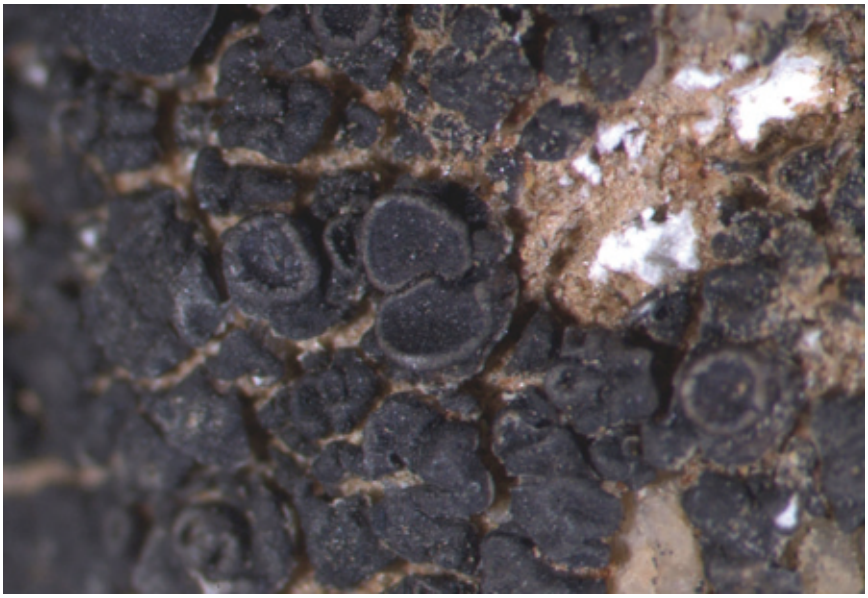
Saxicolous (on rock):

Acarospora spp. (2)
Acarospora strigata
Buellia spp. (2)
Caloplaca cf rubelliana
Caloplaca cinnabarina
Diploschistes aeneus
Diploschistes cf. thelenelloides
Heteroplacidium acarosporoides
Lecidea sp.
Peccania sp.
Peccania tiruncula cf
Peltula coriacea
Peltula inversa
Rinodina gennari
Trapelia sp.
Xanthoparmelia hottentotta
Xanthoparmelia spp. (3)

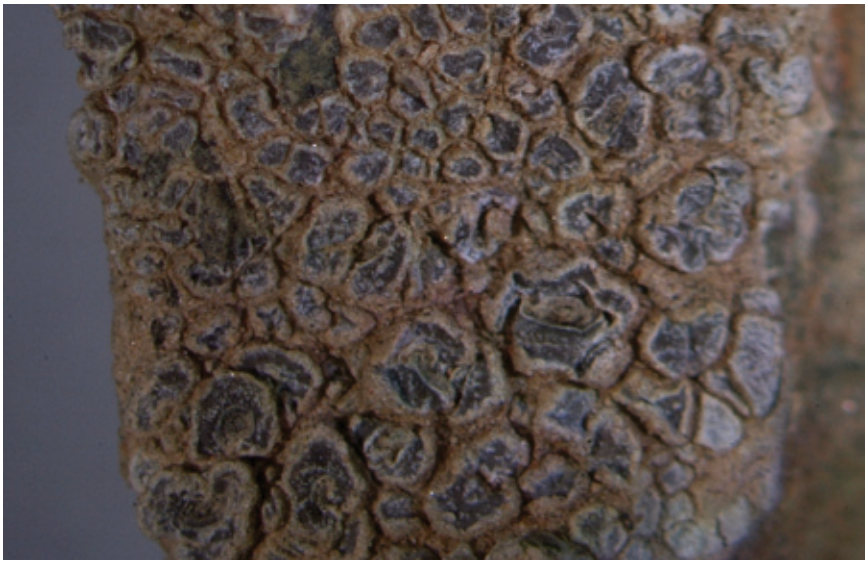
Epiphytic (on plants):

Amandinea extenuata
Arthonia sp.
Arthopyrenia sp.
Arthopyrenia subcerasi
Arthothelium sp.
Buellia sp.
Caloplaca sp.
Hyperphyscia syncolla
Rinodina spp. (2)
Xanthoria karrooensis
Xanthoria parietina
Xanthoria alexanderbaai

Placidium semaforonense. Photo: L. Zedda & G. Rambold.



Protoparmelia sp. Photo: L. Zedda & G. Rambold.



Diploschistes aeneus. Photo: L. Zedda & G. Rambold.

This Observatory possesses lichens on all types of substrate, especially on rock. Suitable phorophytes are only present in some hectare plots on the Observatory (mainly *Aloe ramosissima*, *Salsola* spp. and *Euphorbia* spp.), so that only a few corticolous taxa occur. The number of soil-inhabiting lichen species is comparable to that of other Observatories in Namaqualand, i.e. S22 (Soebatsfontein), S27 (Ratelgat) and S28 (Moedverloren), but the lichen species composition on Numees differs from the others in that foliose taxa are absent and there is a higher percentage occurrence of ubiquitous species. Most of the soil-inhabiting lichens are squamulose, but the proportion of small fruticose and crustose taxa is considerable as well.

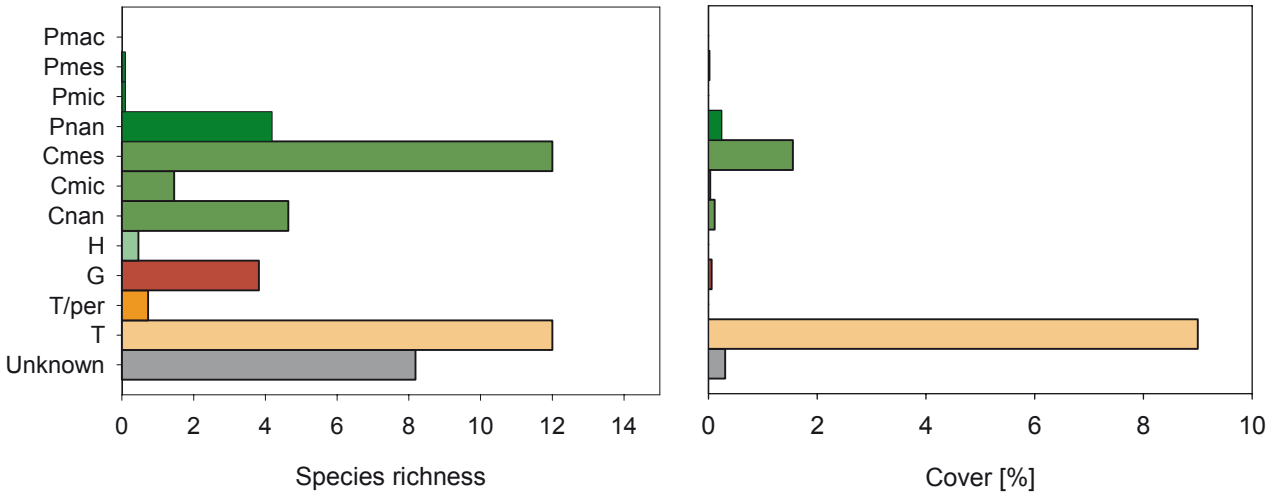
The diversity of lichen morphological groups recorded at this Observatory is high with the most dominant being MG05. Lichen morphogroups were only recorded from H23, H25, H28, H47, H66 and H72. Among these, only H25 shows a high lichen cover (15%). Lichens are generally more common on plots in the mountainous highlands. The hectare plots in the valleys are completely lacking lichens, probably due to a high proportion of sand (especially in the dry river beds), or of stones, and also to higher grazing intensities in the valleys.

Responsible authors:
L. Zedda & G. Rambold

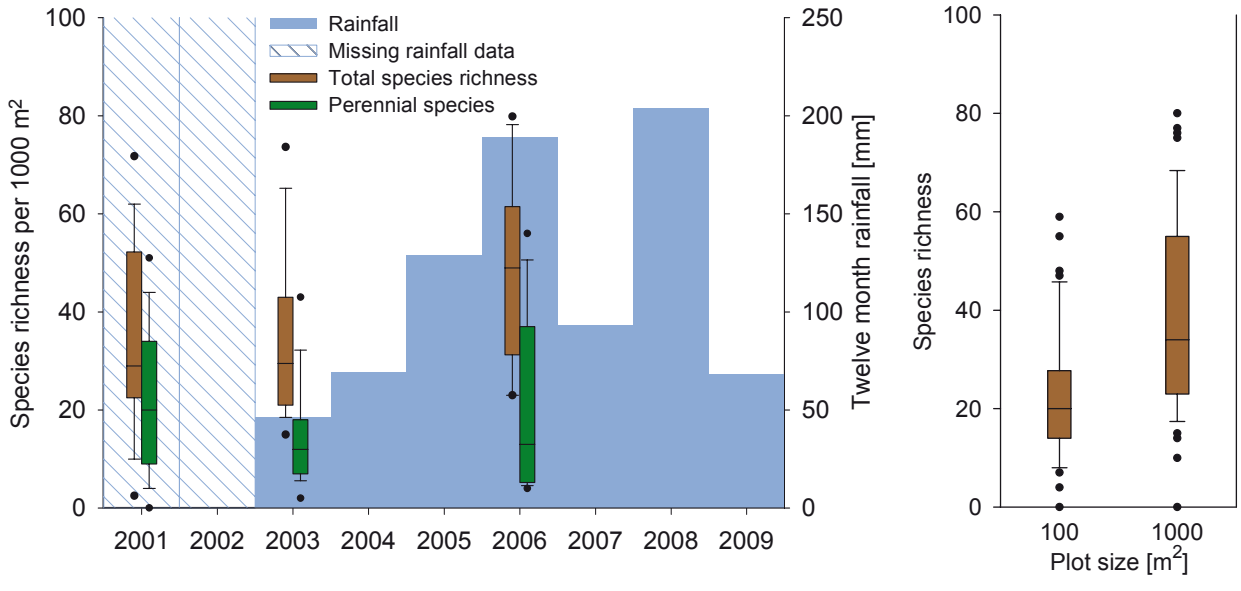
Vascular plants

Sampling period(s)	Hectare plots sampled	Biome
2001–2003, 2006	20 (R1–R20)	Succulent Karoo
Vegetation unit (level 1)	**Vegetation unit (level 2)**	**Identification rate**
Richtersveld Bioregion	SKr 1 Central Richtersveld Mountain Shrubland	39% – 67% – 71%
Cumulative family richness	**Dominant families (cover)**	**Dominant families (richness)**
48	Aizoaceae, Asteraceae, Zygophyllaceae	Aizoaceae, Asteraceae, Crassulaceae
Cumulative species richness (1 km²)	**Species richness (1000 m²)**	**Species richness (100 m²)**
610 – 294	39.1 (0–80)	22.9 (0–59)
z-value	**Species richness change per year (1000 m²)**	**Evenness (1000 m²)**
0.232 (0.000–0.559)	n.a.	0.645 (0.083–0.866)
Evenness (100 m²)	**Simpson (1000 m²)**	**Simpson (100 m²)**
0.619 (0.195–0.899)	0.780 (0.094–0.953)	0.716 (0.194–0.951)

Life forms



Species richness



Classification table (2001)

Column		Cover	All	1	2
Number of relevés			**14**	**8**	**6**
Mean cover [%]			11.5	6.7	18.0
Mean species richness (1000 m²)			42.8	28.5	61.8
Mean soil pH			7.82	8.0	7.65
Mean electrical conductivity [µS·cm^{-1}]			385	555.6	158
Organic carbon [%]			0.67	0.5	0.86
Nitrogen [%]			0.07	0.1	0.08
Unit 1: Mesembryanthemum pellitum-Zygophyllum patenticaule community *					
T	Mesembryanthemum pellitum	2.19	50	86	.
Cnan	Zygophyllum patenticaule	0.55	43	86	.
G	Trachyandra muricata	0.10	43	86	.
Cnan	Cheiridopsis robusta	0.10	36	57	.
H	Stipagrostis obtusa	0.10	36	57	.
G	Gethyllis grandiflora	0.03	36	57	.
T	Oncosiphon grandiflorum	0.06	29	57	.
Pnan	Brownanthus pseudoschlichtianus	2.03	29	57	.
Pnan	Euphorbia mauritanica	0.20	29	57	.
T	Trianthema triquetra	0.08	79	100	43
Unit 2: Astridia longifolia-Stoeberia beetzii community					
Cmes	Astridia longifolia	1.11	50	.	86
Pnan	Stoeberia beetzii	1.61	50	.	86
Cmes	Ceraria fruticulosa	0.10	50	.	86
Pnan	Senecio sarcoides	0.48	36	.	71
Pnan	Euphorbia dregeana	0.10	29	.	57
Cmes	Euphorbia chersina	0.08	29	.	57
Cmes	Cotyledon orbiculata var. orbiculata	0.10	29	.	57
Cnan	Adromischus marianiae var. kubusens	0.10	29	.	57
Cmes	Microloma calycinum	0.10	29	.	57
Cmes	Othonna opima	0.80	29	.	57
Pmic	Aloe pearsonii	0.33	29	.	57
n.a.	Leipoldtia weigangiana	0.33	29	.	57
Cnan	Tylecodon buchholzianus	0.10	29	.	57
Cnan	Conophytum gratum	0.10	29	.	57
n.a.	Antimima sp. sublunate	0.80	29	.	57
Most frequent companions					
T	Amellus nanus	0.10	93	100	71
T	Tripteris microcarpa	0.38	86	100	57
T	Didelta carnosa	0.93	79	71	71
T	Schismus barbatus	0.09	64	71	43
T	Gorteria diffusa ssp. diffusa	0.21	57	29	71
Pnan	Euphorbia gummifera	0.20	57	43	57
Cmes	Psilocaulon subnodosum	0.14	57	71	29
T	Forsskaolea candida	0.09	57	43	57
T	Aristida adscensionis	0.08	57	57	43
T	Oncosiphon suffruticosum	0.07	57	43	57
Cmes	Galenia dregeana	0.64	50	14	71
T	Indigofera pungens	0.29	50	14	71
G	Oxalis obtusa	0.09	50	43	43
T	Mesembryanthemum squamulosum	0.22	43	29	43
Pmic	Aloe dichotoma var. ramosissima	0.10	43	14	57
H	Acanthopsis disperma	0.10	43	29	43
Cnan	Aptosimum spinescens	0.10	43	57	14
Cmes	Solanum burchellii	0.08	43	14	57
Pmic	Rhus populifolia	0.48	36	29	43
H	Stipagrostis ciliata var. capensis	0.44	36	57	14
Cmes	Blepharis furcata	0.10	36	14	57
Cmes	Euphorbia ephedroides	0.10	36	.	57
Cmes	Euphorbia hamata	0.10	36	.	57

**diagnostic species not tested for significance*

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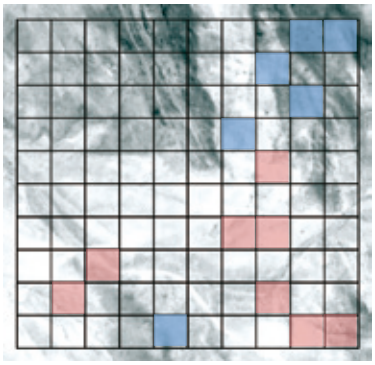
Map of vegetation units



The vegetation of Numees falls into the Central Richtersveld Mountain Shrubland (SKr 1, Mucina et al. 2006), which is characterised by the dominance of leaf-succulent dwarf shrubs. Plant diversity is very rich due to the high environmental diversity in terms of altitudinal range, topographical diversity, geological formations and lithology, as well as soil types and soil parameters. This Observatory possesses the highest environmental diversity of all Observatories in Namibia and South Africa.

The flora of the Observatory represent a broad variety of life forms ranging from shrubs (P nan), dwarf shrubs (C nan - C mes), geophytes (G), and perennial grasses (H) to annuals (T), with annuals and taller dwarf shrubs (C mes) being the most species-rich groups. Annuals possess the highest cover values (> 8%) during years with sufficient rainfall.

Aizoaceae and Asteraceae are the most diverse and abundant floral elements, which is typical of the Succulent Karoo vegetation. The richness in plant families is above the mean value for all the Succulent Karoo Observatories and the BIOTA transects in general. In comparison to the other Observatories in the Richtersveld (i.e. S18 Koeroegap Vlakte and S21 Groot Derm), the Numees Observatory possesses the highest species richness at all plot sizes. The mean species richness of the Numees Observatory approximates that of the mean species richness for the entire transect but is below that of the more southern Succulent Karoo Observatories. However, the cumulative species richness for 1 km²

exceeds the transect-wide mean with 365 species. The β-diversity, expressed as z-values for the transition 100 m²–1000 m², approximates the mean values for all Observatories, but is lower than for the other Succulent Karoo Observatories.

The Observatory Numees can be divided topographically into the plain terraces of the valley bottom (dissected by a few ephemeral river courses), and the mountainous parts (mostly in the northern part). The valley is inhabited by the *Mesembryanthemum pellitum-Zygophyllum patenticaule* community (unit 1), described as *Mesembryanthemo pelliti-Zygophylletum prismatocarpi* (Ch) association by Jürgens (2004). All plots falling into this unit possess very thick calcretes. This community varies depending on smaller-scale soil features. *Zygophyllum patenticaule* reaches relatively high cover values (1%) and is often accompanied by *Trachyandra muricata* in areas of high soil pH (> 8) and salinity where the calcrete layer is close to the soil surface. At other parts of the valley, a layer of probably airborne silt has accumulated (> 35 cm deep) on top of the calcrete. These soils accommodate large cushion-like mats of the dwarf shrub *Brownanthus pseudoschlichtianus*. Species numbers in these valleys range between 10 and 30 per 1000 m².

In contrast to the valley, the vegetation of most of the mountain plots is composed of approximately 60 to 80 species per 1000 m². This is due to the high diversity of micro-habitats where microclimate and soil parameters change over short distances. These areas are inhabited by the very species-rich *Astridia longifolia-Stoeberia beetzii* community (unit 2), which is characterised by leaf-succulent dwarf shrubs such as the Aizoaceae *Cerraria fruticulosa* and *Othonna opima,* and is often dominated by the fruticose dwarf shrub *Galenia dregeana*. Within this unit, the plots H36, H09, and H17 represent the higher-altitude mountain vegetation, characterised by species such as *Tylecodon paniculatum* (Botterboom) and *Didelta spinosa* (Perdebos), which require higher humidity and are important species of the less arid southern

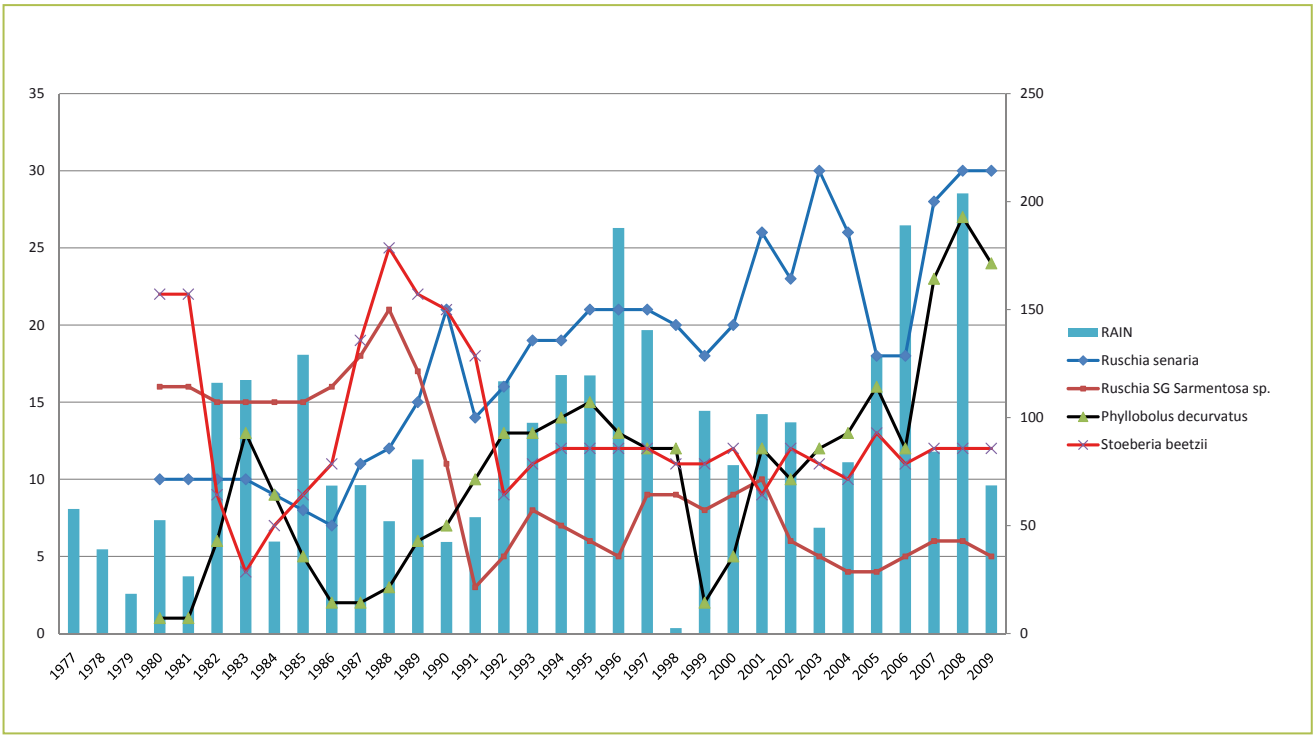
Classification table (continued)

Column		Cover	All	1	2
Number of relevés			**14**	**8**	**6**
Cmes	Monechma mollissimum	0.10	36	14	43
G	Trachyandra bulbinifolia	0.10	36	29	29
Cmic	Zygophyllum cordifolium	0.10	36	43	29
Cnan	Hypertelis salsoloides var. salsolo	0.08	36	29	29
Cmes	Tylecodon reticulatus ssp. reticula	0.06	36	.	57
G	Ornithoglossum viride	0.05	36	43	14
Pnan	Zygophyllum prismatocarpum	1.30	29	.	43
T	Tetragonia echinata	0.58	29	29	14
Pnan	Hermbstaedtia glauca	0.30	29	29	14
Cmes	Salsola zeyheri	0.20	29	14	29
Cnan	Crassula grisea	0.10	29	.	43
T	Cucumis meusii	0.10	29	29	29
T	Codon royenii	0.10	29	29	14
Cmes	Tetragonia verrucosa	0.08	29	14	43
Pnan	Lycium cinereum	0.08	29	.	43
T	Indigastrum argyroides	0.06	29	29	14
n.a.	Justicia cuneata ssp. latifolia	1.07	21	.	29
Pnan	Tripteris oppositifolia	0.87	21	.	43
Cmes	Mitrophyllum clivorum	0.53	21	.	43
Cnan	Antimima sp. pulvinate	0.40	21	.	43
Cmes	Melolobium humile	0.40	21	.	43
Pnan	Euryops namibensis	0.40	21	.	43
Cmes	Eberlanzia ebracteata	0.40	21	.	29
n.a.	Hermannia desertorum	0.23	21	.	43
T	Ehrharta delicatula	0.10	21	.	43
Pnan	Antizoma miersiana	0.10	21	.	43
Cnan	Cephalophyllum numeesense	0.10	21	.	43
Pnan	Crassula macowaniana	0.10	21	.	43
Cmes	Berkheya canescens	0.10	21	.	43
Cnan	Crassula subacaulis ssp. erosula	0.10	21	.	43
Cnan	Crassula clavata	0.10	21	.	43
H	Acanthopsis hoffmannseggiana	0.10	21	.	43
Cmic	Tetragonia fruticosa	0.10	21	.	43
Cnan	Crassula elegans	0.10	21	.	43
Cmes	Crassula muscosa var. muscosa	0.10	21	.	43
Cmes	Ruschia senaria	0.10	21	.	29
Cmes	Kleinia longiflora	0.10	21	14	29
Cmes	Berkheya fruticosa	0.10	21	14	29
Cmes	Asparagus capensis	0.10	21	14	29
Pnan	Aridaria noctiflora ssp. noctiflora	0.10	21	14	29
Cmes	Phyllobolus oculatus	0.10	21	14	14
Cmes	Phyllobolus deciduus	0.10	21	14	14
Cnan	Anacampseros baeseckei	0.07	21	.	43
Cnan	Helichrysum obtusum	0.07	21	.	43
Cnan	Prenia sladeniana	0.07	21	.	29
Cnan	Crassula deceptor	0.07	21	.	43
T	Foveolina dichotoma	0.07	21	43	.
T	Osteospermum pinnatum var. pinnatum	0.04	21	29	.
Cmes	Ruschia sarmentosa	4.05	14	.	29
Cmes	Othonna arbuscula	0.30	14	.	29
Cmes	Ruschia sp. blau	0.30	14	.	29
Hper	Chlorophytum rangei	0.10	14	.	29
Pnan	Microloma incanum	0.10	14	.	29
Cnan	Adromischus alstonii	0.10	14	.	29
Pnan	Tylecodon paniculatus	0.10	14	.	29
Cnan	Crassula namaquensis	0.10	14	.	29
Cmes	Pentzia argentea	0.10	14	.	29
Cnan	Conophytum bilobum	0.10	14	.	29
Cmes	Thesium lineatum	0.10	14	.	29
Cmes	Tylecodon wallichii	0.10	14	.	29
T	Nemesia anisocarpa	0.10	14	.	29
T	Mesembryanthemum barklyi	0.10	14	.	29

Flowers of *Pachypodium namaquanum*. Photo: N. Jürgens.

Namaqualand. In contrast, the species composition of plots H47 and H84 indicates that they are transitional between unit 1 and unit 2.

The Numees Observatory provided the opportunity to analyse vegetation change over time. Starting in 1980, a number of 100 m² relevés were sampled annually over a period of 30 years. Monitoring of these relevés was continued during the BIOTA research. Two important findings arose from this period of observation. Firstly, in spite of variations in the populations of annuals and geophytes, which were depended on rainfall, there has been a steady increase in long-lived perennial species following an extreme drought in 1979/1980. Secondly, the populations of *Brownanthus pseudoschlichtianus* (unit 1) are progressively being replaced by the broom-like shrub *Lebeckia multiflora* (Fluitjiesbos).



The graph shows the abundance of 4 out of 73 species ocurring within a 10 m x 10 m long-term observation plot “Numees 01”, see photo in the introduction to this Observatory) during 30 years of overall increasing rainfall. Data partly from Jürgens et al. 1999, Gotzmann 2002.

On denuded ancient calcrete terraces, the *Mesembryanthemum pellitum-Zygophyllum patenticaule* community is dominant in the valley of Numees. Photo: N. Jürgens.

Due to the character of the average winter rains, drizzle or soft land rains, there is more rock weathering than erosion in the mountainous parts of the Numees Observatory. Therefore, fine textured soil is combined with various quantities of rock and stones creating a sort of rockery. The resulting diversity of micro-habitats is responsible for the species richness. Photo: N. Jürgens.

Othonna opima is one of the character species in the rockery habitats of the lower altitude mountains (plants with long upright succulent leaves). Photo: N. Jürgens.

Pachypodium namaquanum (Apocynaceae) is a flagship species for the lower Gariep region. Photo: N. Jürgens.

Aloe pillansii is a larger relative of the widespread *Aloe dichotoma*, occurring only in the lower Gariep region. Photo: N. Jürgens.

A young plant of *Aloe pillansii* showing growth dynamics similar to *Aloe dichotoma* (see Observatory S12). Photo: N. Jürgens.

Responsible authors: N. Jürgens & J. Luther-Mosebach

Termites

Taxon richness	Abundance index	Dominant (sub-)family
1	n.a.	n.a.

Microhodotermes viator was the only termite species encountered at this Observatory (Vohland & Deckert 2005).

List of taxa

Taxon	(Sub-)family
Microhodotermes viator	Hodotermitidae

Responsible authors: C. Grohmann & K.E. Linsenmair

True bugs

Sampling period(s)	Methods	Family richness
2001/ X	Trapping (light, pitfall traps)	11
Species richness	**Individuals sampled**	**Fisher's alpha diversity**
28	78	15.65

Only 28 species were recorded at the BIOTA Observatory Numees (S20). Miridae, Pentatomidae, Reduviidae, Rhopalidae, and Rhyparochromidae accounted for 71% of all species. *Boisea fulcrata* (Rhopalidae) and *Nysius ericae* (Lygaeidae) were dominant in the pitfall traps. *Boisea fulcrata* is of Afrotropical distribution and is also found in Namibia. However, Numees (S20) is the only Observatory where this species was collected.

Dicranocephalus schmitzi, *D. caffer* (Stenocephalidae), and *Mecidea linearis* (Pentatomidae) are common at the Observatory and were also collected at Koereogap Vlakte (S18). *Leptodemus irroratus* (Oxycarenidae) and *Euthetus pallescens* (Alydidae) were also recorded at both of these Observatories.

Species richness in families

Family	*S*
Miridae	8
Pentatomidae	3
Reduviidae	3
Rhopalidae	3
Rhyparochromidae	3
Alydidae	2
Stenocephalidae	2
Cydnidae	1
Enicocephalidae	1
Lygaeidae	1
Oxycarenidae	1
Total	**28**

Species abundances

Light and pitfall traps

Species	Family	*N*	%
Boisea fulcrata	Rhopalidae	10	13
Nysius ericae	Lygaeidae	9	12
Dicranocephalus schmitzi	Stenocephalidae	7	9
Dicranocephalus caffer	Stenocephalidae	6	8
Mecidea linearis	Pentatomidae	5	6
Enicocephalidae spec.	Enicocephalidae	4	5
Phytocoris spec.	Miridae	4	5
Leptodemus irroratus	Oxycarenidae	4	5
Others (20)		13	37
Total		**62**	**100**

Responsible author: J. Deckert

Butterflies and moths

Sampling period(s)	Number of samples (moths)	Species richness (total)
2001/X	1	140
Species richness (butterflies)	**Species richness (all moths)**	**Species richness (Microlepidoptera)**
5	135	50
Species richness (Pyraloidea)	**Species richness (Macrolepidoptera)**	**Species richness (Noctuidae)**
34	14	37
Individuals sampled (moths)	**Fisher's alpha diversity (moths)**	
3025	29.0	

Butterflies

Butterflies were seen in small numbers at the Observatory S18 (Koeroegap Vlakte) during the sampling period. It can be assumed that only a fraction of the occurring species was observed as the sampling was conducted at the end of the season. Collecting at the onset of the winter rains would in all likelihood have at least doubled the number of species recorded.

Butterfly species and main food plants

Lycaenidae	
Aloeides barklyi	n.a.
Aloeides damarensis damarensis	Aspalatus (Fabaceae)
Cacyreus palemon palemon	Geranium, Pelargonium (Geraniaceae)
Oraidium barberae	Exomis (Chenopodiaceae)
Pieridae	
Pontia helice helice	Heliophila, Lobularia (Criciferae), Rheseda (Rhesedaceae)

Moths

The moth fauna at this Observatory is largely comparable to S18 (Koeroegap Vlakte), sharing a similar abundance of common species. The Microlepidoptera *Australoplacodoma bicolorata* (Psychidae) (see Photo) which was observed at the Observatory has only recently been described from an isolated population on the Brandberg in Namibia by Sobczyk & Mey (2007). This species is endemic to the Succulent Karoo, where it is widespread, especially in Namaqualand and the Knersvlakte. The new genus *Australoplacodoma* was established to accommodate the new species. Another common but hitherto undescribed micromoth was *Agdistis meyi* (Pterophoridae) named recently by Arenberger (2008). *Achyra nudalis* and *Uresiphita polygonalis* of the Pyraloidea group appeared with many other specimens at night lights.

Female of *Astroplacodoma bicolorata*. Photo: W. Mey.

Taxonomic spectrum of moths

Collection period: X/2001

Family	S	N
Nepticulidae	1	2
Tineidae	6	50
Psychidae	2	13
Gracillariidae	1	1
Coleophoridae	3	9
Elachistidae	1	3
Ethmiidae	1	1
Scythrididae	9	141
Oecophoridae	1	1
Gelechiidae	19	1305
Pterophoridae	2	17
Tortricidae	4	34
Microlepidoptera	**50**	**1577**
Pyralidae	25	292
Crambidae	9	128
Pyraloidea	**34**	**420**
Lasiocampidae	1	20
Lymantriidae	1	1
Sphingidae	1	2
Geometridae	10	45
Arctiidae	1	3
Noctuidae	37	957
Macrolepidoptera	**51**	**1028**
Total	**135**	**3025**

Responsible author: W. Mey

Vertebrates

Total species richness	Reptile species richness	Bird species richness
7	n.a.	7
Large mammal species richness	**Small mammal species richness**	
n.a.	n.a.	

Birds

Passeriformes	**Perching birds**
Cercomela sinuata	Sickle-winged Chat
Cercomela tractrac	Tractrac Chat
Oenanthe monticola	Mountain Wheatear
Ptyonoprogne fuligula	Rock Martin
Prinia maculosa	Karoo Prinia
Cinnyris fuscus	Dusky Sunbird
Telophorus zeylonus	Bokmakierie

Tractrac Chat (*Cercomela tractrac*). Photo: J. Deckert.

Responsible authors: J. Deckert, A. Hoffmann & A. Mills

Site-specific studies

Significance of the lithology on the soil genesis and variability in the Richtersveld

► *See* **S18.01**

General data

Number	Name	Alternative name(s)
S21	Groot Derm	Yellow Dune
Implementation	**Country**	**Province/ region**
2001	South Africa	Northern Cape
District/ constituency	**Locality**	**Farm name**
Namakwa	Alexander Bay	Groot Derm
Latitude	**Longitude**	**Altitude**
28.612340 S	16.654331 E	193 m a.s.l.
Rainfall season	**Biome**	**WWF Ecoregion**
Winter	Succulent Karoo	AT1322 Succulent Karoo
Agro-Ecological Zone	**Relative intensity of land use**	**Tenure**
n.a.	Low	Private
Type and history of landuse	**Land owner**	
Conservation area	Private	

Groot Derm (S21)

The old “yellow” dunes are characteristic for the Groot Derm Observatory. The dune valley is dominated by *Brownanthus* shrubs. Photo: N. Dreber.

The Groot Derm Observatory (alternative name Yellow Dune) is located just south of the lower reaches of the Orange River (9.6 km distance) in the triangle between the Atlantic Ocean (15 km distance) and the lower Orange River valley. The Observatory, only 193 m a.s.l., is sufficiently far inland to be part of the yellow dune belt (instead of the coastal duneveld with its white dune sands) and sufficiently far south to form part of the Succulent Karoo (instead of desert).

The underlying geology forms part of the Groot Derm Suite of the Gariep Belt, lithologically composed of schist, gabbro and metabasalt. Today, these rocks are deeply buried under yellow aeolian sands. The present dunes and interdune valleys are clearly arranged in a south-north direction. This observation is in accordance with the assumption that the sand is generated along the coast of the Atlantic Ocean and transported northwards by the predominant SSW winds.

At present, the sand transport is limited to localised areas, born at sites of disturbance and resulting in sand lineaments mostly a few meters wide and a few tens of meters long, but sometimes 10 to 100 times larger. The main bodies of the large parallel dunes are presently not moving, and steep slip faces do not exist with the dunes rather forming broad whaleback structures. These are characteristic of inactive “fossil” dunes.

The region is utilised by small stock farmers with temporary stock posts. During the last decade, one new stockpost

was built within the Observatory. In addition, there seems to be a growing population of Gemsbok (*Oryx gazella*) and Springbok (*Antidorcas marsupialis*), with both species being observed often.

This Observatory was established to observe potential future trends of expansion of the desert biome into the Succulent Karoo, i.e. in a southerly direction. Together with the Observatories Koeroegap Vlakte (S18) and Numees (S20), the Groot Derm Observatory allows monitoring of the boundary and steep gradient between the winter rainfall and the summer rainfall regimes.

Responsible authors: N. Jürgens & D.H. Haarmeyer

Remote sensing and landscape

Geomorphology	Geological units	Lithological units
Dunes and interdunes	Cenozoic Deposits	Unconsolidated superficial deposits, Conglomerate, Limestone, Sandstone, arl, high-level gravel
Mean EVI	**EVI absolute range**	**Mean leaf area index**
0.110 (0.089–0.133)	0.056 (2004)–0.201 (2006)	0.30

Grid map of Observatory

	0	1	2	3	4	5	6	7	8	9
0	41	78	81	11	60	77	84	56	54	5
1	38	67	40	30	100	80	63	85	72	73
2	92	10	1	13	98	18	14	99	65	45
3	6	64	21	59	43	95	35	34	39	9
4	23	61	93	82	48	53	57	69	42	66
5	44	26	3	37	51	75	62	47	46	49
6	91	16	20	28	96	68	36	12	52	89
7	31	33	8	25	19	79	7	97	27	70
8	71	29	32	50	17	74	87	88	58	24
9	86	83	4	94	76	55	90	22	15	2

1 *Stoeberia beetzii*-dominated dwarf shrubland on dune crest
2 *Stoeberia beetzii*-dominated dwarf shrubland on dune slope
3 *Brownanthus pseudoschlichtianus*-dominated dwarf shrubland on interdune

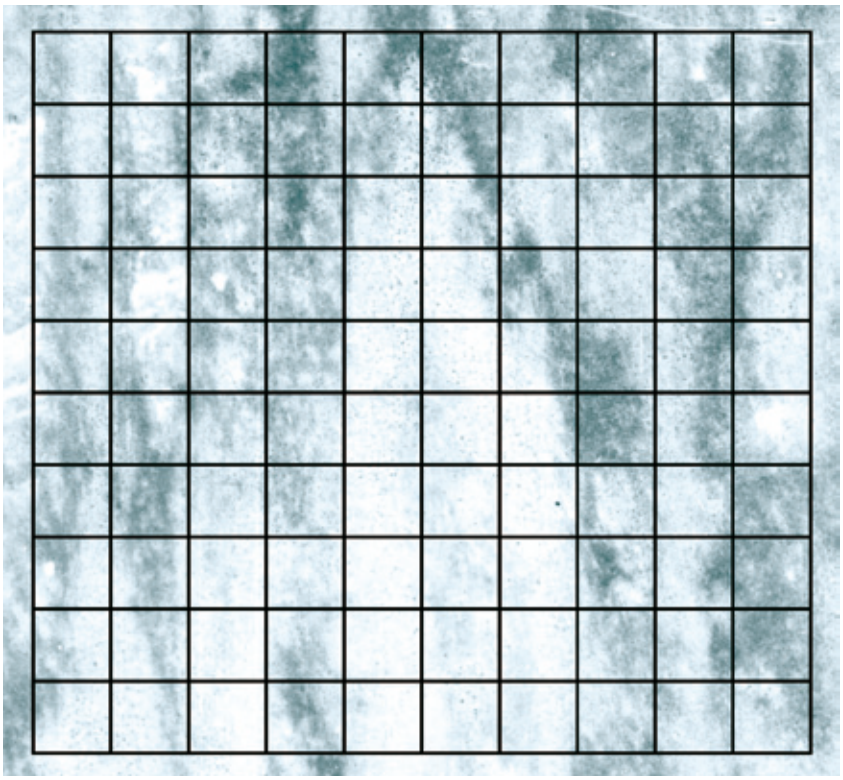
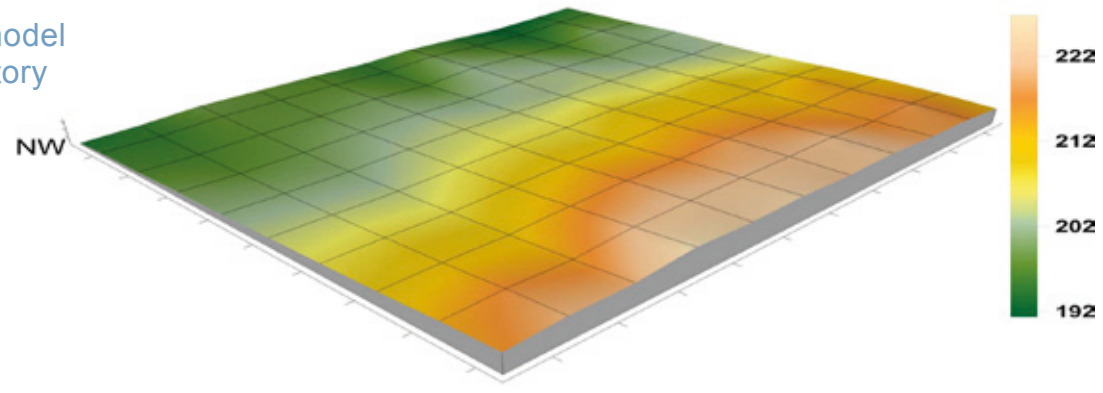


Image: aerial photograph

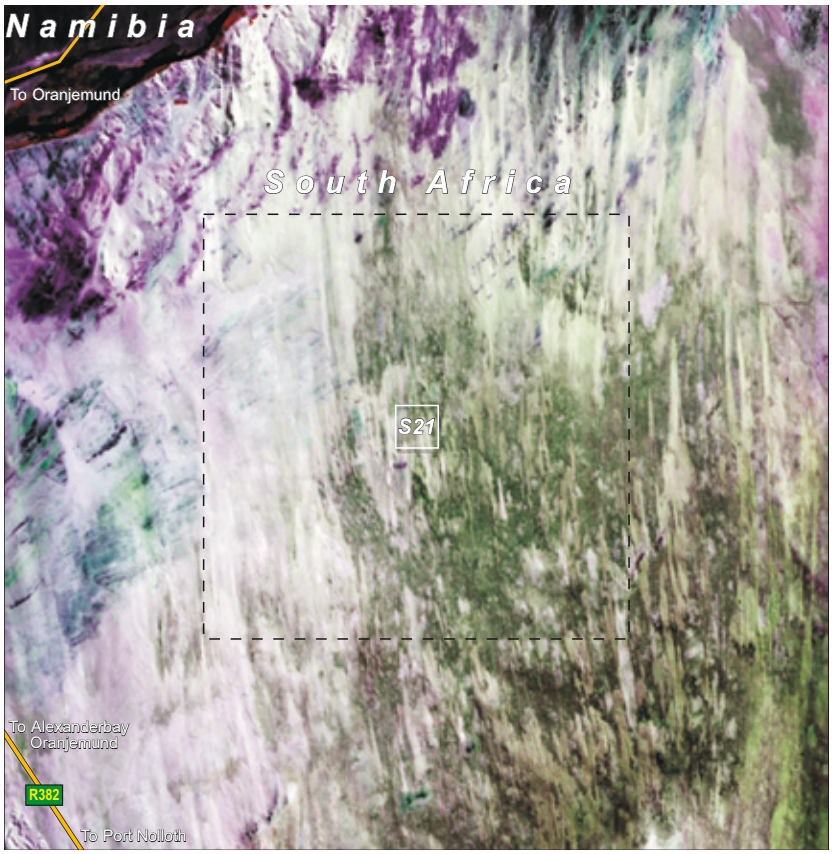
Elevation model of Observatory



Landsat image

Yellow dune structures (grey in this image), which are elevated about 3 m in height above the plain, cross the Observatory and its surroundings in north-south direction.

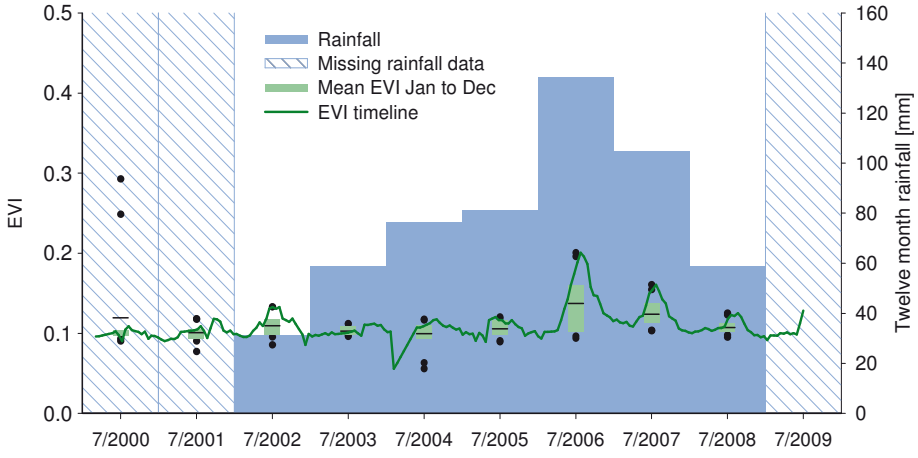
The vegetation is very sparse, as indicated by the bright colours, with localised areas of higher density leaf-succulent dwarf shrubs (darker grey colours).



Scene: 177/80, acquisition date: 08 February 2003

MODIS time series

Temporal patterns of annual rainfall, vegetation cover, and phenology



Responsible authors: M. Keil & T. Labitzky

Climate

Data from BIOTA weather station

Location	Recorded period	Mean temperature
Groot Derm (S21)	2001–2009	18.5 (3.5–42.6) °C
Mean solar radiation	**Mean wind speed**	**Mean annual precipitation**
658 (344–1043) MJ·m^{-2}·month^{-1}	3.5 (11.9) m·s^{-1}	84 (11–134) mm
Mean annual potential evapotranspiration	**Interannual precipitation variability**	**Mean relative humidity**
1458 mm	115%	86% (59–100%)
Aridity index (UNEP)		
0.06 (arid)		

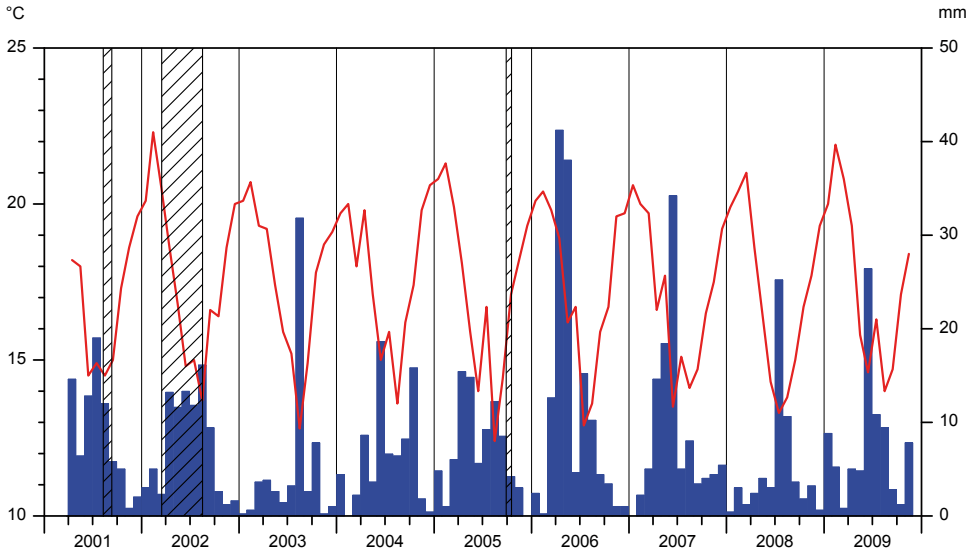
Modelled data

Mean temperature	Mean annual temperature range	Mean diurnal temperature range
16.2 (7.7–23.5) °C	5.4 °C	10.3 °C
Mean annual precipitation	**Precipitation seasonality**	**Percentage winter precipitation**
57 mm	43%	68% (winter)
Climate type	**Length of dry season**	**Aridity index (De Martonne)**
BWk	12 months	2.2 (dry)

The climate at the Observatory is characterised by arid conditions. Rainfall shows a weak seasonality with the major portion of rain falling between April and August. The mean annual rainfall over the observation period was 84 mm, which is dry in comparison to the average rainfall recorded over the entire transect, and is the driest within the Succulent Karoo. However, substantial interannual variability is evident. The near-surface air temperatures show a weak seasonal cycle. The mean annual temperature is 18.5°C and is therefore the second-coldest recorded within this biome. The low mean annual temperature can be explained by the influence of the mitigating effects of the ocean, which is only 14 km west of the Observatory. Compared to the interpolated long-term data taken from the WorldClim dataset, a slightly warmer mean annual temperature is observed at the BIOTA weather station. Furthermore, the station records of extreme temperatures deviate substantially from the interpolated data, showing warmer maximum and minimum temperatures than the WorldClim dataset. For precipitation, mean annual rainfall observed at the station is markedly higher than that of the WorldClim dataset.

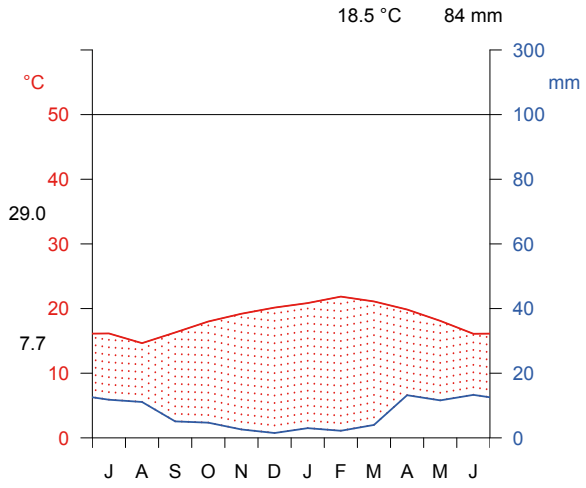
The observed near-surface winds at the Observatory are predominantly constituted of south-southeasterly flows throughout the year. Mean wind speed shows a pronounced annual cycle in the early afternoons and evenings, with slightly higher wind speeds in the afternoons. Winds recorded in the mornings are noticeably weaker and vary only slightly over the course of the year.

Time series: rainfall and temperature

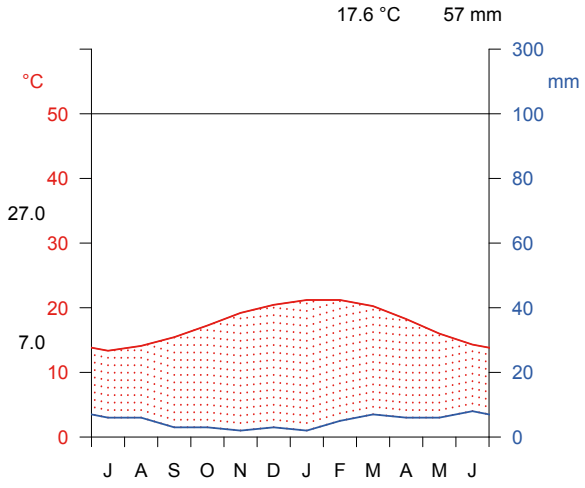


Climate diagrams

Recorded data (BIOTA)

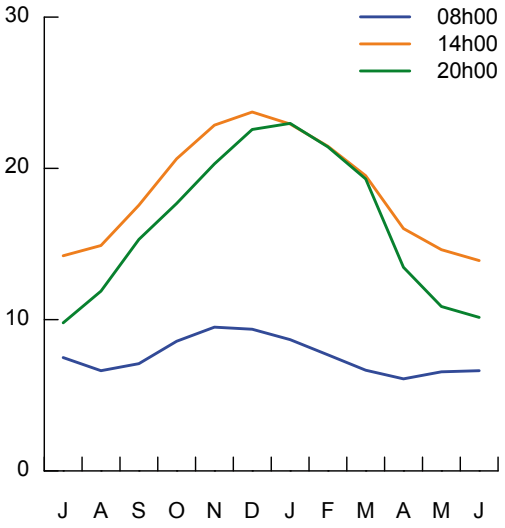


Modelled data (WorldClim)

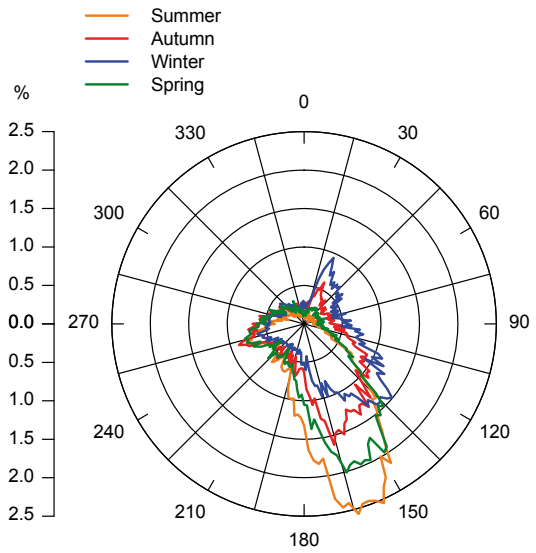


Wind diagrams

Speed



Directions



Responsible authors: K. Berger, A. Haensler & J. Luther-Mosebach

Soils

Year of sampling	Hectare plots sampled	SOTER unit
2002	15 (R1–15)	ZA1448
Soilscape	**Dominant soil group(s)**	**Reference group richness**
Arenosols (AR)	Arenosol	2
Soil unit richness	**Soil unit evenness**	**Soil ecotype richness**
4	0.392	3
Parametric space	**pH**	**Electrical conductivity**
1.21	9.0 (8.3–9.9)	244 (57–5130) $\mu S \cdot cm^{-1}$
Organic carbon		
0.27% (0.06–0.86%)		

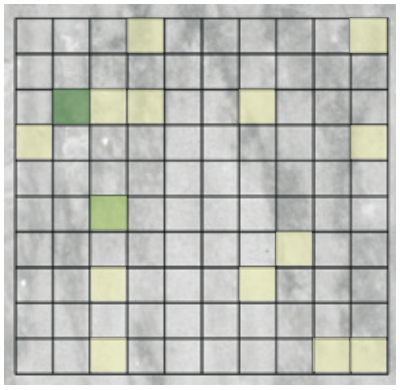
On the aerial photograph of this Observatory (see Remote sensing and Landscape Section), two zones are well visible: darker areas for sessile dunes with higher vegetation and biological soil crusts and lighter zones of active sand layers with reduced vegetation cover. Light-grey patches in the north-west of the Observatory represent shallower, calcareous, and saline soils. These soils were classified as Solonchak, surrounded by a matrix of Ferralic Arenosols (Aridic), differentiated further by their salinity (prefix 'Hyposalic'). One profile characterised by a desert pavement on the soil surface and a thin sand cover highly enriched in calcium carbonate and salts over the bedrock, was classified as a Calcic Hypersalic Solonchak (Yermic). The development of this profile is in accordance with the low topographical position and the lack of deep drainage prevented by underlying bedrock.

The pH values show a relatively small range from neutral to moderately alkaline conditions and no substantial variation with depth. Electrical conductivity shows great variability in the upper horizons, caused by shallow, salt-accumulated sites, and decreased variation in the deepest layer, where these salt-enriched soils are not included. Organic carbon shows a similar pattern with relatively wide ranges in both topsoil layers caused by variations in the age of the substrate and the coverage of biological soil crusts. The fine particle percentage (clay and silt) shows no variation except for one outlier caused by the Calcic Hypersalic Solonchak with loamier substrate. The rooting space is only limited in a few inter-dune profiles by the underlying bedrock. All macronutrients except nitrogen occur at a medium to low level, while the concentrations of micronutrients are very low.

As typical for its dunal origin, the substrate on this Observatory has a texture of pure sand with nearly no silt and clay percentage. The dune sands are predominantly (around 70%) medium sands with a small proportion (< 5%) of coarse sand. Loamy textures occur in the schist-derived material of the Solonchaks.

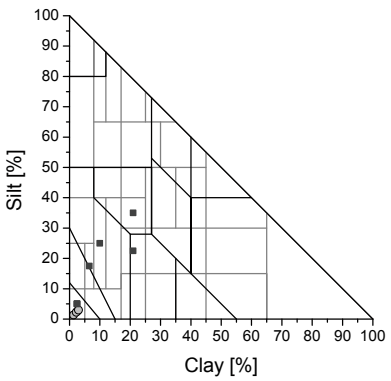
Strongly developed biological soil crusts occur, but cannot be related to analysed soil properties but rather seem to be affected by topography, driven by patterns of shifting sand and fog precipitation. Another feature of soils is the shallow root distribution, mainly restricted to the first 20 cm of soil, which is in accordance to the low rainfall amount.

Map of soil profiles

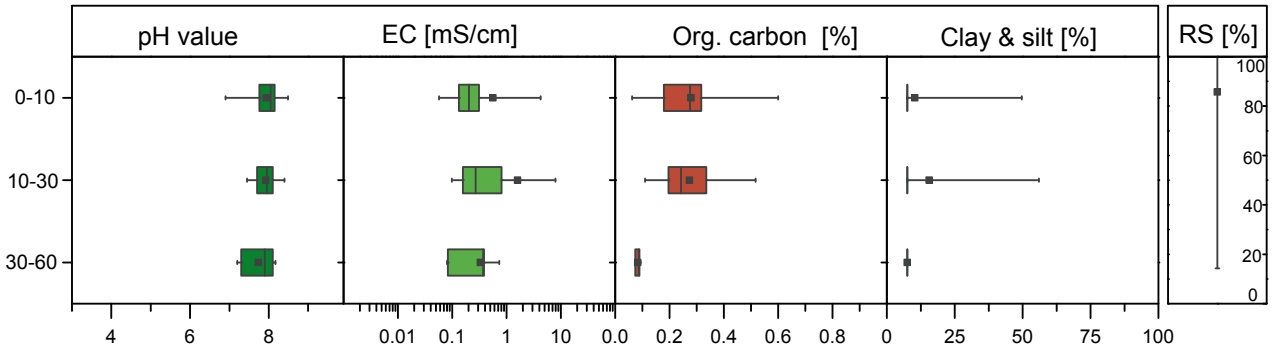


Ferralic Arenosol
Haplic Solonchak
Calcic Solonchak

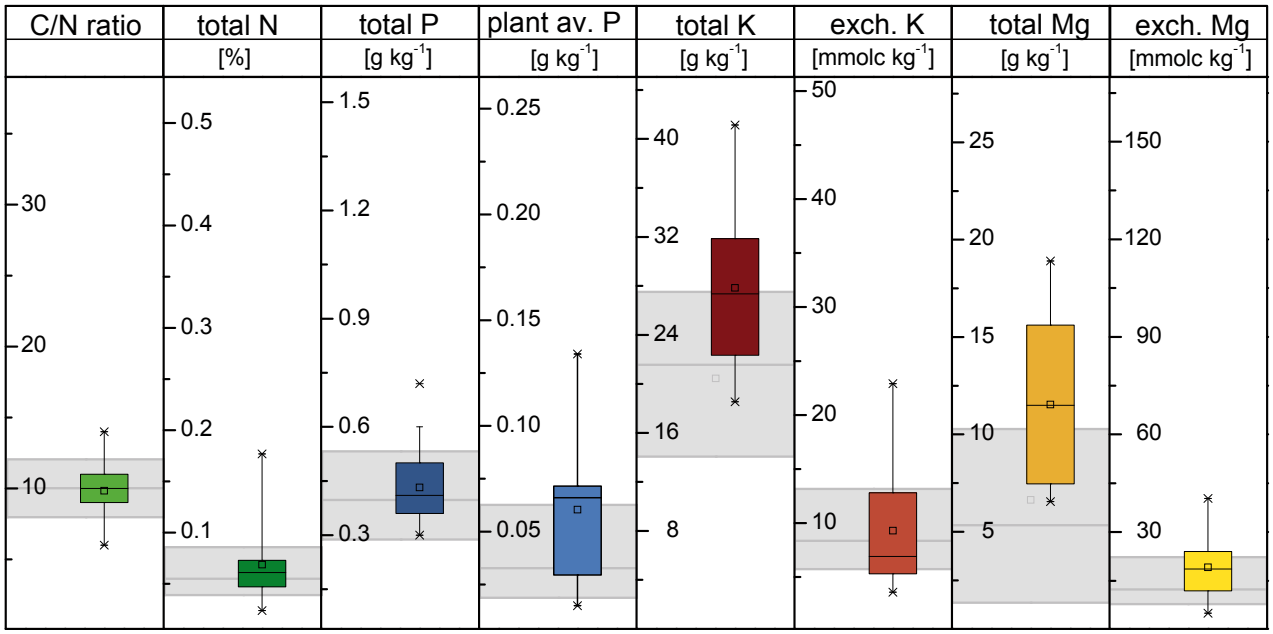
Soil texture triangle



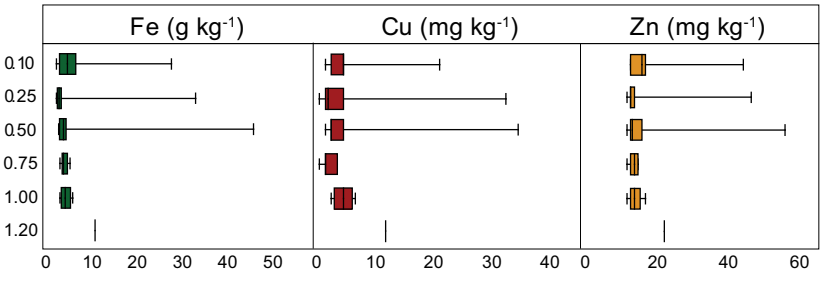
Soil characteristics



Soil nutrients



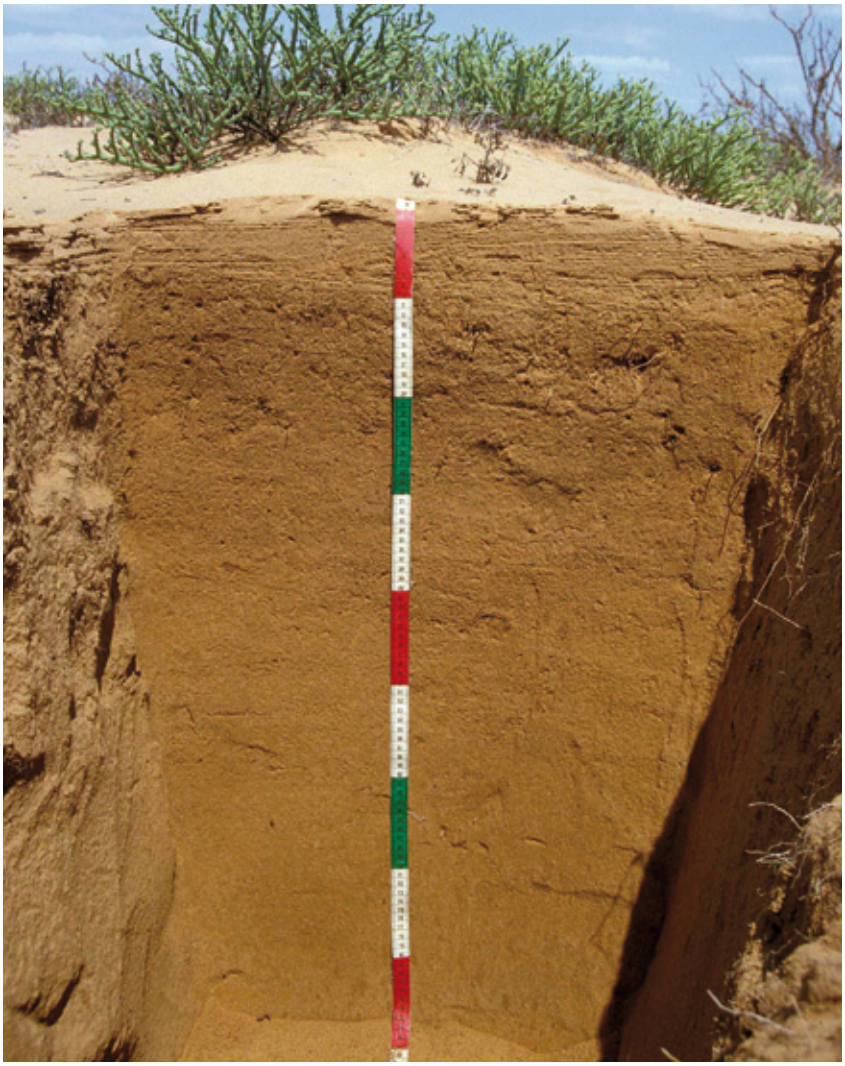
Soil micronutrients

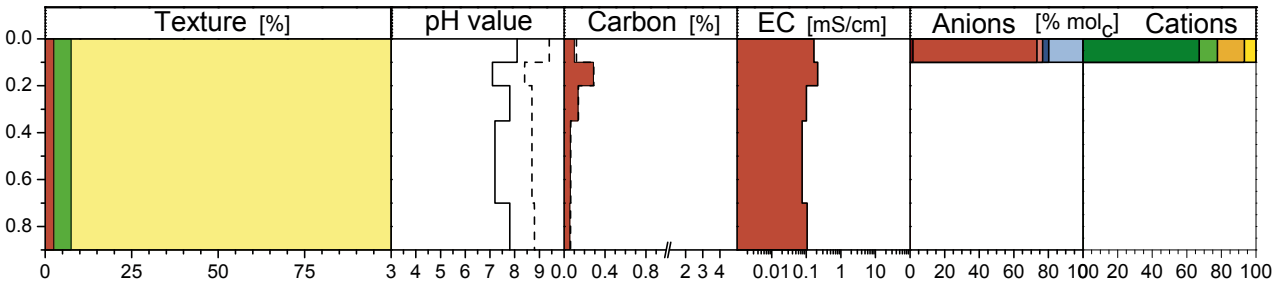


Reference profile (H92)

The **Ferralic Arenosol (Hypereutric, Aridic)** is a typical example for the soils developed in pure dune sands. The profile was situated close to a shrub and thus affected by recent accumulation of wind blown sand (phytogenic mound). The upper layer of 10 cm covers a buried topsoil horizon, which is clearly detectable through the higher number of roots and the higher content of organic carbon. Additionally, the top layer shows clear signs of layered accumulation of wind-blown sands. The main texture of the profile is medium sand with only small amounts of fine sand. Compared to other profiles, biological crusts are not evident due to the burial of the former soil surface and ongoing sedimentation.

The electrical conductivity of around 100 µS cm^{-1} is nearly constant with depth whereas the pH value shows some variation, especially between the recent accumulation and the former topsoil. The total element content increases with depth from the former topsoil, indicating some shifts in mineral composition of the sands.





Texture

- Fine silt
- Medium silt
- Coarse silt
- Clay
- Fine sand
- Medium sand
- Coarse sand

- pH ($CaCl_2$)
- pH (H_2O)
- Organic carbon
- Inorganic carbon
- Electrical conductivity

Water soluble ions

- Cloride
- Sulfate
- Nitrate
- Hydrocarbonate
- Fluoride, Bromide, Nitrite
- Calcium
- Magnesium
- Potassium
- Sodium

Responsible authors: U. Wisch, A. Petersen, A. Gröngröft & D. Mager

Biological soil crusts

Sampling period(s)	Hectare plots sampled	Types of soil crusts
2004	3 (R1−R3)	1, 2
Crust thickness	**Cover**	**Carbon [weight %]**
< 3 mm	up to 35%	0.238
Nitrogen [weight %]	**Chlorophyll *a* [mg/m²]**	**Chlorophyll *a+b* [mg/m²]**
0.012	61	103

In this semiarid Observatory biological soil crusts occur mainly in shrub interspaces (see Photo). This contrasts to observatories located in areas with higher precipitation (like Observatories S03 and S29) where crusts are mainly restricted to below shrub canopies. The crusts are well-established and well-aggregated, reaching moderate chlorophyll values. Carbon and nitrogen content, on the other hand, are very low. If loose sand particles are present, only initial light-coloured biological soil crusts (type 1) can develop.

Cyanobacteria not finally treated yet.
Green algae: *Diplosphaera* cf. *chodatii, Klebsormidium* cf. *flaccidum, Lobosphaera* sp., *Myrmecia israeliensis, Scenedesmus* cf. *rotundus, Scenedesmus* sp. 4, *Spongiochloris minor, Trebouxia* cf. *arboricola.*

Biological soil crust characteristics

	H22	H52	H99
Soil characteristics	Yellow sand	Yellow coarse sand; few small stones	Yellow medium-grained sand
Crust characteristics	Widespread light to dark-grey thin undulated BSC; light and well-established cyanobacterial crusts	Wide-spread very dark BSC; with cyanobacterial lichens	Medium- to dark-coloured crust; widespread but thin; without lichens
Chlorophyll a [mg/m²]	34.17	82.42	67.26
Chlorophyll a+b [mg/m²]	54.24	138.35	117.68
Carbon [weight %]	0.14	0.29	0.29
Nitrogen [weight %]	0.01	0.01	0.02

Light coloured biological soil crusts in areas with loose sand. Photo: K. Deutschewitz.

Close-up of light coloured biological soil crusts. Photo: K. Deutschewitz.

In areas where surface soils have been compacted, well-established cyanobacterial crusts prevail between shrubs. Photo: K. Deutschewitz.

Responsible authors: B. Weber, K. Deutschewitz, S. Dojani, T. Friedl, T. Darienko, K. Mohr & B. Büdel

Lichens

Sampling period(s)	Hectare plots sampled	Cover
2001, 2002	n.a.	n.a.
Total species richness	**Species richness on soil [1 km²]**	**Species richness on rock [1 km²]**
26	0	1 (4%)
Species richness on plants [1 km²]	**Species richness on soil [1000 cm²]**	
25 (96%)	n.a.	

Epiphytic lichen species richness is very high and well represented by green algal taxa at this Observatory, due to fog events which are frequent as a result of the vicinity to the coast. By contrast, terricolous lichens are absent due to the unstable sandy soils in the area. Rocky substrates are limited, and only a few pebbles with *Acarospora* were recorded. Foliose and fruticose species dominate, which indicates high air humidity and incidence of fog. Species composition clearly differs from that of the Observatory S20 (Numees), which is also located in the Richtersveld, but at a greater distance from the sea.

List of Taxa

Terricolous (on soil):

No records

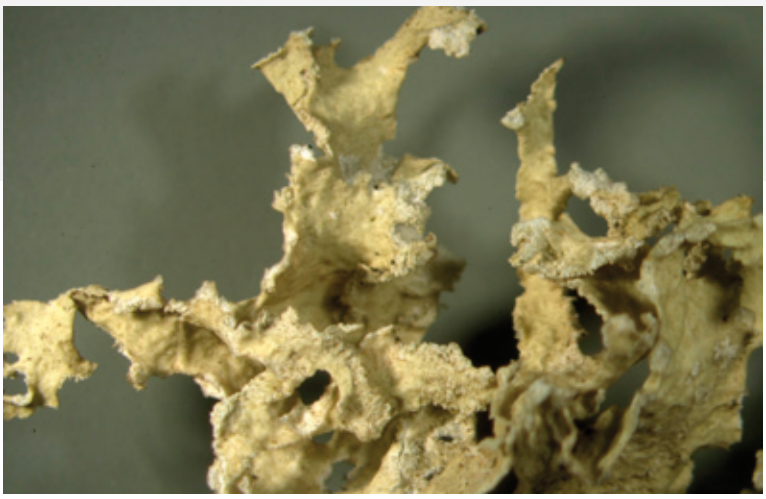
Saxicolous (on rock):

Acarospora sp.

Epiphytic (on plants):

Amandinea insperata
Caloplaca aff. hungarica
Candelariella sp.
Diploicia canescens
Lecanora chlarotera s.l.
Lecanora dispersa
Lecanora spp. (2)
Lecidella sp.
Opegrapha sp.
Physcia adscendens
Physcia jackii cf
Ramalina canariensis
Ramalina capensis
Ramalina celastri
Ramalina lacera
Rinodina spp. (2)
Teloschistes capensis
Teloschistes chrysophthalmus
Tephromela sp.
Xanthoria bonae-spei
Xanthoria dissectula
Xanthoria parietina
Xanthoria turbinata

Xanthoria turbinata. Photo: L. Zedda & G. Rambold.



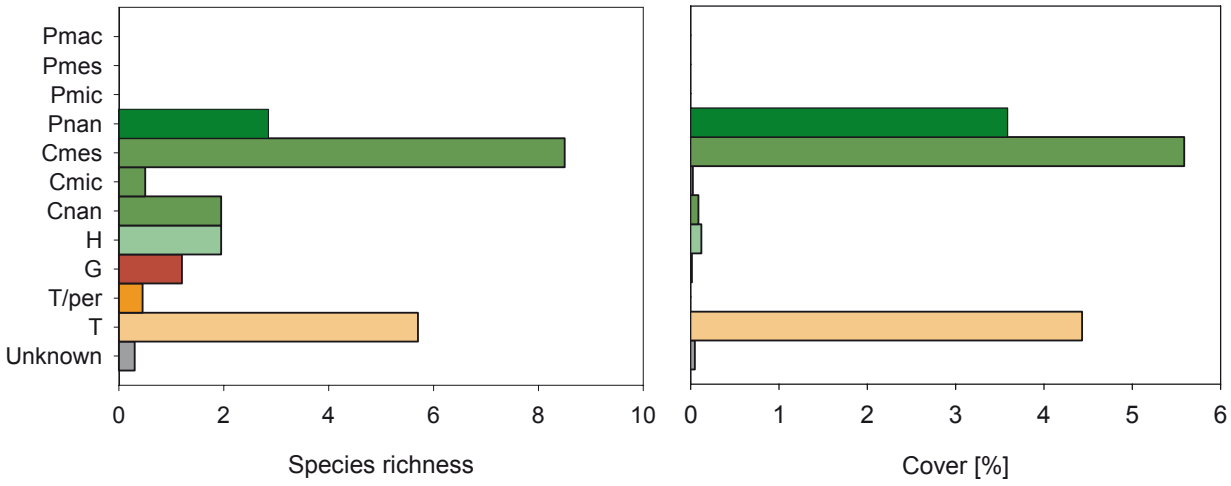
Ramalina lacera. Photo: L. Zedda & G. Rambold.

Responsible authors:
L. Zedda & G. Rambold

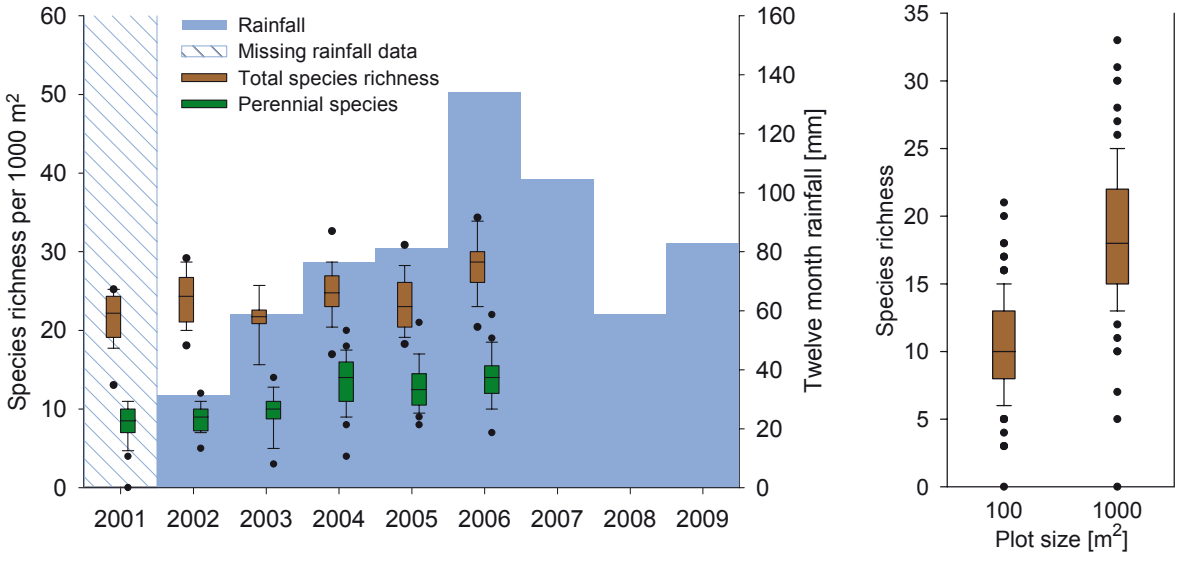
Vascular plants

Sampling period(s)	Hectare plots sampled	Biome
2001–2006, 2008	20 (R1–R20)	Succulent Karoo
Vegetation unit (level 1)	**Vegetation unit (level 2)**	**Identification rate**
Namaqualand Sandveld Bioregion	SKs 2 Northern Richtersveld Yellow Duneveld	51% – 85% – 88%
Cumulative family richness	**Dominant families (cover)**	**Dominant families (richness)**
23	Aizoaceae, Asteraceae, Chenopodiaceae	Aizoaceae, Asteraceae, Scrophulariaceae
Cumulative species richness (1 km²)	**Species richness (1000 m²)**	**Species richness (100 m²)**
194 – 79	18.6 (0–33)	10.5 (0–21)
***z*-value**	**Species richness change per year (1000 m²)**	**Evenness (1000 m²)**
0.249 (0.051–0.824)	0.64	0.608 (0.090–0.803)
Evenness (100 m²)	**Simpson (1000 m²)**	**Simpson (100 m²)**
0.666 (0.139–0.875)	0.742 (0.066–0.890)	0.692 (0.109–0.910)

Life forms



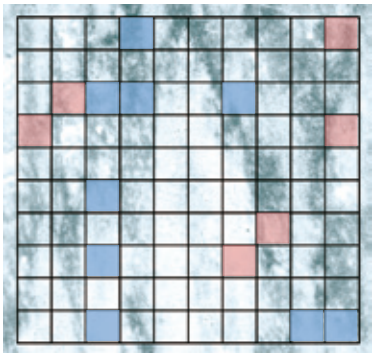
Species richness



Classification table (2006)

Column		Cover	All	1	2
Number of relevés			**20**	**7**	**13**
Mean cover [%]			13.3	11.3	15.4
Mean species richness (1000 m²)			22.3	19.4	25.5
Mean soil pH			7.94	7.92	7.95
Mean electrical conductivity [µS·cm^{-1}]			598	901	396
Organic carbon [%]			0.43	0.27	0.54
Nitrogen [%]			0.03	0.02	0.03
Unit 1: Oncosiphon piluliferum-Mesembryanthemum guerichianum community					
T	Oncosiphon piluliferum	0.12	43	86	.
Cmes	Phyllobolus oculatus	0.03	36	57	8
Cmes	Asparagus capensis	0.02	21	43	.
Unit 2: Conicosia elongata-Lampranthus hoerleinianus community					
Cnan	Conicosia elongata	0.04	50	.	92
Pnan	Lampranthus hoerleinianus	0.34	43	.	77
G	Trachyandra falcata	0.01	50	14	92
Pnan	Stoeberia utilis	0.87	36	.	69
Cnan	Pharnaceum croceum	0.01	29	.	69
T	Heliophila coronopifolia	0.02	36	.	62
H	Ehrharta calycina	0.08	57	29	92
Cmes	Ruschia sarmentosa	0.31	36	.	54
Most frequent companions					
T	Oncosiphon grandiflorum	3.16	100	100	100
Cmes	Salsola zeyheri	0.25	100	100	100
n.a.	Hypertelis salsoloides var. salsoloides	0.02	100	100	100
Cmes	Amphibolia succulenta	1.18	95	86	100
T	Mesembryanthemum guerichianum	1.00	95	86	100
Pnan	Aridaria serotina	0.44	95	86	100
Cmes	Phyllobolus decurvatus	0.43	95	100	92
Pnan	Stoeberia beetzii	3.27	90	86	92
Pnan	Brownanthus pseudoschlichtianus	1.11	90	100	85
Cmes	Galenia sarcophylla	0.52	90	71	100
T	Tetragonia echinata	0.04	70	86	62
H	Stipagrostis lutescens	0.03	70	43	85
Cmes	Brownanthus arenosus	2.06	65	57	69
T	Phyllopodium phyllopodioides	0.00	60	57	62
Cmes	Psilocaulon subnodosum	0.66	50	29	62
Cmes	Tetragonia fruticosa	0.05	45	14	62
Cmes	Othonna cylindrica	0.11	30	14	38
n.a.	Lycium ferocissimum	0.07	30	43	23
H	Cladoraphis cyperoides	0.05	30	29	31
T	Zaluzianskya affinis	0.01	30	57	15
n.a.	Manulea androsacea	0.04	25	.	38
T	Zaluzianskya benthamiana	0.01	25	.	38
T	Mesembryanthemum hypertrophicum	1.25	20	43	8
Pnan	Lampranthus otzenianus	0.35	20	43	8
T	Mesembryanthemum squamulosum	0.22	20	29	15
Cnan	Cheiridopsis robusta	0.16	20	43	8
T	Felicia microsperma	0.01	20	.	31
T	Manulea cheiranthus	0.01	20	14	23
H	Stipagrostis ciliata	0.19	15	.	23
Cmes	Psilocaulon dinteri	0.08	15	14	15
Cnan	Jordaaniella cuprea	0.07	15	.	23
Pnan	Stoeberia gigas	0.02	15	.	23
G	Kedrostis capensis	0.01	15	.	23

Map of vegetation units



The Groot Derm Observatory falls under the vegetation type Northern Richtersveld Yellow Duneveld (SKs 2, Mucina et al. 2006). The landscape is dominated by yellow, wind-blown sands of coastal origin, which are part of an ancient mobile dune field that became partly stabilised during the climatic amelioration after the last glaciation period. The landscape and vegetation is characterised by mobile dunes and dunes that have been stabilised by biological soil crusts on the soil surface. Localised patches of calcrete occur at varying depths underneath the sandy soils (see also Dreber 2005, Oguz et al. 2004).

The most important perennial life form in terms of cover and species richness are the mesochamaephytes (C mes). Therophytes (T) possess the highest cover values, followed by the mesochamaephytes, with all other life forms having very low cover values (< 0.5%). Aizoaceae and Asteraceae are the most diverse and abundant floral elements, which is typical of the Succulent Karoo vegetation. However, this Observatory has the lowest family richness of all Observatories within the Succulent Karoo, and possesses the lowest diversity along the entire BIOTA transect. Similarly, species richness and Simpson diversity at different spatial scales are the lowest amongst the Succulent Karoo Observatories and are amongst the lowest along the entire transect. The equally low species richness at all spatial scales results in intermediate *z*-values at both transitions (100–1000 mm² and 1000 m²–1 ha), which approximate the mean values

Unit 1, with biological soil crusts stabilising the dunes, 2004. Photo: N. Dreber.

Unit 2, with mobile dunes, 2004. Photo: N. Dreber.

The annual *Mesembryanthemum hypertrophicum*, 2009. Photo: N. Jürgens.

The annual *Mesembryanthemum guerichianum*, 2009. Photo: N. Jürgens.

Yellow dune landscape, 2003. Photo: N. Jürgens.

for all Observatories along the BIOTA transects.

The *Oncosiphon piluliferum-Mesembryanthemum guerichianum* community (unit 1) occurs on the dunes, which are stabilised by biological soil crusts and/or possess calcretes underneath the soil surface. *Oncosiphon piluliferum* and *Mesembryanthemum guerichianum* (Soutslaai) are annuals that do not occur on mobile sands. This community, which is poorer in species than unit 2, is mainly characterised by the absence of the dune-inhabiting species that characterise unit 2.

The *Conicosia elongata-Lampranthus hoerleinianus* community (unit 2) occurs on mobile dunes with well-drained soils that possess lower mean electrical conductivity (salinity) values than the soils of unit 1. Both *Conicosia elongata* (Varkiesknol) and *Lampranthus hoerleinianus* are typically found on mobile sands, as is the case for the leaf-succulent shrub (P nan) *Stoeberia utilis* (Rooivy), which prefers dune crests, the ramified shrub *Ruschia sarmentosa*, and the creeping nanochamaephyte *Jordaaniella cuprea*.

Responsible authors:
N. Dreber, U. Schmiedel &
J. Luther-Mosebach

True bugs

Sampling period(s)	Methods	Family richness
2001/X; 2002/IX, X	Trapping (pitfall traps, yellow pan trap)	2
Species richness	**Individuals sampled**	**Fisher's alpha diversity**
3	63	0.65

Only three species were collected at Groot Derm Observatory (S21) using pitfall traps. These included one specimen of the predatory Anthocoridae, three specimens of the widespread predatory *Geocoris phaeopterus* (Geocoridae), and 58 specimens of *Leptodemus irroratus* (Oxycarenidae). *L. irroratus* is an active insect and immediately flies off when disturbed. This species is common in Namibia and South Africa, especially in xeric habitats. *Matricaria* spp. and *Helichrysum* spp. (Asteraceae) are its host plants. Two specimens of *Geocoris phaeopterus* were also collected using yellow pans and with Malaise traps.

Species richness in families

Family	*S*
Anthocoridae	1
Geocoridae	1
Oxycarenidae	1
Total	**3**

Species abundances

Pitfall traps

Species	Family	*N*	%
Leptodemus irroratus	Oxycarenidae	58	94
Geocoris phaeopterus	Geocoridae	3	5
Orius spec.	Anthocoridae	1	2
Total		**62**	**100**

Responsible author: W. Mey

Butterflies and moths

Sampling period(s)	Number of samples (moths)	Species richness (total)
2001/X	1	35
Species richness (butterflies)	**Species richness (all moths)**	**Species richness (Microlepidoptera)**
0	35	9
Species richness (Pyraloidea)	**Species richness (Macrolepidoptera)**	**Species richness (Noctuidae)**
9	2	15
Individuals sampled (moths)	**Fisher's alpha diversity (moths)**	
233	11.4	

Moths

Collecting nocturnal species in the desert or desert environments close to the coast requires a large amount of flexibility and spontaneous action. Its outcome largely depends on the prevailing wind regime. Usually, strong winds blow from the sea, although at night the wind sometimes ceases, only to resume a short while later from the opposite direction. Light trap samples can only be taken during this short window of windless conditions, and the hour of its occurrence is unpredictable. One sample was obtained and showed that the moth fauna is dominated by two microlepidopterans from the family Gelechiidae: *Ochrodia pentamacula* and an unidentified *Hedma* species. They appeared in large numbers in the light traps and at the light tower. The noctuids are represented by 15 species, mainly singletons, but with several individuals of *Agrotis ipsilon*. The caterpillars of this species are subterranean cutworms which are adapted to live in both the Succulent and Nama Karoo Biomes. *Ceutolopha isidis* (see Photo), a common resident in the region, was the most abundant species of the Pyraloidea.

No butterflies were observed.

Taxonomic spectrum of moths

Collection period: X/2001

Family	S	N
Scythrididae	2	2
Gelechiidae	5	179
Pterophoridae	2	10
Microlepidoptera	**9**	**191**
Pyralidae	7	14
Crambidae	2	4
Pyraloidea	**9**	**18**
Cossidae	1	4
Lymantriidae	1	2
Noctuidae	15	18
Macrolepidoptera	**17**	**24**
Total	**35**	**233**

Male of *Ceutolopha isidis*. Photo: W. Mey.

Responsible author: W. Mey

Vertebrates

Total species richness	Reptile species richness	Bird species richness
3	n.a.	3
Large mammal species richness	Small mammal species richness	
n.a.	n.a.	

Birds

Passeriformes	**Perching birds**
Certhilauda burra	Red Lark
Certhilauda curvirostris	Cape Long-billed Lark
Cercomela tractrac	Tractrac Chat

Responsible authors: J. Deckert, A. Hoffmann & A. Mills

Relationship of biotic soil crusts and spatio-temporal patterns in dune vegetation of the northern Richtersveld (S21.01)

[N. Dreber]

Biotic soil crusts (BSCs) are known to affect soil properties that determine plant establishment and growth, and thus are likely to play an important role in vegetation patterning and long-term dynamics. As several empirical and modelling studies suggest significant impacts of climate change on the vegetation of the Succulent Karoo vegetation, current vegetation patterns associated with the presence or absence of BSCs were investigated in a dune field of the Richtersveld, and temporal stability in observed patterns evaluated.

Field work was done during three weeks in winter 2004 in an area of about 75 km², whose most southern sector was located adjacent to this Observatory. Vegetation and habitat types were mapped, environmental gradients identified, and verified by plant demographical data. Using aerial photographs, identified patterns were checked with regard to stability in spatial extend over a 60-year period.

The presence of BSCs significantly changed soil textural and chemical properties, whereas topsoil stability due to crusting was the main driving factor for the spatial patterning of vegetation units, and population dynamics at species-level. Large-scale patches of BSCs, and likely associated plant communities, had basically remained stable since 1937. Only locally minor alterations occurred due to disturbance by livestock. The results indicate a fairly stable dune ecosystem with hardly any shift of boundaries between vegetation units due to climatic impacts.

Dreber, N. (2005): Ecological transect analysis of vegetation along a gradient from sessile to mobile land surfaces in the dune fields of the northern Richtersveld, Republic of South Africa. – Diplom thesis in Biology. Hamburg: University of Hamburg.

Further studies

Koch, F. (2006): Snail shells (Mollusca, Gastropoda, Dorcasiidae) as microhabitats in South African deserts, with description of a new chrysisid wasp (Insecta, Hymenoptera, Chrysididae) discovered by BIOTA-Southern Africa Project. – Mitteilungen aus dem Museum für Naturkunde in Berlin, Zoologische Reihe **82**: 191–197.

General data

Number	Name	Alternative name(s)
S22	Soebatsfontein	Quaggasfontein
Implementation	**Country**	**Province/ region**
2001	South Africa	Northern Cape
District/ constituency	**Locality**	**Farm name**
Namakwa	Soebatsfontein	Soebatsfontein Commonage
Latitude	**Longitude**	**Altitude**
30.186502 S	17.543373 E	392 m a.s.l.
Rainfall season	**Biome**	**WWF Ecoregion**
Winter	Succulent Karoo	AT1322 Succulent Karoo
Agro-Ecological Zone	**Relative intensity of land use**	**Tenure**
n.a.	Medium	Communal
Type and history of landuse	**Land owner**	
Farming with sheep and goats	Kamiesberg Municipality	

Soebatsfontein (S22)

Quartz fields in the northern part of the Soebatsfontein commonage. Photo: J. Luther-Mosebach and I.U. Röwer.

The Soebatsfontein BIOTA Observatory is situated on the communal lands of the Soebatsfontein settlement, about 50 km south-west of Springbok and is 30 km from the west coast of South Africa. The topography and geology of this area of Lowland Succulent Karoo vegetation is characterised by broad valleys and gently undulated hills (up to 400 m a.s.l.) with gneiss outcrops. The vegetation is dominated by leaf-succulent dwarf shrubs and presents a spectacular display of annual flowering plants during springtime. The average annual rainfall is low but additional precipitation from fog and dew plays an important ecological role for the shallow rooted shrubs.

The inhabitants of Soebatsfontein use the 15,000 hectares of land for farming with small stock (sheep and goats), and other resources used from this communal land are firewood and medicinal plants. The Soebatsfontein commonage was only handed over to the small community in 2000 as part of the land redistribution initiative of the new post-apartheid government of South Africa.

Soebatsfontein BIOTA Observatory was established to monitor climate change in the Lowland Succulent Karoo in comparison to the pair of BIOTA Observatories Paulshoek and Remhoogte in the Upland Succulent Karoo, about 50 km further inland. Biodiversity changes due to land use are monitored on this BIOTA Observatory and an adjacent four-hectare exclosure camp in order to provide the Soebatsfontein farmers with

benchmark information to aid with management decisions.

Responsible author: U. Schmiedel & D.H. Haarmeyer

Remote sensing and landscape

Geomorphology	Geological units	Lithological units
Slope, valley, outcrops	Namaqua and Natal Metamorphic Provinces	Migmatie, gneiss, ultrametamorphic rocks
Mean EVI	**EVI absolute range**	**Mean leaf area index**
0.141 (0.111–0.209)	0.106 (2001)–0.283 (2006)	0.51

Grid map of Observatory

	0	1	2	3	4	5	6	7	8	9
0	20	90	65	66	64	40	13	56	93	31
1	43	17	57	62	42	54	1	89	48	10
2	35	24	80	92	76	16	61	53	98	91
3	52	60	94	33	68	34	75	72	73	25
4	86	11	30	74	84	79	77	37	99	58
5	96	5	49	46	78	15	81	28	22	83
6	67	23	2	26	38	88	36	85	95	97
7	18	47	82	70	6	8	41	69	45	87
8	9	59	32	44	14	55	12	51	100	39
9	27	63	3	29	21	71	50	19	7	4

1	Valley and lower slope with heuweltjies
2	Granite boulders and surroundings with dense stands of shrubs
3	Mountain saddle with succulent shrub vegetation
4	Valley and lower slope with eroded heuweltijes

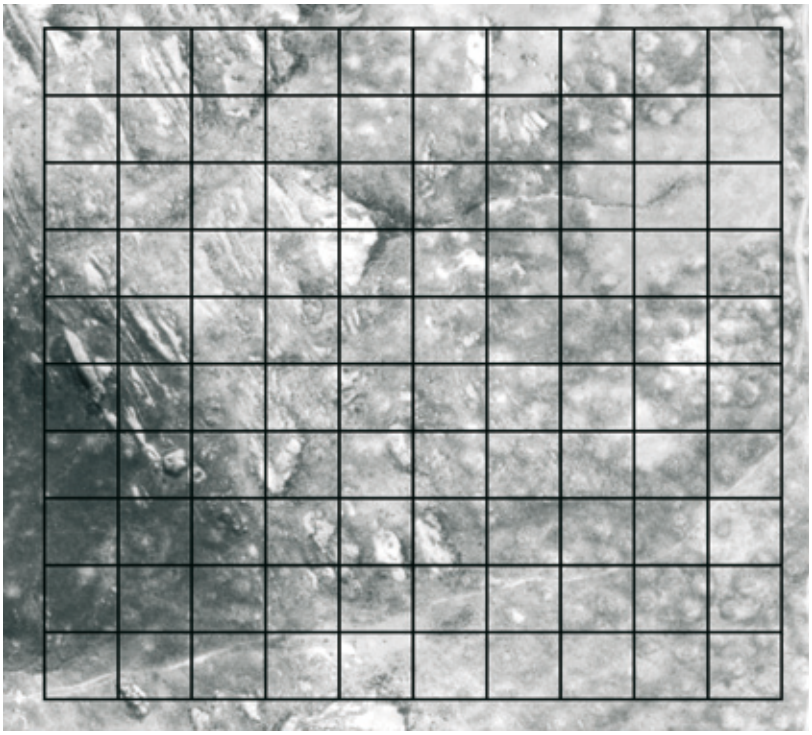
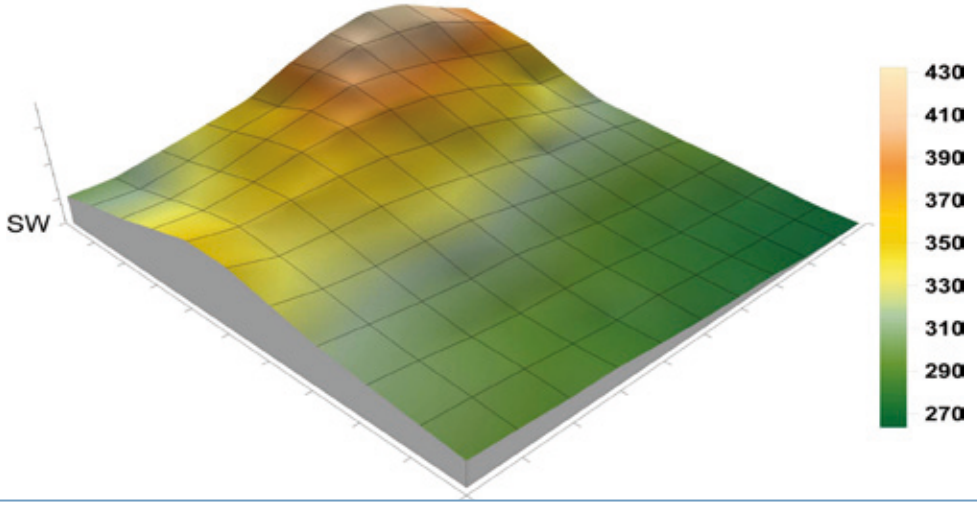


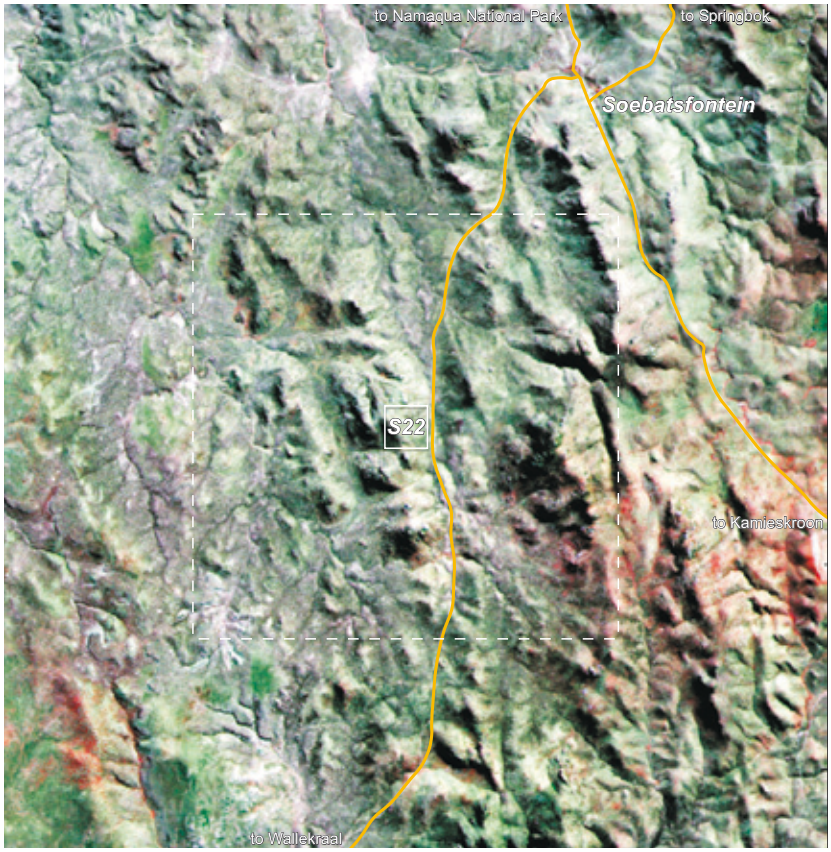
Image: aerial photograph

Elevation model of Observatory



Landsat image

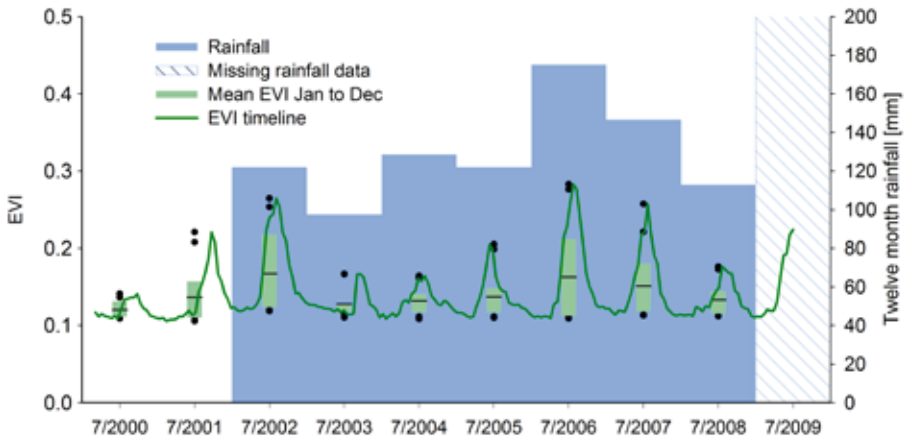
The relief conditions in the gently undulated hills of the Soebatsfontein area are emphasised by illumination and shadow effects in the Landsat image because of the low solar altitude in May. Rocky outcrops with no vegetation appear as white or grey areas. The run-off areas below the gneissic outcrops on the upper slopes are often covered by tall shrubs and small trees (brown and red tones, especially in the south-eastern parts). The low-lying areas are dominated by low-growing leaf succulent shrubs, annuals, and geophytes (green tones).



Scene: 176/81, acquisition date: 09 May 2005

MODIS time series

Temporal patterns of annual rainfall, vegetation cover, and phenology



Responsible author: M. Keil & T. Labitzky

Climate

Data from BIOTA weather station

Location	Recorded period	Mean temperature
Soebatsfontein (S22)	2001–2009	19.4 (3.5–42.5) °C
Mean solar radiation	**Mean wind speed**	**Mean annual precipitation**
618 (304–1007) MJ·m^{-2}·month^{-1}	4.1 (12.3) m·s^{-1}	131 (97–175) mm
Mean annual potential evapotranspiration	**Interannual precipitation variability**	**Mean relative humidity**
1480 mm	112%	58% (39–85%)
Aridity index (UNEP)		
0.09 (arid)		

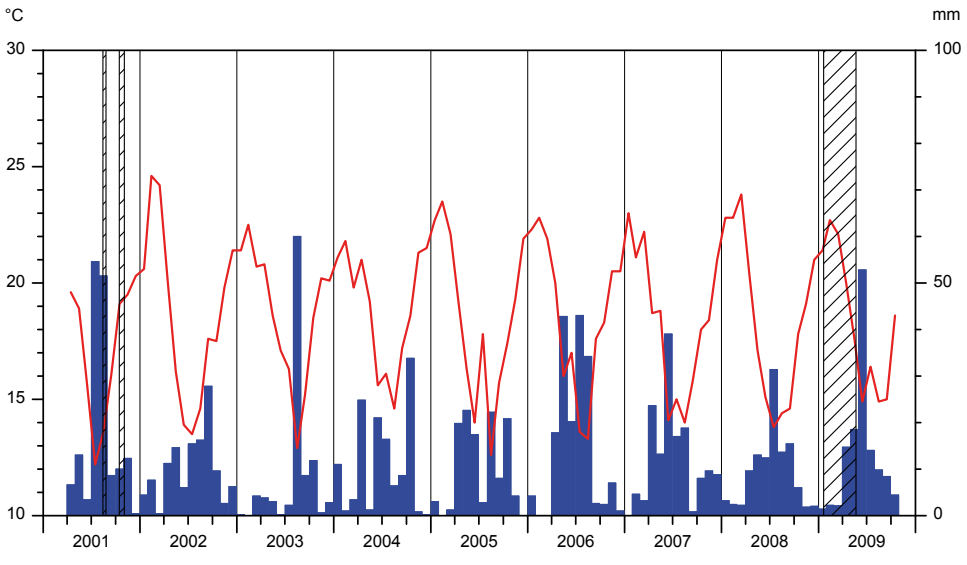
Modelled data

Mean temperature	Mean annual temperature range	Mean diurnal temperature range
17.0 (6.5–28.0) °C	8.5 °C	13.1 °C
Mean annual precipitation	**Precipitation seasonality**	**Percentage winter precipitation**
146 mm	65%	80% (strong winter)
Climate type	**Length of dry season**	**Aridity index (De Martonne)**
BWk	11 months	5.4 (dry)

The climate at the Observatory is characterised by arid conditions. Rainfall shows a moderate seasonality with more rain falling during the winter season, peaking in August. The mean annual rainfall over the observation period was 131 mm, which is fairly dry in comparison to the average rainfall recorded over the entire transect, but is in line with the average for the Succulent Karoo Observatories. However, substantial interannual variability is evident. The observed near-surface air temperatures show a weak seasonal cycle. The mean annual temperature is 19.4°C, which approximates the average for this biome. Compared to the interpolated long-term data taken from the WorldClim dataset, a markedly warmer mean annual temperature is observed at the BIOTA weather station. Furthermore, the station records of temperature extremes deviate substantially from the interpolated data, showing warmer maximum and minimum temperatures than the WorldClim dataset. For precipitation, mean annual rainfall observed at the station is noticeably lower than that of the WorldClim dataset.

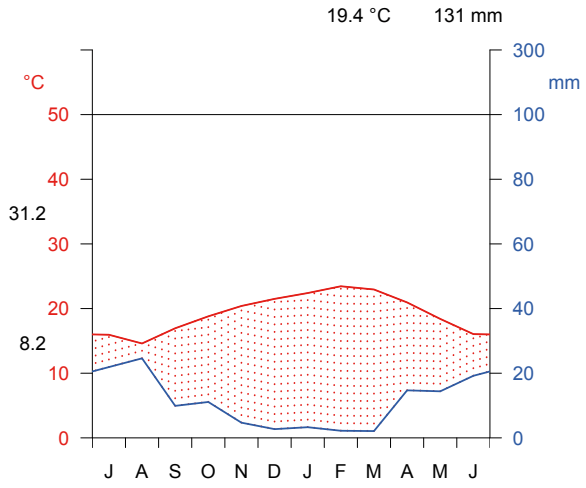
The observed near-surface winds at the Observatory are predominantly constituted of south-southeasterly flows throughout the year. Mean wind speed shows a pronounced annual cycle in the early afternoons and evenings, with slightly higher wind speeds in the evenings. Winds recorded in the mornings are noticeably weaker and are only moderately variable over the course of the year.

Time series: rainfall and temperature

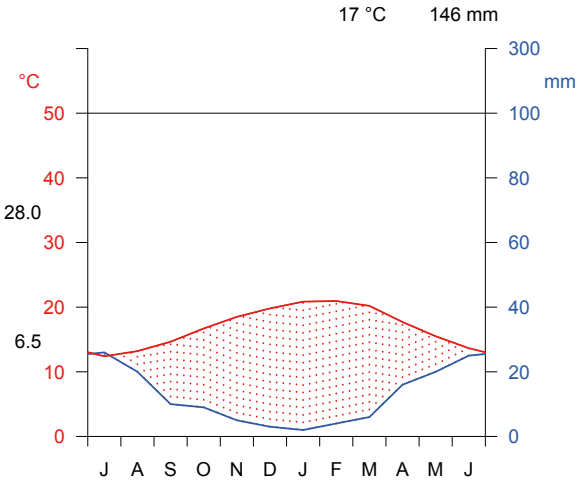


Climate diagrams

Recorded data (BIOTA)

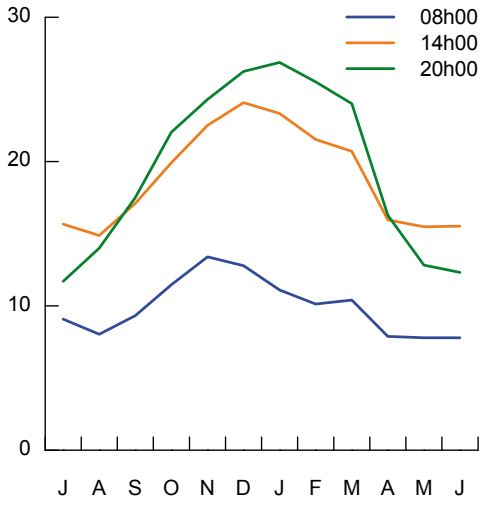


Modelled data (WorldClim)

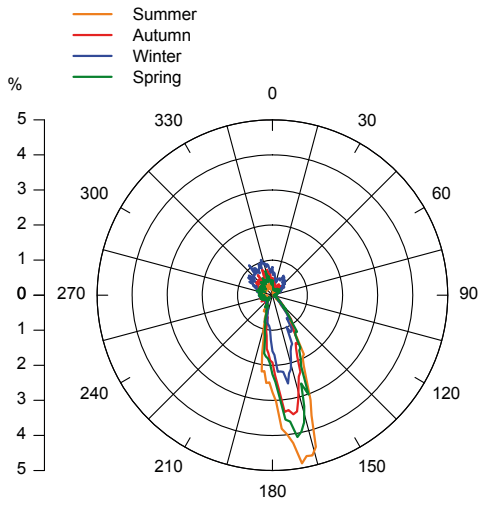


Wind diagrams

Speed



Directions



Responsible authors: K. Berger, A. Haensler & J. Luther-Mosebach

Soils

Year of sampling	Hectare plots sampled	SOTER unit
2002	27 (R1–25, R27, R29)	ZA1905
Soilscape	**Dominant soil group(s)**	**Reference group richness**
Durisol/Leptosol	Leptosol, Durisol, Cambisol	4
Soil unit richness	**Soil unit evenness**	**Soil ecotype richness**
20	0.897	21
Parametric space	**pH**	**Electrical conductivity**
4.84	8.1 (3.8–10.4)	180 (14–5010) µS·cm^{-1}
Organic carbon		
1.08% (0.04–11.47%)		

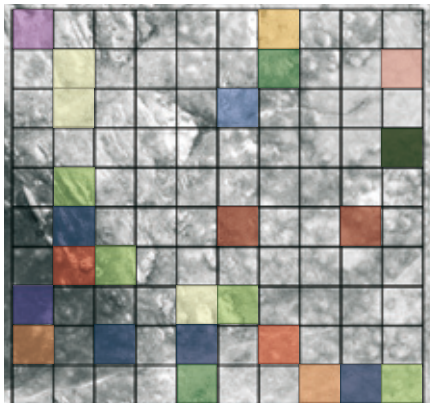
On this Observatory, the predominant soil reference groups are Durisols and Cambisols. Durisols are exclusively associated with the occurrence of heuweltjies, while Cambisols are mainly found in deeper substrates of lower valleys between heuweltjies. For these soil units, properties depend on the depth of the duripan or bedrock and the content of coarse rock fragments. A unique feature and not typical for this climate is the presence of Mollic Cambisols, which has developed below an exposed bedrock. It receives run-on water as well as debris and nutrients by weathering of the rock surface. These site conditions led to a band around the outcrop that is intensively colonised by soil organisms such as lichens, creating a distinctive 'Mollic' topsoil. Leptosols and Regosols occur mainly on higher positions, but lower valleys also include areas with shallow bedrock, as indicated by the Leptosols found in the eastern part. In general, the soils are characterised by the presence of bedrock within the first metre, indicating different 'Leptic' qualifiers except for the accumulation area in the north-eastern section of the Observatory.

The pH values exhibit great variability in space and with depths, characterised by a decrease in the second horizon. This is a typical feature for this Observatory. Electrical conductivity covers wide ranges from low to high salinity, with median values around 200 µS cm^{-1}. A high variability combined with a clear decrease with depth in organic carbon reflects the varying amounts of humus accumulation, which is due to different site conditions, i.e. varying water supply. The fine particle percentage (clay and silt) shows little variation, with no differences with depth indicating a rather similar substrate except for the heuweltjie site with higher silt content. The median rooting space represents the overall shallow and rocky character of the area, but deep profiles as well as extremely shallow sites also cause the wide range of rooting space. In general, the high variability of soil properties is evident by both the total range in parameters and the wide interquartile ranges (boxes).

The texture ranges from sandy to silty loam, with the finest textures occurring in the heuweltjies while pure sands occur in the topsoils of the allochthonous structure of the 'alluvial fan' in the northeast of the Observatory. With regard to the sand fraction, the samples can be regarded as one cluster with few outliers. Samples with the lowest content of coarse sand originate from the heuweltjies. In contrast, the matrix soils of the heuweltjie veld and the Leptosols of the outcrop areas show a higher coarse sand content while the relation of the medium to fine sand fractions remains comparable. Thus, a basic similarity of the substrates is found on the Observatory, only affected by (i) higher coarse sand contents in horizons above bedrock and (ii) probably by a reduction of coarse sand during the formation of heuweltjies.

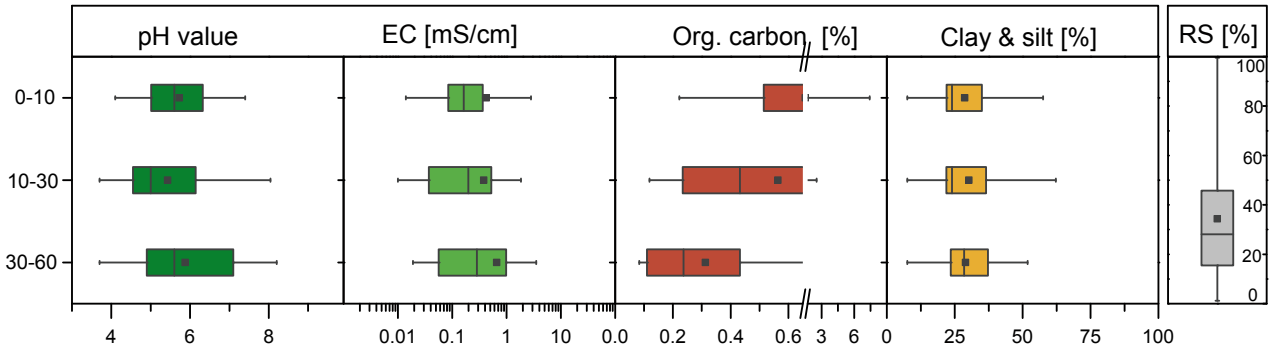
To demonstrate small-scale soil differences, five profiles were investigated along a transect across a heuweltjie. All profiles within and in direct vicinity of the mound were heavily affected by the occurrence of durinodes in the centre and massive duripans outside the heuweltjie. A general trend of high values in the centre to lower values outside was evident for silt, pH, calcium carbonate, electric conductivity, and total element content including calcium, magnesium, but also manganese, and iron. It is important to note that the increase in elements was much higher than the increase in silt. Therefore the differences in ele-

Map of soil profiles

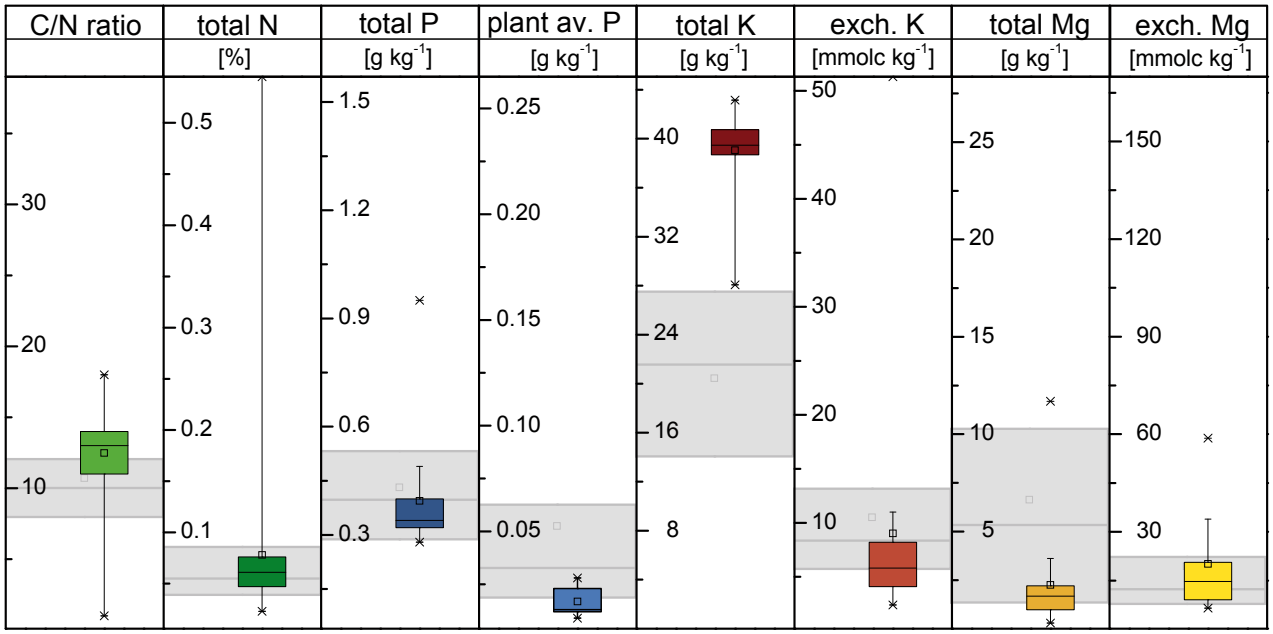


Haplic Leptosol
Lithic Leptosol
Hyperskeletic Leptosol
Haplic Durisol
Epipetric Durisol
Endopetric Durisol
Haplic Cambisol
Endoleptic Cambisol
Epileptic Cambisol
Leptic Cambisol
Hypersalic Solonchak
Endoleptic Regosol
Epileptic Regosol

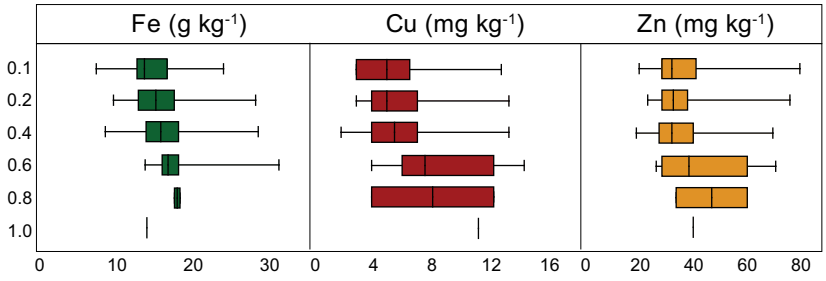
Soil characteristics



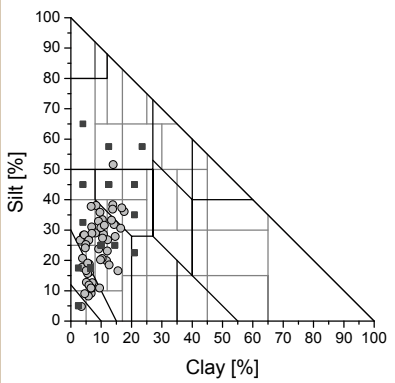
Soil nutrients



Soil micronutrients



Soil texture triangle

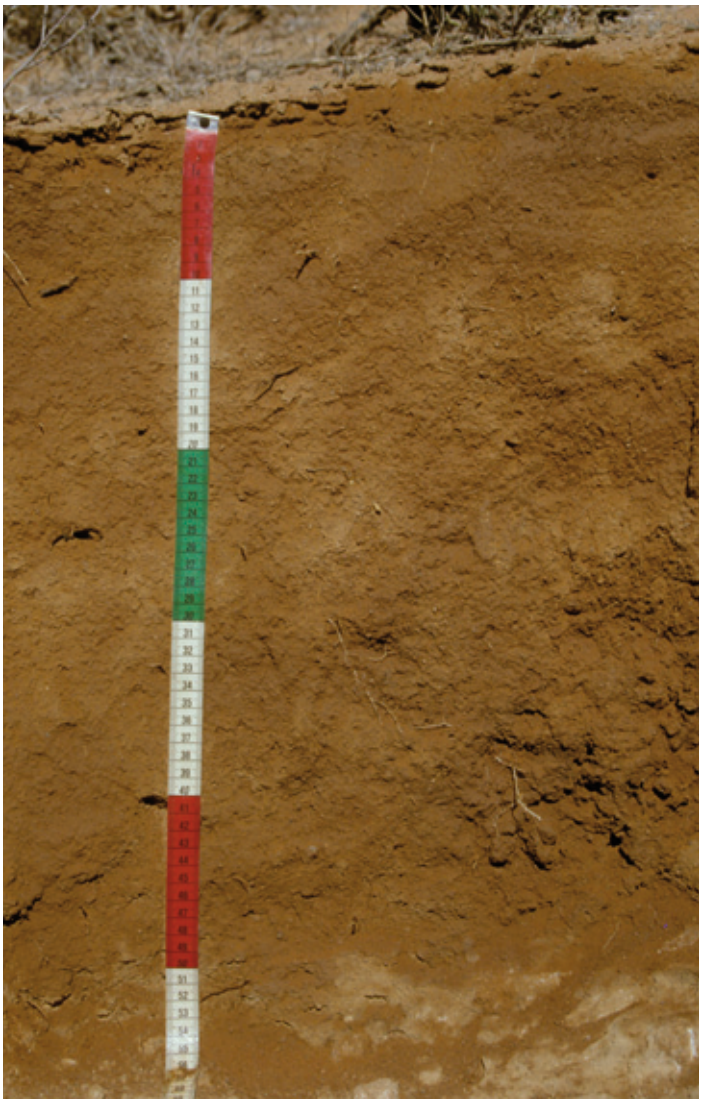


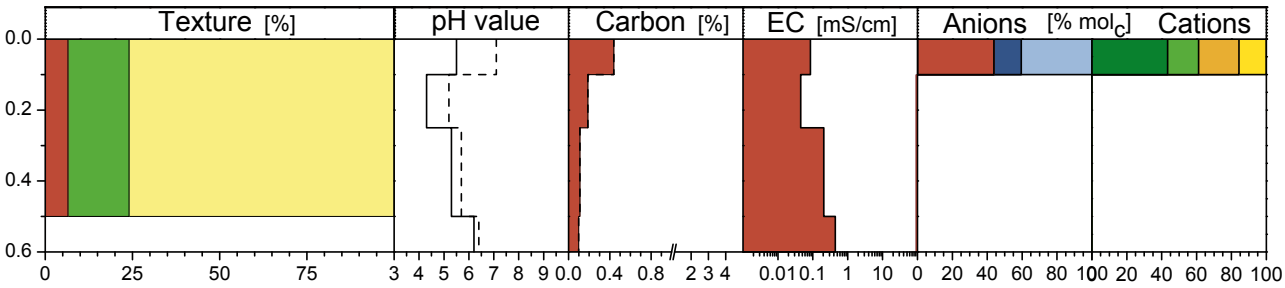
ment content might not have been the sole result of textural changes between the microhabitats. Additionally, highly soluble salts such as sodium chloride were strongly enriched in the mound and might be related to electrical conductivity values of up to 40 mS cm^{-1} and high osmotic potentials, which increase water stress for the plants. Nevertheless, as studies on other heuweltjies revealed, salt enrichment is only prominent in some of these landscape features (Labitzky 2009).

Reference profile (H55)

The **Endopetric Durisol** is a typical example of the soils in immediate vicinity of the heuweltjies, which go along with a massive concentric shaped duripan. In areas with a high heuweltjie density, these soils form the matrix soils, whereas in areas with greater distances between the mounds, Cambisols without cementations occur frequently. In general, Endopetric Durisols are similar to those Cambisols except for the main feature, the cemented duric horizon, which can occur in shallow depths restricting rooting depth.

This non-calcareous profile shows a duripan as a massive, bedrock-like cementation below the depth of 50 cm. The main texture of the upper horizon is sandy loam with a low percentage of silt and a mean bulk density of 1.65 g cm^{-3}. Field tests showed no textural change with depth, which indicates an induration within the profile. With a pH value of about 6.0 in the top- and in the subsoil, the soil reaction is neutral, but significantly more acidic in the second horizon. Electrical conductivity is much lower than in the heuweltjies with 80–300 µS cm^{-1}, and organic carbon shows a typical decrease with depth. The total element content is constant with depth except for magnesium increasing with depth. The amounts of water-soluble and exchangeable ions are comparatively low.





Texture

- Fine silt
- Medium silt
- Coarse silt
- Clay
- Fine sand
- Medium sand
- Coarse sand

- pH ($CaCl_2$)
- pH (H_2O)
- Organic carbon
- Inorganic carbon
- Electrical conductivity

Water soluble ions

- Cloride
- Sulfate
- Nitrate
- Hydrocarbonate
- Fluoride, Bromide, Nitrite
- Calcium
- Magnesium
- Potassium
- Sodium

Responsible authors: U. Wisch, A. Petersen, A. Gröngröft & D. Mager

Biological soil crusts

Sampling period(s)	Hectare plots sampled	Types of soil crusts
2002	3 (R1–R3)	1, 2, 3, 4, 5a, 5b, 6
Crust thickness	**Cover**	**Carbon [weight %]**
> 4 mm	up to 30%	2.438
Nitrogen [weight %]	**Chlorophyll *a* [mg/m²]**	**Chlorophyll *a+b* [mg/m²]**
0.033	115	181

The Succulent Karoo is not only characterised by a rich vascular plant diversity, but also several types of biological soil crusts can be found in this biome. The species richness of biological soil crust components particularly that of cyanobacteria, is high. The list of identified cyanobacterial taxa includes thin and thick filamentous taxa with gelatinous sheaths as well as nitrogen fixing species. Coccal taxa were not found in this Observatory. Careful considerations should be taken into account when comparing the results from this observatory as more samples were analysed in total here, which may partly account for the relatively high cyanobacterial richness. The high cover of well-established biological soil crusts produces high biomass as well as higher carbon and nitrogen content as compared to other Observatories.

Moss-dominated crusts are found under shrub canopies preferably in areas where high air humidity occurs. Photo: B. Weber.

Cyanobacteria

Calothrix sp.
Leptolyngbya compacta
Leptolyngbya foveolarum
Leptolyngbya subtilissima
Leptolyngbya sp. 1
Leptolyngbya sp.
Microcoleus paludosus
Microcoleus vaginatus
Nostoc cf. *calcicola*
Nostoc cf. *punctiforme*
Nostoc sp.
Oscillatoria limosa
Oscillatoria subbrevis
Oscillatoria tenuis
Phormidium aerugineo-caeruleum
Phormidium cf. *caerulescens*
Phormidium cf. *nigrum*
Phormidium sp.
Pseudanabaena minima
Pseudanabaena cf. *starmachii*
Pseudanabaena sp.
Pseudophormidium hollerbachianum
Schizothrix lardacea
Schizothrix cf. *arenaria*
Schizothrix sp.
Scytonema hofmanni
Scytonema cf. *millei*
Scytonema sp.

Green algae

Chlorosarcinopsis cf. *variabilis*
Desmodesmus cf. *subspicatus*
Eustigmatos magnus
Klebsormidium cf. *flaccidum*
Scenedesmus sp. 4
Spongiochloris minor
Spongiochloris sp.

Biological soil crust characteristics

	H16	H62	H92
Soil characteristics	Reddish-brown silty sand with few small stones	Dark brown sand with fine stones	Grey-brown silty sand with few small stones
Crust characteristics	Widespread light and dark BSC with lichens	Partly very thick widespread light and dark BSC	Widespread light and dark BSC with cyanolichens
Chlorophyll a [mg/m²]	161.87	67.19	117.34
Chlorophyll a+b [mg/m²]	238.12	124.32	179.4
Carbon [weight %]	2.19	2.59	2.53
Nitrogen [weight %]	0.03	0.04	0.03

Responsible authors: B. Weber, K. Deutschewitz, S. Dojani, T. Friedl, T. Darienko, K. Mohr & B. Büdel

Lichens

Sampling period(s)	Hectare plots sampled	Cover
2001, 2002	10 (R1–R10)	4% (0–24%)
Total species richness	**Species richness on soil [1 km²]**	**Species richness on rock [1 km²]**
73	23	29
Species richness on plants [1 km²]	**Species richness on soil [1000 cm²]**	
21	2.7 (0–6)	

List of taxa

Terricolous (on soil):

Anthracocarpon virescens
Buellia sp. 01 (M-0039965)
Caloplaca sp. 01 (M-0038397)
Collema coccophorum
Collema tenax
Diploschistes henssenianae
Endocarpon sp. 01 (M-0039960)
Lichinella stipatula
Peccania arabica
Peccania font-queriana
Peccania subnigra
Peltula patellata
Placidium semaforonense
Placidium squamulosum
Placidium tenellum
Psora crenata
Sarcogyne sp. 01 (M-0038400)
Siphula flavovirens
Toninia australis
Toninia lutosa
Toninia ruginosa ssp. ruginosa
Toninia ruginosa ssp. pacifica
Xanthoparmelia sp. 01 (M-0038403)

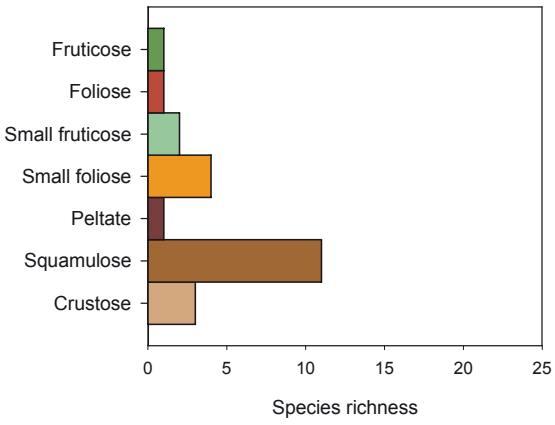
Saxicolous (on rock):

Acarospora cf. heufleriana
Acarospora sp.
Buellia cf. distrata
Buellia sp.
Caloplaca cinnabarina
Caloplaca haematodes
Caloplaca rubelliana
Caloplaca sp.
Chrysothrix cf. chlorina
Diploschiste euganeus
Diploschistes aeneus
Heppia sp.
Lecidea sp.
Lecidella sp.
Paraparmelia sp.
Peccania sp.
Peltula inversa
Peltula spp. (2)
Pertusaria sp.
Rinodina longisperma
Rinodina sp.
Xanthomaculina hottentotta
Xanthoparmelia spp. (7)

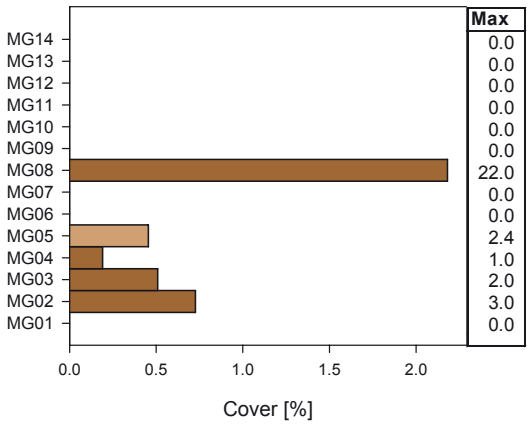
Epiphytic (on plants):

Amandinea punctata
Arthonia aff. arthonioides
Arthothelium cf. orbilliferum
Caloplaca cf. luteoalba
Caloplaca holocarpa
Caloplaca obscurella
Candelaria concolor
Chrysothrix candelaris
Flavoparmelia soredians
Hyperphyscia syncolla
Lecanora dispersa
Lecanora gr. symmicta
Opegrapha varia
Ramalina celastri
Rinodina capensis
Rinodina furfuracea
Teloschistes chrysophthalmus
Xanthoria karrooensis

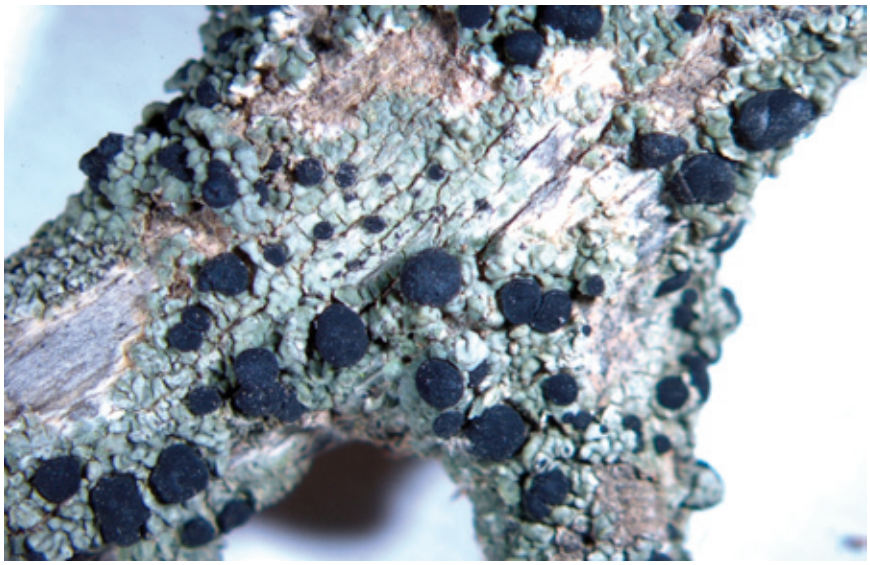
Growth forms



Morpho groups



Diploschistes hensseniae. Photo: L. Zedda & G. Rambold.



Rinodina capensis. Photo: L. Zedda & G. Rambold.

Siphula flavovirens. Photo: L. Zedda & G. Rambold.

This Observatory is characterised by an extremely high lichen diversity on all types of substrates. Soil-inhabiting lichens, which contribute to the formation of biological soil crusts, represent a remarkable part of the total diversity of this site. Because of a number of rare and ecologically interesting species, this Observatory belongs to one of the most lichenologically notable observatories along the entire BIOTA transect. Furthermore, this site is the type locality for a newly described soil-inhabiting lichen species, *Siphula flavovirens* (Kantvilas et al. 2003). The high species richness here is promoted by the high relative air humidity and frequent fog events in this area. Most of the terricolous taxa are squamulose or small foliose. The occurrences of foliose and fruticose lichens, as well as the predominance of green algal photobionts (70%), are indicative of high relative air humidity.

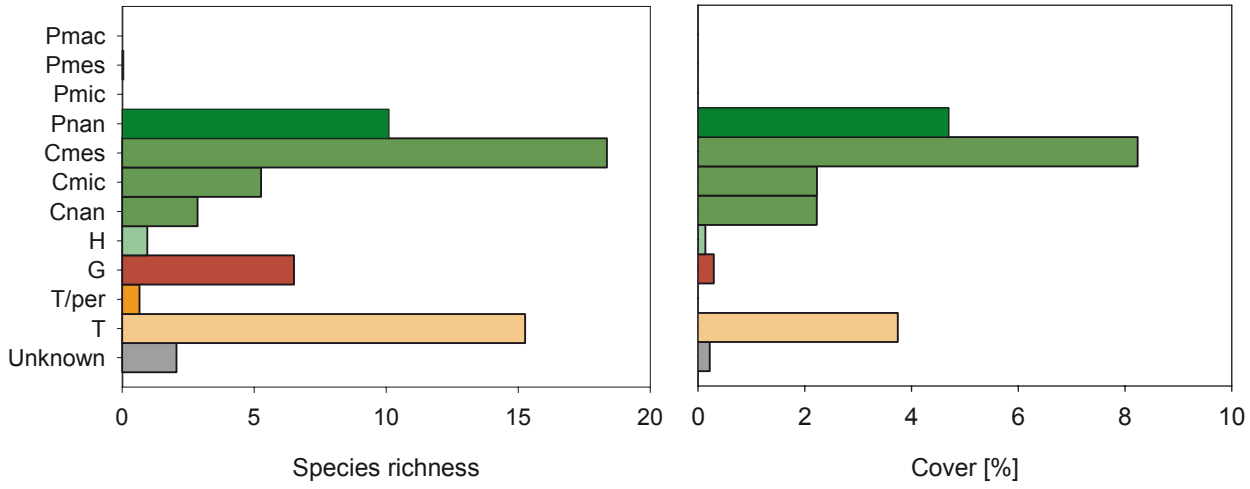
70% of the total recorded soil-inhabiting species occur in the investigated hectare plots. Richness is higher in plots with relatively high soil pH. The most frequent species are *Collema coccophorum*, *Peccania arabica*, *Psora crenata* and *Placidium squamulosum*. These are ubiquitous species, which are very common along the BIOTA transect, especially in the Succulent Karoo and the Savanna Biomes. Five morphological groups occur on the examined hectare plots of this Observatory, and are often associated with one another. Only the mean cover of MG08 is relatively high, while the cover of other morphogroups is much lower, probably due to competition with vascular plants and disturbance by livestock trampling. The cover of lichens is very patchy due to the high spatial variability of soils with regard to acidity, electrical conductivity, cover of stones and anthropogenic impacts.

Responsible authors: L. Zedda & G. Rambold

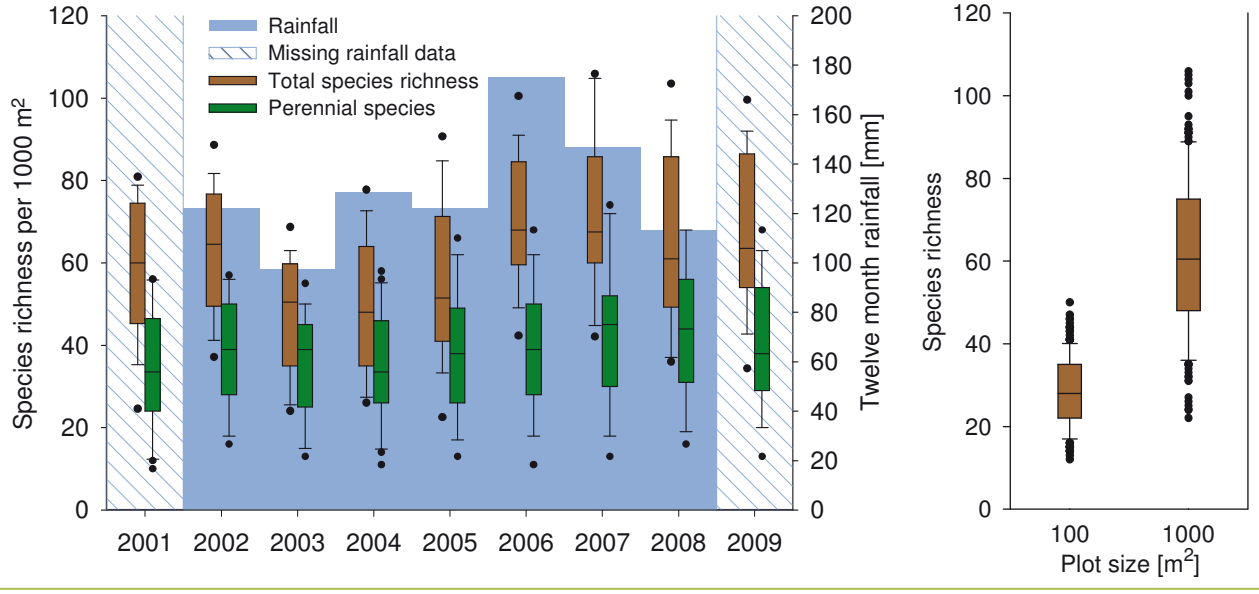
Vascular plants

Sampling period(s)	Hectare plots sampled	Biome
2001–2009	20 (R1–R20)	Succulent Karoo
Vegetation unit (level 1)	Vegetation unit (level 2)	Identification rate
Namaqualand Hardeveld Bioregion	SKn 1 Namaqualand Klipkoppe Shrubland	66% – 92% – 93%
Cumulative family richness	Dominant families (cover)	Dominant families (richness)
51	Aizoaceae, Poaceae, Asteraceae	Aizoaceae, Asteraceae, Crassulaceae
Cumulative species richness (1 km²)	Species richness (1000 m²)	Species richness (100 m²)
565 – 282	61.1 (22–106)	28.6 (12–50)
z-value	Species richness change per year (1000 m²)	Evenness (1000 m²)
0.329 (0.038–0.551)	0.53	0.613 (0.157–0.855)
Evenness (100 m²)	Simpson (1000 m²)	Simpson (100 m²)
0.662 (0.158–0.896)	0.803 (0.181–0.963)	0.795 (0.175–0.953)

Life forms



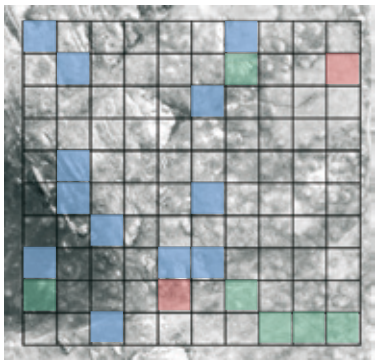
Species richness



Unit 1, H06, 2006. Photo: R. Christiaan.

Unit 2, H00, between gneiss boulders on the mountain top; 2006. Photo: R. Christiaan.

Map of vegetation units



The vegetation of the Soebatsfontein Observatory falls into the Namaqualand Heuweltjieveld (SKn 4, Mucina et al. 2006), which is characterised by small-scale soil patterns caused by fossil termitaria (heuweltjies) and the surrounding zonal soils. Heuweltjies dominate the low-lying areas (broad valleys up to the mid-slopes) with deeper loamy-sandy soils, while they are largely absent between the gneissic boulders and outcrops on the upper slopes and hilltops.

The vegetation is dominated by leaf-succulent shrubs (C mes, P nan) and, after good seasonal rainfall, annual Asteraceae (T). Species richness is highest for shrubs, annuals, and geophytes (G). Aizoaceae and Asteraceae are the most important plant families in terms of cover and species richness. The Observatory is amongst the most species-rich of all the Observatories at larger spatial scales (i.e. 1000 m², 1 ha, 1 km²) along the southern Africa transect. The species richness at the smallest plot size (mean of 28.6 species per 100 m²) is only slightly higher than the mean for all Observatories. The strong increase in species richness from 100 m²- to 1000 m²-plots is reflected in the very high (mean-to-mean) *z*-values for the transition 100 m² to 1000 m², which reflects high β-diversity. The abundance of annual and geophyte species may differ strongly between years depending on seasonal rainfall.

The three vegetation units described below correspond with vegetation units of higher hierarchical level, comprising several associations, described for the vegetation of the entire Soebatsfontein commonage (Luther-Mosebach 2009).

Classification table (2008)

Column		Cover	All	1	2	3
Number of relevés			**20**	**2**	**12**	**6**
Mean cover [%]			23.1	28.0	20.9	25.8
Mean species richness (1000 m²)			64.7	48.0	72.9	53.8
Mean inclination [°]			14.7	5.0	18.3	10.5
Mean soil pH			5.71	5.85	5.60	2.98
Mean electrical conductivity [µS·cm^{-1}]			161	1478	173	116
Organic carbon [%]			0.81	0.51	0.89	0.73
Nitrogen [%]			0.06	0.04	0.06	0.06
Fine material [%]			84.6	100	76.8	95.2
Rock outcrops [%]			14.1	0.0	22.2	2.5
Soft litter [%]			7.2	10.5	6.6	7.2
Biotic crust [%]			56.5	80.0	54.2	53.3
Unit 1: Grielum humifusum-Lebeckia multiflora community						
T	Helichrysum alsinoides	0.05	5	50	.	.
T	Zaluzianskya affinis	0.19	45	100	25	67
T	Grielum humifusum	0.09	30	100	17	33
Cmes	Galenia sarcophylla	0.12	75	100	67	83
T	Gazania tenuifolia	0.04	15	50	8	17
T	Karroochloa schismoides	1.31	85	100	83	83
Pnan	Lebeckia multiflora	0.40	70	100	58	83
Hper	Lotononis falcata	0.01	5	50	.	.
Unit 2: Rhus undulata-Stoeberia utilis community						
Pnan	Rhus undulata	1.23	60	50	83	17
T	Ehrharta longiflora	0.08	30	.	42	17
T	Heliophila variabilis	0.02	75	100	83	50
Cmes	Berkheya fruticosa	0.30	65	.	83	50
T	Bromus pectinatus	0.83	70	50	83	50
Pnan	Stoeberia utilis	1.84	45	50	67	.
Cmes	Crassula expansa ssp. expansa	0.02	40	50	50	17
Pnan	Zygophyllum morgsana	0.60	55	50	75	17
Pnan	Rhus incisa	0.46	35	50	50	.
Pnan	Microloma sagittatum	0.02	50	50	58	33
Pnan	Antizoma miersiana	0.22	30	.	50	.
Pnan	Didelta spinosa	0.15	35	50	42	17
Hper	Aizoon canariense	0.10	55	.	83	17
T	Tripteris amplectens	0.01	55	.	75	33
Pnan	Montinia caryophyllacea	0.57	35	.	58	.
Pnan	Asparagus burchelli	0.11	65	50	75	50
Cmes	Crassula muscosa var. obtusifolia	0.10	35	.	50	17
T	Tribolium utriculosum	0.81	55	50	67	33
Cmes	Ruschia goodiae	0.38	30	.	42	17
Pnan	Lebeckia sericea	1.48	25	50	25	17
Pnan	Lycium ferocissimum	0.62	90	50	100	83
Cmes	Thesium lineatum	0.28	35	50	50	.
Cmes	Hermannia amoena	0.30	40	50	58	.
Cmes	Manochlamys albicans	0.28	75	50	83	67
T	Hebenstretia parviflora	0.01	45	50	58	17
n.a.	Jamesbrittenia racemosa	0.04	15	.	17	17
T	Atriplex semibaccata	0.02	40	.	67	.
n.a.	Ehrharta pusilla	0.19	45	50	50	33
T	Lepidium desertorum	0.06	55	50	50	67
T	Helichrysum leontonyx	0.04	65	50	75	50
Pnan	Euphorbia mauritanica	0.76	35	.	50	17
Cmic	Drosanthemum hispidum	0.48	80	100	92	50
Pnan	Tripteris oppositifolia	0.46	25	.	42	.
T/Hper	Leysera tenella	0.05	50	50	58	33
Cmes	Galenia africana	0.10	35	.	50	17

**classification is based on data also including relevés outside the Observatory*

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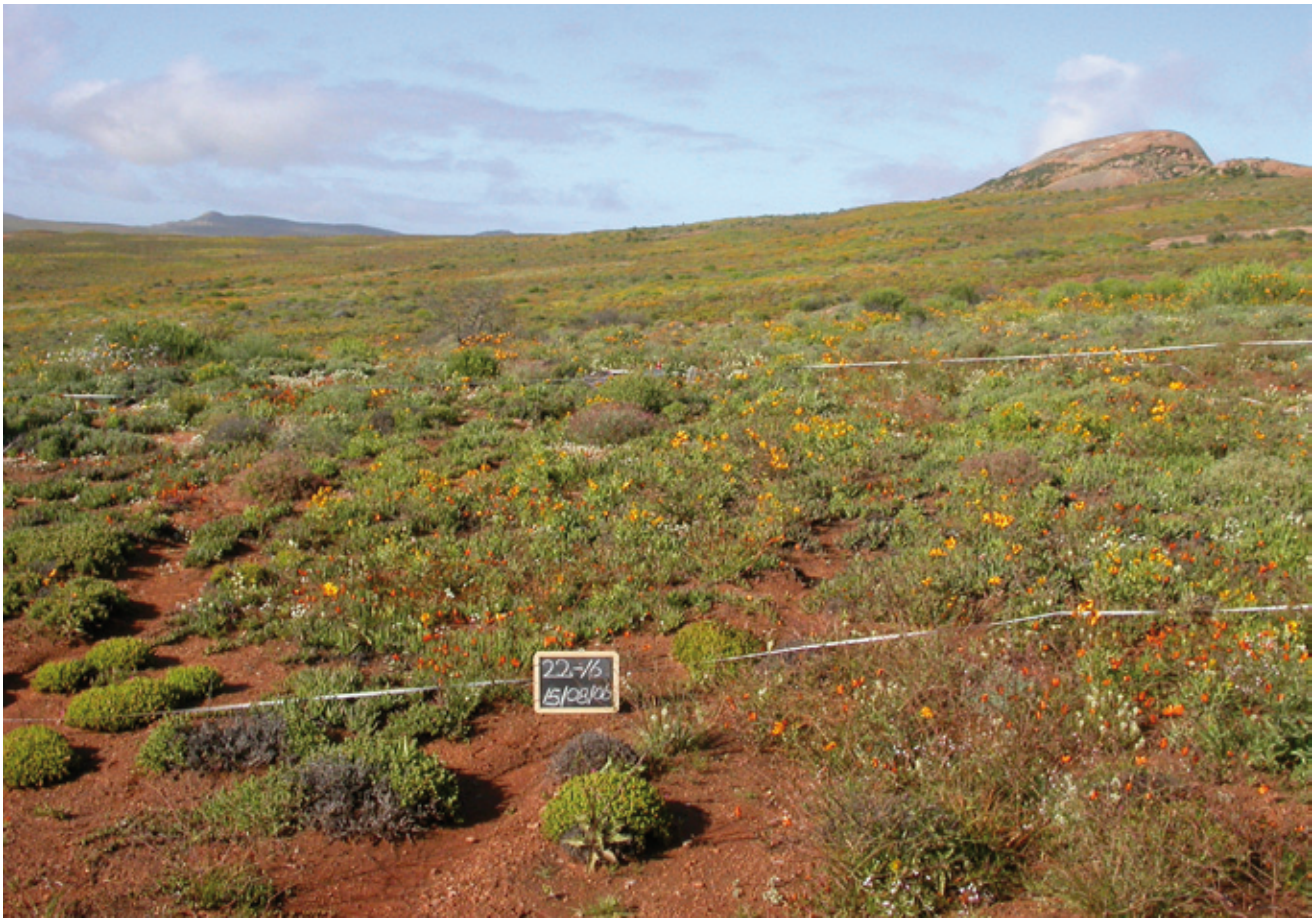


Unit 3, H16, 2006. Photo: R. Christiaan.

Unit 3, H99, 2006. Photo: R. Christiaan.

The *Grielum humifusum-Lebeckia multiflora* community (unit 1) is dominated by non-succulent annuals (T), such as the prostrate herb *Grielum humifusum* (pietsnot), and the tall shrub (P nan) *Lebeckia multiflora* (Fluitjiesbos). This community, which was only recorded on two of the sampled hectares at the Observatory, occurs on nutrient poor, partly sandy and shallow soils. The species composition is typical of areas that have been overutilised by livestock in the past.

The *Rhus undulata-Stoeberia utilis* community (unit 2) is the most common vegetation unit on the Soebatsfontein Observatory. It typically occurs on rocky outcrops from the mid-slopes to the top of gneissic mountain slopes. The community is comprised of a high number of tall shrubs (P nan) that can reach high cover values, such as *Rhus undulata* (Taaibos), *Stoeberia utilis* (Rooivy). *Berkheya fruticosa* (Vaalperdebos), *Didelta spinosa* (Perdebos), *Lycium ferocissimum* (Karriedoring), *Montinia caryophyllacea* (Peperbos), *Tripteris oppositifolia* (Skaapbos), *Zygophyllum morgsana* (Skilpadbos) are typically found in rocky habitats. Annual daisies and grasses may thrive in high numbers in open patches between the dense shrubby clumps. This vegetation unit is characterised by a relatively high species richness (at 1000 m²-scale) compared to other vegetation units on the Observatory.

The *Cephalophyllum inaequale-Eberlanzia cyathiforme* community (unit 3) is the typical vegetation of the lower-lying parts of the Observatory. The creeping leaf-succulent dwarf shrub *Cephalophyllum inaequale* (Rankvye) covers large parts of the shallow soils surrounding heuweltjies, whereas *Eberlanzia cyathiforme* is concentrated on the heuweltjie centres. Other shrubs that occur frequently and with relatively high cover values in this community are *Galenia fruticosa*, *Meyerophytum meyeri*, *Ruschia versicolor*, and *Zygophyllum cordifolium* (Sjielingsbos or Skilpadbos). After good winter rainfall the annual *Didelta carnosa* (Perdeblom) may occur in high abundance.

Classification table (continued)

Column			All	1	2	3
Number of relevés		**Cover**	**28**	**8**	**10**	**10**
Unit 3: Cephalophyllum inaequale-Eberlanzia cyathiforme community						
Cnan	Cephalophyllum inaequale	5.30	40	50	17	83
T	Didelta carnosa	0.05	90	100	83	100
Pnan	Salsola sp. 14196	0.47	40	50	17	83
Cmes	Zygophyllum cordifolium	3.06	60	50	50	83
Cmic	Ruschia leucosperma	0.03	35	.	17	83
Cmes	Eberlanzia cyathiformis	1.40	70	100	50	100
Hper	Gazania krebsiana ssp. krebsiana	0.05	5	.	.	17
T	Foveolina dichotoma	0.21	30	50	25	33
Cmes	Meyerophytum meyeri	1.49	55	.	42	100
Cmes	Euphorbia hamata	0.12	35	.	25	67
Cmes	Galenia fruticosa	0.68	100	100	100	100
Cnan	Phyllobolus trichotomus	0.01	25	.	17	50
Cmes	Drosanthemum curtophyllum	0.56	30	.	17	67
Most frequent companions						
G	Oxalis pes-caprae	0.10	95	100	92	100
T	Mesembryanthemum guerichianum	0.10	95	100	100	83
G	Trachyandra revoluta	0.04	95	100	92	100
Cmic	Tetragonia fruticosa	0.19	90	50	92	100
T	Gorteria diffusa ssp. diffusa	0.10	90	100	92	83
T	Tetragonia microptera	0.06	90	100	92	83
T	Dimorphotheca sinuata	0.60	85	100	75	100
G	Chlorophytum crassinerve	0.02	80	50	92	67
Pnan	Asparagus capensis	0.03	75	50	75	83
Pnan	Lycium oxycarpum	0.14	70	50	58	100
T	Oncosiphon suffruticosum	0.57	65	100	75	33
T	Atriplex lindleyi ssp. inflata	0.17	65	50	58	83
Cnan	Hypertelis salsoloides var. salsoloides	0.05	60	50	58	67
Cmac	Antimima komkansica	0.91	55	.	58	67
Cmes	Ruschia viridifolia	0.79	55	50	50	67
Cmes	Ruschia sp. 2485ff	0.49	55	50	58	50
Cmes	Psilocaulon dinteri	0.19	55	100	42	67
Cmes	Trachyandra involucrata	0.16	55	.	67	50
Cmes	Tetragonia verrucosa	0.08	55	.	75	33
Cmes	Leipoldtia schultzei	4.56	50	50	50	50
Cmes	Ruschia versicolor	1.03	50	.	42	83
Pnan	Aridaria noctiflora ssp. noctiflora	0.51	50	50	33	83
Cmes	Hermannia cuneifolia var. glabrescens	0.12	50	50	58	33
G	Oxalis sp. 118594	0.01	50	.	58	50
Cmes	Ruschia sp. 11863	0.66	45	.	58	33
Cmic	Pelargonium karooicum	0.02	45	.	50	50
n.a.	Ehrharta melicoides	0.24	40	.	67	.
Cmic	Phyllobolus spinuliferus	0.09	35	.	33	50
Cmes	Sarcostemma viminale	0.06	35	.	50	17
Cmic	Helichrysum dregeanum	0.04	35	.	58	.
G	Oxalis obtusa	0.02	35	50	42	17
Cmic	Asparagus multituberosus	0.02	35	50	50	.
Cmes	Zygophyllum retrofractum	0.53	30	.	33	33
Cmes	Othonna sedifolia	0.06	30	50	33	17
Cmes	Zygophyllum spinosum	0.06	30	50	42	.
Cmes	Tylecodon wallichii	0.03	30	50	25	33
G	Albuca cooperi	0.01	30	50	17	50
Cmes	Crassula muscosa var. muscosa	0.01	30	.	17	67
Cmic	Limeum africanum	0.01	30	.	42	17
T	Nemesia anisocarpa	0.01	30	50	17	50
G	Oxalis sp. 118669	0.01	30	.	25	50
T	Wahlenbergia androsacea	0.01	30	50	33	17
Pnan	Putterlickia pyracantha	0.32	25	.	42	.

Dense display of Namaqua daisies at the Soebatsfontein Observatory in August 2006. Photo: U. Schmiedel.

Zygophyllum cordifolium. Photo: J. Deckert.

Pelargonium echinatum. Photo: U. Schmiedel.

Responsible authors: J. Luther-Mosebach & U. Schmiedel

Termites

Taxon richness	Abundance index	Dominant (sub-)family
2	n.a.	n.a.

Besides the harvester termite *Microhodotermes viator*, which was also collected from the more northerly Observatories S18 (Koeroegap Vlakte) and S20 (Numees), the so called "sand termite" *Psammotermes allocerus* (see Observatory S11/Nabaos) was also encountered at this Observatory (Vohland & Deckert 2005).

List of taxa

Taxon	(Sub-)family
Microhodotermes viator	Hodotermitidae
Psammotermes allocerus	Rhinotermitidae

Responsible authors: C. Grohmann & K.E. Linsenmair

True bugs

Sampling period(s)	Methods	Family richness
2001/ X; 2002/ IX, X; 2003/ IX	Trapping (light, pitfall traps, yellow pan trap)	14
Species richness	**Individuals sampled**	**Fisher's alpha diversity**
51	190	22.85

Fifty one Heteroptera species from 14 families were recorded at the Soebatsfontein Observatory (S22). The most species rich family was the Miridae, which accounted for 43% of all species. Pentatomidae (17%), Reduviidae (6%), and Rhyparochromidae (6%) were subdominant. Eight species of Miridae, one species of *Euthetus leucospilus* (Alydidae), and one species of *Dicranocephalus caffer* (Stenocephalidae) were collected from light traps. Wind and low temperatures in the evening probably reduced the number of specimens collected from the light traps.

Ten species were collected using pitfall traps. One third of these species belong to the family Miridae. *Geocoris phaeopterus* (Geocoridae), *Nysius ericae* (Lygaeidae), a species of Reduviidae, and *Leptodemus irroratus* (Oxycarenidae) were dominant in the pitfall traps. All these species are widely distributed. One undescribed, presumably endemic *Plinthisus* species (Rhyparochromidae) was also collected from the pitfall traps. *Plinthisus* species are wingless and known to have a restricted distribution. As in S18 (Koeroegap Vlakte), a single specimen of *Saxicoris verrucosa* (Piesmatidae) was captured. Five species were collected from yellow pans and three species were collected from malaise traps.

Thirty two species were collected by hand.

Species richness in families

Family	*S*
Miridae	22
Pentatomidae	9
Reduviidae	3
Rhypharochromidae	3
Coreidae	2
Cydnidae	2
Lygaeidae	2
Piesmatidae	2
Stenocephalidae	2
Alydidae	1
Blissidae	1
Geocoridae	1
Oxycarenidae	1
Rhopalidae	1
Total	**51**

Species abundances

Yellow pans

Species	Family	*N*	%
Geocoris phaeopterus	Geocoridae	1	20
Piesma spec.	Piesmatidae	1	20
Leptodemus irroratus	Oxycarenidae	1	20
Miridae spec.	Miridae	1	20
Euthetus leucospilus	Alydidae	1	20
Total		**5**	**100**

Pitfall traps

Species	Family	*N*	%
Geocoris phaeopterus	Geocoridae	3	16
Nysius ericae	Lygaeidae	3	16
Reduviinae spec.	Reduviidae	3	16
Leptodemus irroratus	Oxycarenidae	2	9
Elasmolomus transversus	Rhyparochromidae	2	11
Others (6)	Miridae	6	32
Total		**19**	**100**

Southern Harvester Termite (*Microhodotermes viator*). Photo: J. Deckert.

Big-eyed Bug (*Geocoris haeopterus*). Photo: J. Deckert.

The Heel Walker *Karoophasma biedouwensis* (Austrophasmatidae, Mantophasmatodea) is an unusual wingless orthopteroid insect of the Succulent Karoo. It belongs to an insect order discovered in 2001. Several endemic species of this group are known from Namibia, Northern and Western Cape, and Tanzania. Photo: J. Deckert. 2003.

Responsible author: J. Deckert

Vertebrates

Total species richness	Reptile species richness	Bird species richness
21	n.a.	21
Large mammal species richness	**Small mammal species richness**	
n.a.	n.a.	

Large mammals

Hyracoidea	**Hyraxes**
Procavia capensis	Rock Hyrax
Lagomorpha	**Rabbits**
Lepus saxatilis	Scrub Hare
Tubulidentata	**Aardvarks**
Orycteropus afer	Aardvark

Reptiles

Testudines	**Tortises and turtles**
Chersina angulata	Angulate Tortoise
Sqamata	**Lizards and snakes**
Trachylepis capensis	Cape Skink
Agama hispida	Southern Spiny Agama
Bitis arietans	Puff Adder
Ptenopus garrulus	Barking Gekko

Birds

Passeriformes	**Perching birds**
Calandrella cinerea	Red-capped Lark
Certhilauda albescens	Karoo Lark
Chersomanes albofasciata	Spike-heeled Lark
Cinnyris fuscus	Dusky Sunbird
Cisticola subruficapillus	Grey-backed Cisticola
Corvus albus	Pied Crow
Emberiza capensis	Cape Bunting
Galerida magnirostris	Large-billed Lark
Mirafra apiata	Clapper Lark
Oenanthe monticola	Mountain Wheatear
Oenanthe pileata	Capped Wheatear
Passer melanurus	Cape Sparrow
Prinia maculosa	Karoo Prinia
Telophorus zeylonus	Bokmakierie
Columbiformes	**Doves and Pigeons**
Columba guinea	Speckled Pigeon
Streptopelia capicola	Ring-necked Dove
Anseriformes	**Ducks, geese and swans**
Alopochen aegyptiacus	Egyptian Goose
Accipitriformes	**Birds of prey**
Buteo rufofuscus	Jackal Buzzard
Strigiformes	**Owls**
Bubo africanus	Spotted Eagle Owl
Gruiformes	**Cranes, rails, coots, and allies**
Neotis ludwigii	Ludwigs Bustard
Pteroclidiformes	**Sandgrouse**
Pterocles namaqua	Namaqua Sandgrouse

Barking Gekko (*Ptenopus garrulus*). Photo: J. Deckert.

Spotted Eagle Owl (*Bubo africanus*). Photo: J. Deckert.

Responsible authors: J. Deckert, A. Hoffmann & A. Mills

The people

Study periods	Size of study area	Population in study area
2004; 2005–2006	ca. 151 km²	273 people
Number of households	**Mean household size**	**Mean age of farmers**
59	4.6 people	56 years
Education of farmers	**Ethnicity of farm owners**	**Ethnicity of farm workers**
Functionally illiterate to secondary school	"Coloured"	"Coloured"
Population growth	**Total fertility rate**	**Cohort fertility**
1970–1995: 4.2% 1995–2004: 1.8%	4.7 children per woman	1913–1945: 7.9; 1946–1965: 2.9 children per woman
Unemployment rate	**Main sources of income**	
ca. 38% (2004)	Wage labour, pensions	

Photo 22.1: The Soebatsfontein Settlement. Photo: T. Linke.

The Soebatsfontein Community

Soebatsfontein is a small rural community consisting of about 270 residents. Before and during the apartheid era many white farmers settled in Soebatsfontein and ran the surrounding farms whereas the "coloured" population had no access to land and worked mainly as labourers. In 1954 the "Verenigde Gereformeerde" church bought a small piece of land, which was declared as the "coloured" settlement of Soebatsfontein. Nowadays, mostly "coloured" families live in the village and since the end of apartheid, modernisation processes have changed the settlement. People moved from the church ground to public land, new houses were built, and in 2007 the village was electrified. Furthermore, with post-apartheid land and agrarian reform, 15,069 ha of communal farm land was transferred to the community. The BIOTA Observatory is located on this land.

Demography and social organisation

Between 1970 and 1995 the population of the community increased at a rate of 4.2% (Linke 2009, Surplus Peoples Project 1995). This rate dropped to 1.8% between 1995 and 2004. Consistent with these results, the community experienced a substantial fertility decline. To analyse the fertility change, women were grouped into three birth cohorts (i.e. groups of women born during a particular time period). The total fertility rate decreased from 7.9 children per woman born in the eldest cohort (1913 until 1945) to 2.9 children per woman born between 1946 and 1965. The total fertility rate could not be calculated for the youngest cohort as women are still in the reproductive phase. Nevertheless, age specific birth rates can be compared (Fig. 22.1) showing that fertility is declining further in this cohort. Population size can heavily influence the sustainable use of natural resources. However, demographic results show

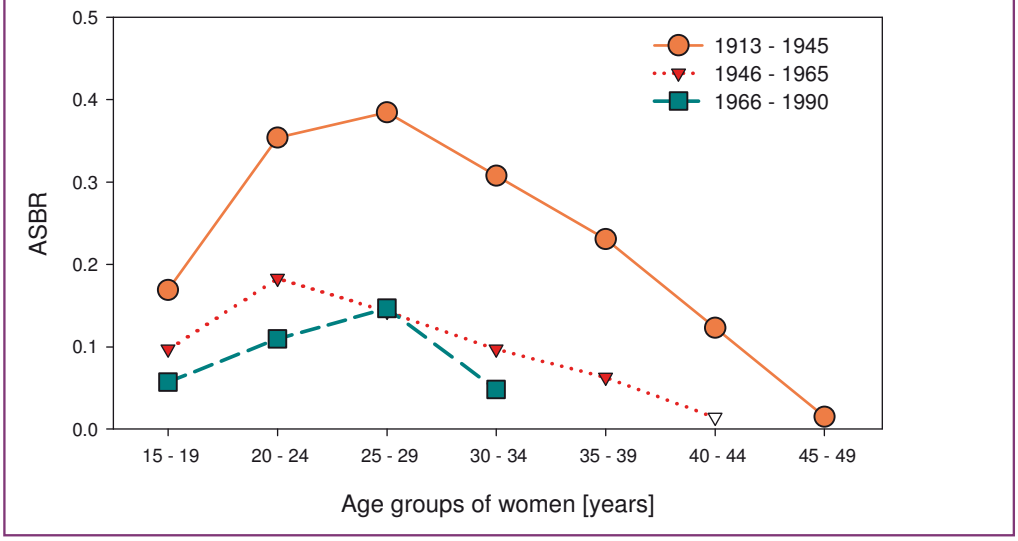


Fig. 22.1: Age specific birth rates compared, cohort analysis (Linke 2009).

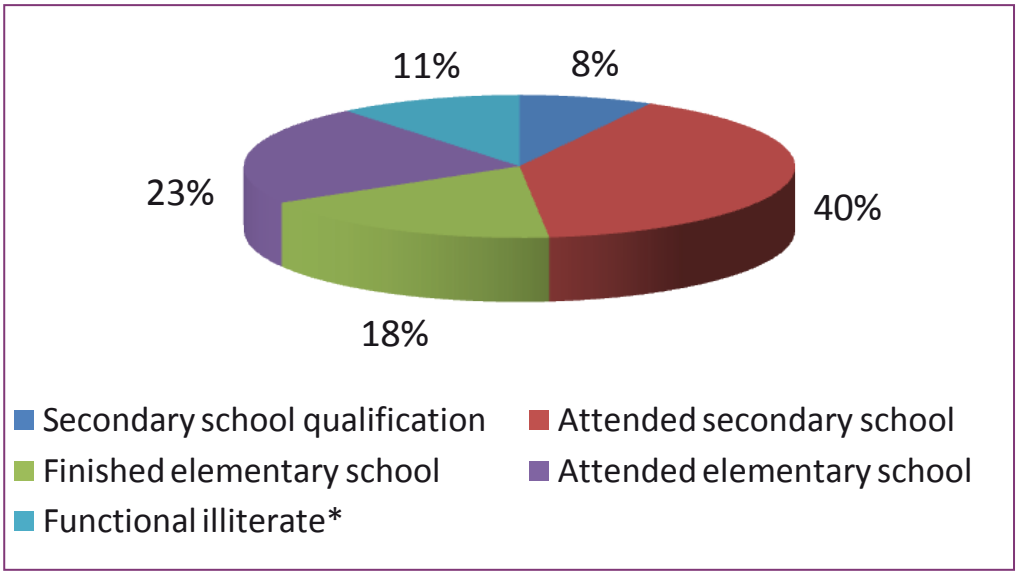


Fig. 22.2: School qualification, census 2004 (Linke, own data). *No school education or rudimental school education.

that population pressure on biodiversity caused by natural growth is not expected in Soebatsfontein. Further analysis revealed that in the 1970s and 1980s the demographic development was shaped by immigration. Families immigrated mainly from communities and farms in the Namaqualand region as well as from places in the Western Cape. This process influenced the social organisation of the village. Today the community is divided into several family groups, who define themselves according to their place of origin. About 26% of the total population has an immigration background (see Subchapter IV.4.5).

Household economy

The Soebatsfontein community compromises about 60 households and the majority of household members (76%) belong to the nuclear family. Livelihoods are typically diversified, and wage labour, pensions and retirement benefits are the main sources of income. The majority of people are engaged in casual work on farms or in construction where employment contracts are limited to a few weeks or months. This is the reason why, in 60% of all cases, household income is low and insecure (< 120 US$/household) (see Subchapter IV.4.5). Just 30% of the working population is permanently employed, most of them in the mines along the west coast. Permanent work increases household income significantly.

Education

Education has changed substantially over time. Cohort analysis showed that the majority of community members born before 1953 are functionally illiterate. The first elementary school for the "coloured" population in Soebatsfontein was founded at the beginning of the 1940s. Today, 40% of the population has attended secondary school for at least a few years and 8% have a secondary school qualification (Fig. 22.2). In 2008, free public transport to the secondary school was established for community members.

Responsible author: T. Linke

Landuse

Study periods	Size of study area	Recommended stocking rate
2004; 2005–2006	ca. 151 km²	10 ha·SSU^{-1}
Actual stocking rate	Number of camps	Households owning livestock
13 (5–25) ha·SSU^{-1}	17 (grazed: 15)	ca. 39% (2005)
Number of farmers managing camps	Number of animals	Mean camp size
12 (20% of households)	2005: 1137 SSU (ratio grazers/ browsers: 6/5)	940 (ca. 380–1250) ha
Number of windpumps	Farming activities	
4	Meat production for subsistence, livestock sales for cash income	

Photo 22.2: Farmer herding his flock. Photo: T. Linke.

Since 2000, when the farmland was handed over to the community, community members have the opportunity to engage in small stock farming and build up their own herds. Livestock farming is intended to contribute to the livelihoods of poor and disadvantaged households, in particular.

Infrastructure on the communal land

Soebatsfontein is part of the so-called "new commons" and the Kamiesberg municipality officially owns the land (for information on property and access rights see Subchapter IV.4.5 and Falk 2008). In collaboration with the community and other parties (mainly NGOs), a management plan was implemented in order to regulate access to, and management of the land. In general, many features of the "new commons" resemble the land-use practices of commercial farms in the region (May & Lahiff 2007). The communal land is subdivided into 17 fenced camps and farmers can apply for usage-rights in these camps. For each camp, stocking rates are prescribed. Depending on herd size, animals should be grazed in rotation, so that camps can recover from grazing. Four wind pumps deliver brackish ground water to all camps, whereas basic infrastructure—such as kraals and stock posts—is restricted to a few main camps only.

Management, herd size and stocking density

In 2005, 1137 sheep and goats grazed and browsed on the communal land, which is below the recommended stocking rate. Herds consist mostly of "Boer" goats and "Dorper" sheep for meat production. Farmers rely on economic and social resources to manage their herds. Some of them, mostly pensioners, invest a high labour input and stay permanently on the stock post, drawing on the manpower of close family members. Others employ a

Photo 22.3: Windpump at stockpost. Photo: T. Linke.

Photo 22.4: Farmers busy slaughtering. Photo: T. Linke.

herder to watch over the animals, while some herds are left unattended on the communal land and are brought together once every week or two. Total herd size per camp varies considerably from 9 SSU (small stock units) up to 300 SSU and some of the herds contain animals of other owners, usually close family members (Fig. 22.3). Stocking density differs depending on herd and camp size. Farmers with small herds usually understock their camps. However, as mines are closing down in the region, farmers have invested gratuities to increase their herds. Even if farmers have access to two or more camps, rotational grazing is hardly practised. These factors lead to high stocking rates, especially at camps near the stock posts. The grazing management and different strategies of the farmers are further explained in Subchapter IV.4.5.

Economic benefits

The amount of communal land available to livestock owners is small in relation to the size of the community. According to the recommended stocking rate, every household should only keep approximately 20 animals. About 40% of all households own livestock but just 20% of these households are farming on the communal land. All farmers are male household heads and some of them have worked for many years on commercial farms.

Livestock contributes mainly to subsistence needs, providing households with meat. To start animal husbandry, approximately 60% of the farmers took out a landbank loan. In most cases, surplus animals were used to pay back the loan. Only a few farmers with large herds make a profit out of their sales. The nearest market is in Springbok, but livestock is mostly sold to private livestock traders who fetch the animals near the village.

Monitoring over a period of five months (Nov 2005–March 2006) showed that expenditure for livestock farming exceeds returns in many cases, especially when herds are small. Expenses are categorised in Fig. 22.4. Furthermore, the labour input is high as herds need to be looked after several times per week to avoid livestock losses. Thus, livestock farming is costly at the outset and less risky for farmers who belong to economically stable households. Indeed, it is the latter group who own and manage large livestock herds (> 100 SSU).

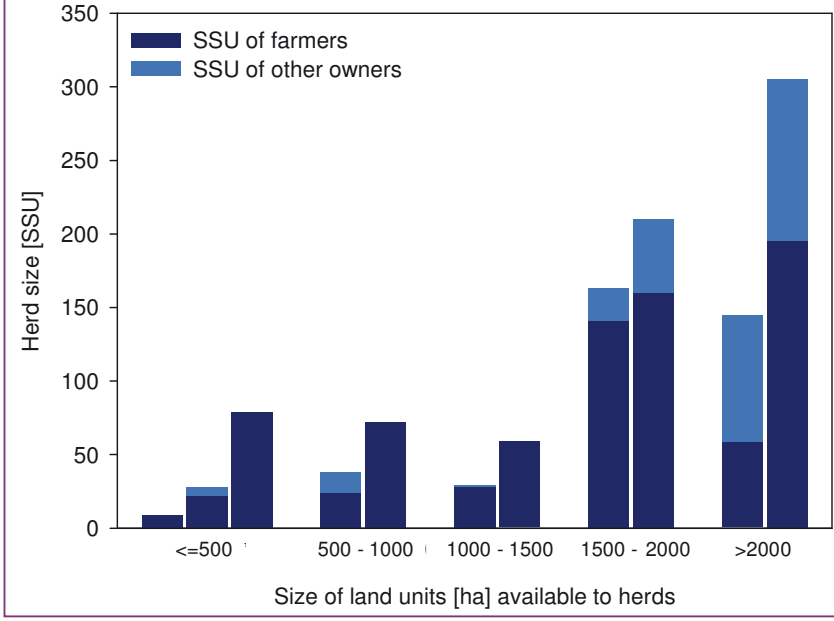


Fig. 22.3: Total herd size per farmer in relation to the size of the land available to farmers. Each herd used one or two camps (Linke 2009).

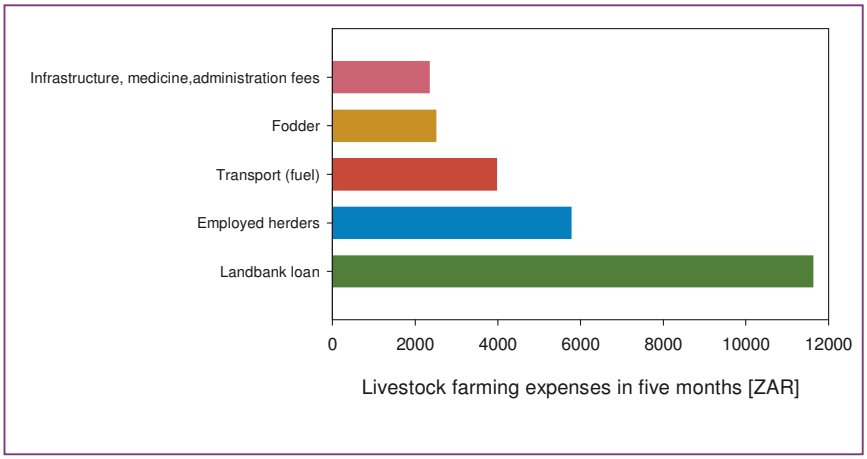


Fig. 22.4: Total livestock farming expenses at Soebatsfontein (Nov 2005–March 2006) (Linke 2009).

Responsible author: T. Linke

Site-specific studies

Photo SSS22.1: Centre vegetation zone on an elevated heuweltjie. Visible are stems of dead *Mesembryanthemum guerichianum* plants and bioturbation (a burrow of an Aardvark, *Orycteropus afer*). Photo: I.U. Röwer.

Vegetation patterns on heuweltjies under different grazing pressures in Soebatsfontein (S22.01)

[I.U. Röwer]

The aim of this study was to understand how heuweltjies (fossil termitaria, Photo SSS22.1) influence vascular plant diversity, vegetation composition, and grazing resources. Further, the impact of livestock grazing of varying intensity on vegetation structure and composition, as well as soil properties on heuweltjies sites was studied.

The study was carried out in August and September 2008 on the 15,000-ha communal farmland of Soebatsfontein, which includes the Observatory S22 in the southeast. Three concentric vegetations zones on heuweltjies and three historic (i.e. before 2000) grazing intensities were sampled, with 10 replicates for each factor combination. Vegetation relevés were carried out on 100-m² plots, and parameters for soil, plant diversity, and habitat structure were determined. Differentiating effects of historic grazing and heuweltjie zones were assessed; predictors for vegetation of historical and recent grazing, of topographical, and of soil parameters were quantified. A potential bias due to north-south gradient in grazing intensity was excluded by analysing heuweltjie centres only, as these were assumed to be relatively independent of parent material.

The study revealed extreme small-scale patterns of environmental conditions and species composition through heuweltjies. Disturbance, pH, and cover of annual plants increased from the surroundings via the margin to the centres of the heuweltjies, with the pH values of the surroundings being more than two units lower (mean: 5.97) than those in the centres (mean: 8.10). By contrast, vegetation cover and species richness decreased in the same direction. Differentiating effects of heuweltjie zones were more pronounced than those of historic grazing. Typical responses to grazing occurred towards low historic grazing intensity. Responses of vegetation and soil to grazing were explained best in the regression models by recent grazing intensity, suggesting that this system had relatively fast responded to a change of grazing regime. Grazing impacts on heuweltjie centres existed independently of a possible north-south habitat gradient.

Röwer, I.U. (2009): Small-scale vegetation and biodiversity patterns of termitaria (heuweltjies) under different grazing pressures in the communal area of Soebatsfontein, South Africa. – Diplom thesis in Biology. Hamburg: University of Hamburg.

The institutional framework guiding natural resource management of Soebatsfontein farmers (S22.02)

[T. Falk]

Sustainable biodiversity management requires effective institutional incentives. Document analyses, expert interviews, and empirical surveys were applied to describe the multiple rules and norms guiding the management of land reform beneficiaries around the Observatory S22 (Soebatsfontein).

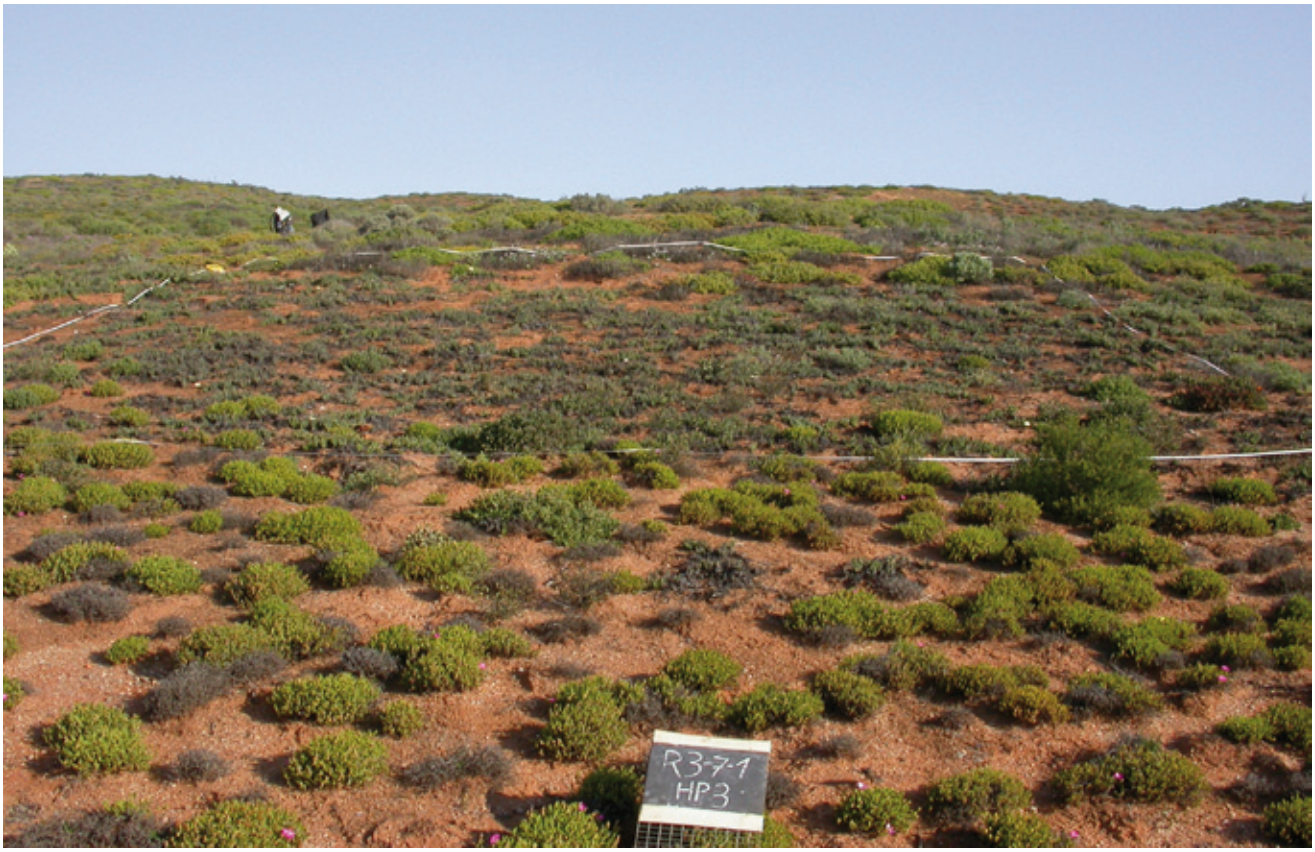


Photo SSS22.2: Typical matrix vegetation from the class *Cephalopyllo inaequalis-Dideltetea carnosae* in prep. with dominant *Cephalophyllum matrix* in the foreground and a heuweltjie in the background. Photo: J. Luther-Mosebach.

Key results show that subsidiary rules are inconsequently implemented in Soebatsfontein, which strongly increases the transaction costs of land management. Government organisations have limited capacity to carry out the operational management of the commonage but largely monopolise management authority. Especially the local government shows little awareness of the power of endogenous institutions and their community-based enforcement. The perceived distribution of property rights is becoming increasingly blurred creating an institutional vacuum which is a serious threat for sustainable natural resource management.

► *See also* Subchapter IV.4.5.

Falk, T. (2008): Communal farmers' natural resource use and biodiversity preservation. A new institutional economic analysis from case studies in Namibia and South Africa. – Göttingen: Cuvillier.

Understanding factors for soil erosion in the Succulent Karoo (S22.03)

[A. Gröngröft & P. Hoyer]

This study laid emphasis on the factors causing soil erosion on this Observatory. Therefore, standard field and laboratory methods were complemented by laboratory measurements of the potential infiltrability, which is a proxy for the soil's tendency to crust. The results showed that the content of fine sand and silt is crucial for topsoil crusting. Caused by the strong small-scale variability of soil properties, promoted by the occurrence of heuweltjies, the explanation of visible erosion phenomena by standard erosion models failed.

Hoyer, P. (2004): Bodenvariabilität und ihre Bedeutung für die Erosion auf einer Fläche in der Sukkulenten Karoo (Soebatsfontein, Südafrika). – Diplom thesis in Soil Science. Hamburg: University of Hamburg.

Patterns of phytodiversity along environmental and landuse gradients on the Observatory Soebatsfontein its surroundings (S22.04)

[Tene Kwetche Sop & U. Schmiedel]

The aims of this study were (i) to assess the factors determining the distribution of plant species in Soebatsfontein in general and especially on the Observatory Soebatsfontein (S22) and it surroundings; (ii) to analyse the impact of land-use practices on biodiversity patterns, and (iii) to identify the changes in species diversity, life form distribution, and community composition along land-use and topographical gradients.

Using the standard BIOTA sampling design (see Chapter II.1), vegetation on the Observatory S22 was sampled with 100-m², 1000-m² and 10,000-m² plots, in the years 2001, 2002, and 2003. In order to determine the parameters that are responsible for the variation in the vegetation composition, a number of soil parameters were recorded including

altitude, pH, electrical conductivity, organic carbon, inorganic carbon, calcium, magnesium, potassium, sodium, inclination, and aspect. Impact of land degradation (grazing, ploughing, trampling, etc.) on species distribution was studied using five transects of different length (400 m, 250 m, 200 m, 150 m, and 100 m) starting from watering points. We assumed that there is a radial decrease in intensity of landuse from the watering points to the furthest sites. Ordination techniques (correspondence analysis – CA; detrended correspondence analysis – DCA; canonical correspondence analysis – CCA) were used to capture the main gradients on the data set and to determine the species relation to the sampled environmental variables.

In total, 428 vascular plant species were recorded in the study area, of which more than one third were succulents. The flora was dominated by the Asteraceae (20%), the Aizoaceae (17%), and the Crassulaceae (8%). The vegetation table revealed eight vegetation units, which were correlated with topography (lowlands vs. slopes) and some other environmental variables. Total species richness increased linearly with altitude. The vegetation units on slopes had higher species richness than the ones in the plains. Since water is the most limiting factor in desert ecosystems, the advantageous moisture conditions of the slopes in conjunction with a higher number of different microhabitats there could explain the higher species richness compared to the more homogenous plains. Total species cover decreased from the heavily overgrazed environment (near the water points), to the less disturbed sites (hills and slopes). Along the degradation gradient, species richness was higher on sites furthest to the water points than on habitats at the immediate vicinity of the waterholes. In the wider context, the Soebatsfontein Observatory appears to be among those Observatories with the highest α-diversities along the transects of BIOTA Southern Africa, with a range of 20–90 species and a median of 64 species on its 1000-m² plots.

Sop, T.K. (2005): Analysis of the patterns of phytodiversity of the BIOTA Observatory at Soebatsfontein (Lowlands Namaqualand – South Africa) along environmental and land-use gradients. – Diplom thesis in Biology. Hamburg: University of Hamburg.

Hierarchical classification of the vegetation on the communal farmland of Soebatsfontein (S22.05)

[J. Luther-Mosebach, J. Dengler & U. Schmiedel]

This study aims at providing a first detailed hierarchical classification of the Namaqualand lowland vegetation of the communal area of Soebatsfontein. We related the vegetation to habitat characteristics and grazing intensity of the recent past (1980s–2000s) and analysed which factors determine diversity and composition of the vegetation. The study was carried out on the communal farmland (15,000 ha) of the Soebatsfontein settlement, including Observatory S22.

The vegetation was recorded on randomly chosen plots (100 m²), which were stratified according to five predefined habitat types and four different historic grazing intensities (high, intermediate, low, unknown). The relevés were classified using the modified Two-Way Indicator Species Analysis (TWINSPAN). The variability of structural, soil, and vegetation parameter between the vegetation units were analysed with analyses of variance (ANOVAs). The units of the TWINSPAN analysis were then slightly modified in order to improve the ecological relevance of the units.

In total, 502 vascular plant species from 56 families were recorded. On average, 22 species were found per 100-m² plot, with a range of 4–51 species. The most frequent families were Aizoaceae and Asteraceae, followed by Crassulaceae. The most constant species were *Galenia fruticosa* (66%), *Didelta carnosa* (51%), and *Trachyandra revoluta* (51%).

Water availability and soil pH were the main driving factors, responsible for vegetation differentiation. Seventeen associations within seven alliances, five orders, and two classes are described, which are closely related to the named gradients. The class Karroochloo schismoidis-Oncosiphonetea suffruticosi in prep. represents the vegetation on less saline soils. This unit contains vegetation communities of rocky slopes as well as sandy plains with higher water availability. The class Cephalopyllo inaequalis-Dideltetea carnosae in prep. (Photo SSS22.2) represents the vegetation of the saline soils and was further subdivided into subunits referring to quartz field vegetation and the vegetation around heuweltjies (fossil termitaria). The strong gradients of water availability and soil pH as well as high heterogeneity of habitats and soil types overlay the historic grazing effects on the scale of the present units.

As it classifies the complex vegetation patterns into the more comprehensive structure of vegetation units, this study provides a good base for further research concerning e.g. impacts of current grazing. This may help to improve management strategies with respect to sustainable and balanced use of resources for the benefit of both, the local people and biodiversity conservation.

Luther-Mosebach, J. (2009): Hierarchical classification of the vegetation on the communal farmland of Soebatsfontein in Namaqualand, South Africa. – Diplom thesis in Biology. Hamburg: University of Hamburg.

Luther-Mosebach, J., Gröngröft, A., Dengler, J., Labitzky, T., Röwer, I.U., Schmiedel, U. (2010): Hierarchical classification of the vegetation on the communal farmland of Soebatsfontein in the Succulent Karoo, South Africa. – Poster at the 9th international Meeting on Vegetation Databases, 24–26 February 2010 in Hamburg. http://www.botanik.uni-greifswald.de/fileadmin/workshop/2010/Post_Symposium/contrib/Poster_37.pdf.

Further studies

Herpel, N. (2008): The scale-dependent variability of topsoil properties reflecting ecosystem patchiness in drylands of southern Africa. – Hamburger Bodenkundliche Arbeiten **62**: 1–299. http://www.sub.uni-hamburg.de/opus/volltexte/2008/3831/.

Labitzky, T. (2009): Natural features and land use impact on soils of the Soebatsfontein region (Namaqualand, South Africa). – Diplom thesis in Soil Science. Hamburg: University of Hamburg.

Petersen, A., Gröngröft, A., Miehlich, G. (2003): Einfluss der Termiten auf die Pedodiversität südafrikanischer Trockengebiete. – Mitteilungen der Deutschen Bodenkundlichen Gesellschaft **102**: 313–314.

General data

Number	Name	Alternative name(s)
S24	Paulshoek	Leliefontein
Implementation	Country	Province/ region
2001	South Africa	Northern Cape
District/ constituency	Locality	Farm name
Namakwa	Leliefontein	Leliefontein 624
Latitude	Longitude	Altitude
30.385680 S	18.275790 E	1048 m a.s.l.
Rainfall season	Biome	WWF Ecoregion
Winter	Succulent Karoo	AT1322 Succulent Karoo
Agro-Ecological Zone	Relative intensity of land use	Tenure
n.a.	High	Communal
Type and history of landuse	Land owner	
Farming with sheep and goats	Kamiesberg Municipality	

Paulshoek (S24)

The Paulshoek Observatory with a rivier and a small road in the foreground. Photo: G. Miehlich.

The BIOTA Observatory Paulshoek (S24) is situated on the communal rangelands of Paulshoek village, which is part of the Leliefontein communal area. The Observatory is in the Kamiesberg uplands, an escarpment (900–1500 m a.s.l.) about 50 km wide between the low-lying Sandveld in the west and the Bushmanland plateau in the east. The area is characterised by distinctive round, rocky, granite hills. The mountains are separated by valleys with sandy flats, often dissected by ephemeral watercourses. Paulshoek has a mean annual rainfall of 252 mm, which falls predominantly during the winter months of May to September. Precipitation from fog and dew also plays an important ecological role for the shallow-rooting shrubs.

The vegetation is dominated by dwarf shrubs. Following good winter rain, the flatlands between the mountains are covered by ephemeral plant species providing a spectacular display of colourful flowers during springtime.

The 20,000 ha communal rangelands of Paulshoek are grazed by sheep, goats and feral donkeys. Cereals and fodder crops are cultivated on small fields along the watercourses. The inhabitants of Paulshoek also collect firewood and medicinal plants there. Like many other communal rangelands in the Succulent Karoo, the area is overstocked and in a highly degraded state, and the diverse succulent dwarf shrub communities tend to be replaced by a few toxic shrubs and ephemeral species.

This BIOTA Observatory forms a pair with the Observatory Remhoogte (S25), situated on a neighbouring private farm, which is grazed with low to moderate intensity. The two Observatories are divided by a fence along which there is a pronounced fenceline contrast. They were established to monitor vegetation dynamics at different grazing intensities and to detect interactions with the potential impacts of climate change. The BIOTA monitoring forms part of various, interdisciplinary research activities conducted by South African scientists in this region.

Responsible authors: W. Hanke & D.H. Haarmeyer

Remote sensing and landscape

Geomorphology	Geological units	Lithological units
Plains, slopes, rivier	Namaqua and Natal Metamorphic Provinces	Migmatie, gneiss, ultrametamorphic rocks
Mean EVI	**EVI absolute range**	**Mean leaf area index**
0.105 (0.092–0.125)	0.086 (2003)–0.139 (2001)	0.40

Grid map of Observatory

	0	1	2	3	4	5	6	7	8	9
0	40	19	38	25	13	92	57	35	82	84
1	8	48	16	59	90	98	72	41	99	51
2	95	54	71	7	18	69	78	9	22	64
3	15	63	74	83	34	73	93	4	79	75
4	5	44	46	91	10	80	62	96	67	97
5	61	49	30	29	6	77	42	31	56	100
6	52	14	17	87	89	24	28	36	94	33
7	66	58	55	23	47	60	39	68	27	45
8	20	3	70	21	65	32	81	1	86	88
9	43	11	37	26	12	53	2	76	85	50

1 Sandy plains with succulent shrubs
2 Gravelly, sandy slope with shrubby non-succulents
3 Rocky slopes with succulent dwarf shrubs
4 Riverbed with tall shrubby vegetation

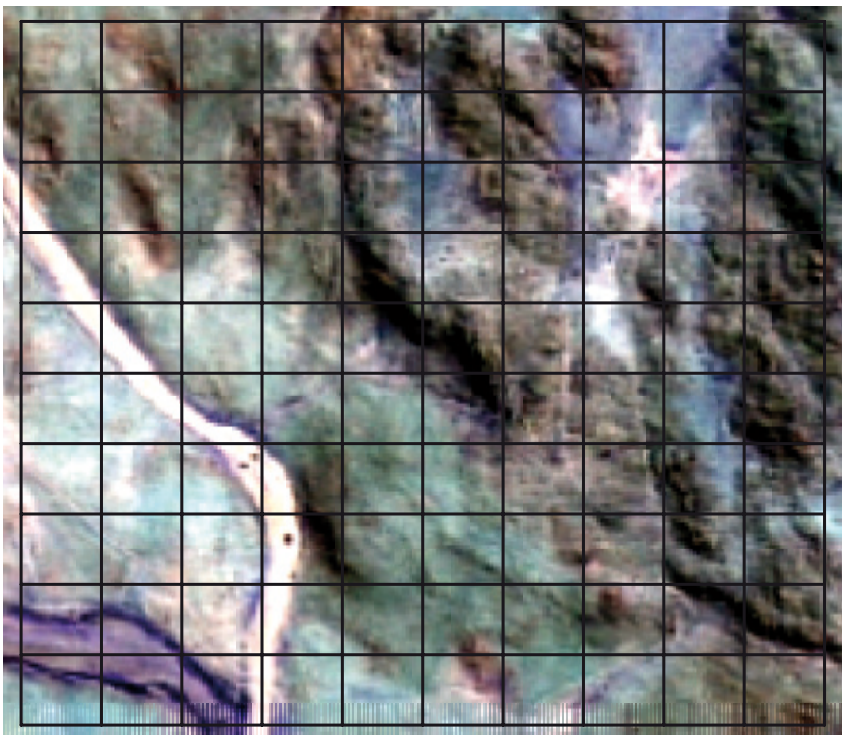
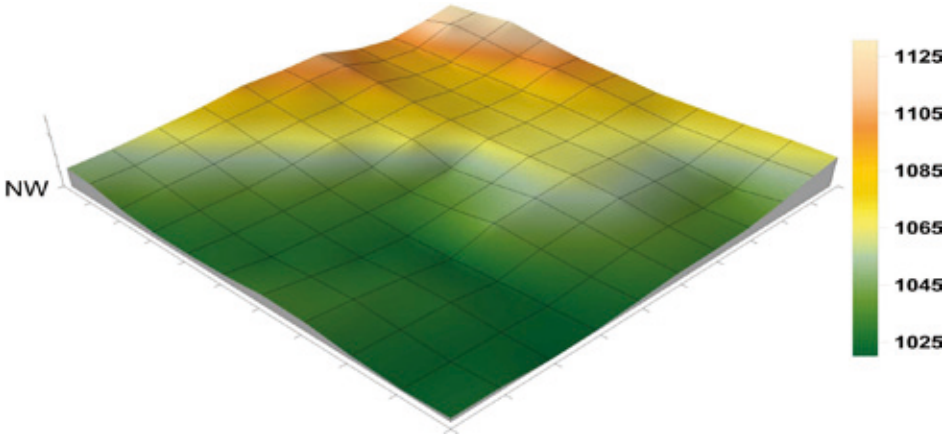


Image: SPOT, 7 October 2005

Elevation model of Observatory



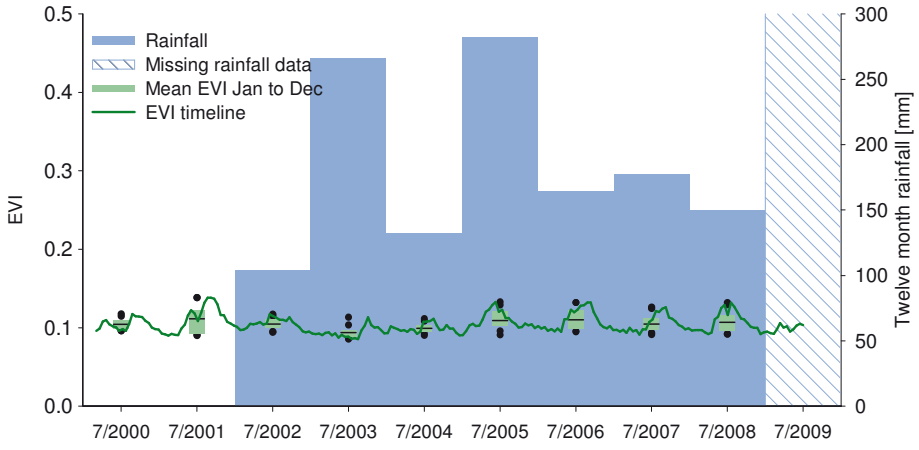
Landsat image

The drainage lines in the south-eastern parts flow to the south, and flow to the west in the other areas. The mountains are covered by more or less dense bush vegetation (light green to green-grey and blue-grey tones). Distinctive round, granite outcrops (violet-grey tones) can be detected in the north-western and south-eastern parts of the image. At Paulshoek Observatory, the vegetation cover is more open (more blue-grey tones) than on the Farm Remhoogte (south of Paulshoek Observatory, with more green tones), indicating overgrazing effects. The dispersed settlements of the community of Paulshoek and a few small productive vegetation spots (in bright red, probably irrigated gardens) can be detected at the foot of the higher mountains in the north-western part of the image. Alluvial and freshwater vegetation along riverbeds and watercourses is also shown in bright red indicating very productive vegetation.

Scene: 176/81, acquisition date: 09 May 2005

MODIS time series

Temporal patterns of annual rainfall, vegetation cover, and phenology



Responsible authors: M. Keil & T. Labitzky

Climate

Data from BIOTA weather station

Location	Recorded period	Mean temperature
Paulshoek (S24)	2001–2009	16.9 (-1.8–40.7) °C
Mean solar radiation	**Mean wind speed**	**Mean annual precipitation**
608 (306–957) MJ·m^{-2}·month^{-1}	2.5 (9.1) m·s^{-1}	168 (98–282) mm
Mean annual potential evapotranspiration	**Interannual precipitation variability**	**Mean relative humidity**
1381 mm	108%	55% (35–78%)
Aridity index (UNEP)		
0.12 (arid)		

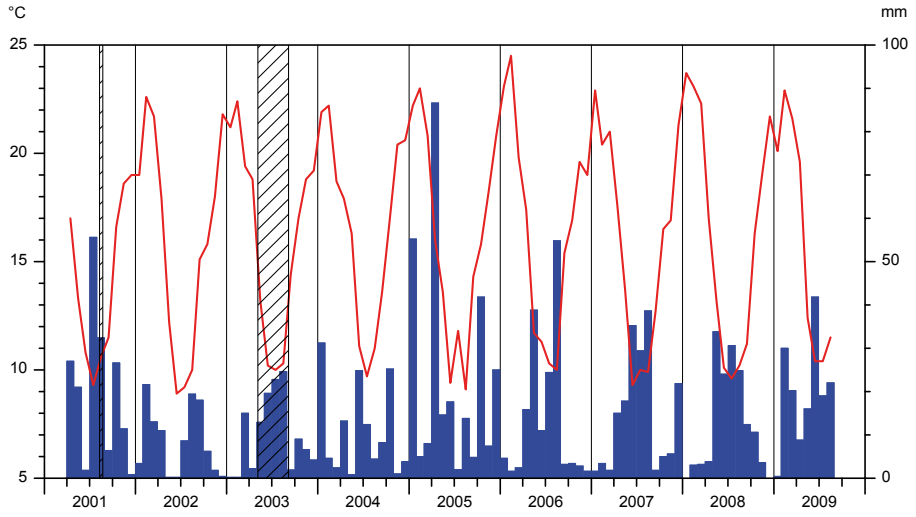
Modelled data

Mean temperature	Mean annual temperature range	Mean diurnal temperature range
15.3 (3.3–28.9) °C	11.3 °C	14.6 °C
Mean annual precipitation	**Precipitation seasonality**	**Percentage winter precipitation**
252 mm	48%	72% (winter)
Climate type	**Length of dry season**	**Aridity index (De Martonne)**
BSk	8 months	10.0 (dry)

The climate at the Observatory is characterised by arid to semi-arid conditions. Rainfall shows a moderate seasonality with more rain falling during the winter season, peaking in August. The mean annual rainfall over the observation period was 168 mm, which is drier than the average rainfall recorded over the entire transect, but is the wettest within the Succulent Karoo. However, substantial interannual variability is evident. The comparatively high annual rainfall for this and the adjacent Observatory Remhoogte can be explained by their high elevation (1050 m a.s.l.). The observed near-surface air temperatures show a moderate seasonal cycle. The mean annual temperature is 16.9°C and is therefore the coldest of all Observatories, which is also related to the high elevation of the Observatory. The observed mean minimum temperature is above the freezing point, but there is still a possibility of the occurrence of frost during the months of June to September. Compared to the interpolated long-term data taken from the WorldClim dataset, a markedly warmer mean annual temperature is observed at the BIOTA weather station. In particular, the maximum temperatures of the station records deviate substantially. For precipitation, mean annual rainfall observed at the weather station is markedly lower than that of the WorldClim dataset. The rainfall seasonality is also less pronounced in the BIOTA weather station data.

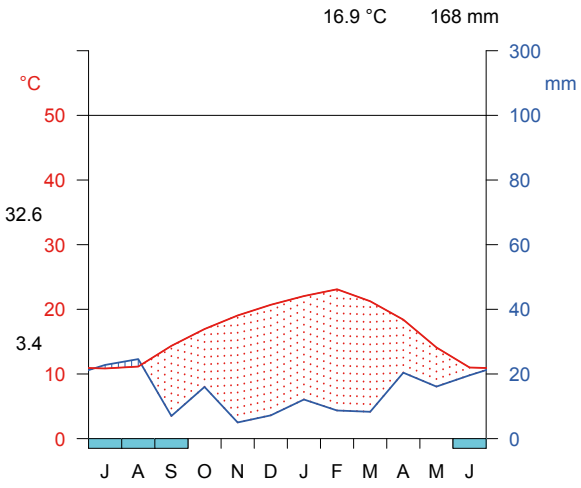
The observed near-surface winds at the Observatory are predominantly constituted of north-northwesterly and south-southeasterly flows. The north-northwesterly component is predominant during winter. Mean wind speed is highest during the early afternoons, reaching about 10 km/h. Winds during that time of the day stay fairly constant throughout the year, whereas a pronounced annual cycle is evident for the mean wind speed recorded during the evenings.

Time series: rainfall and temperature

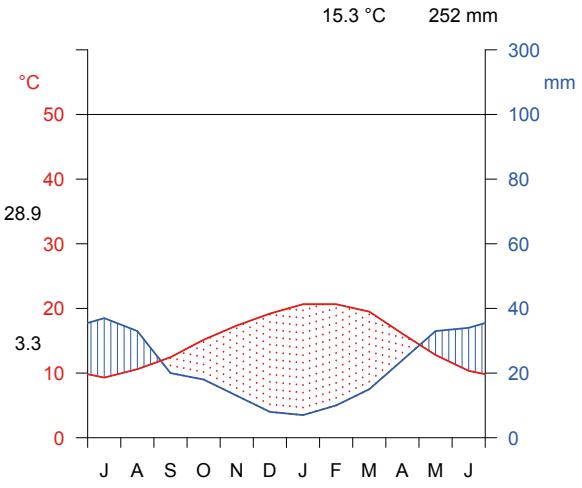


Climate diagrams

Recorded data (BIOTA)

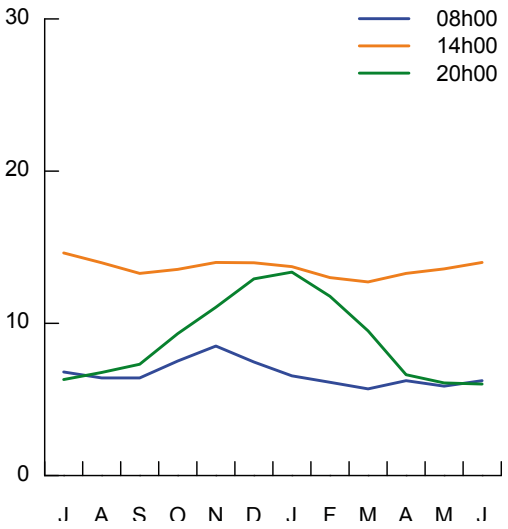


Modelled data (WorldClim)

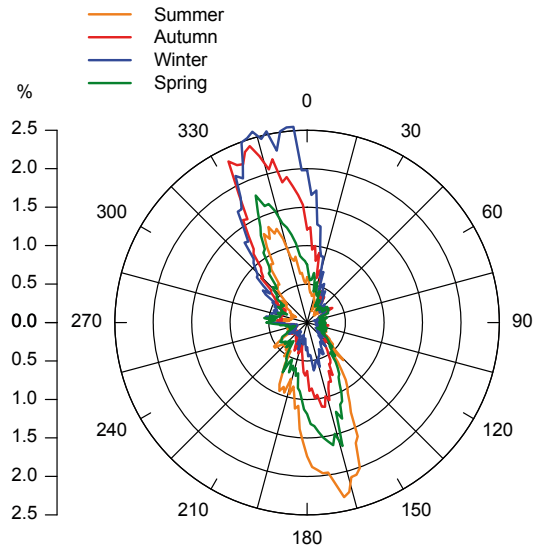


Wind diagrams

Speed



Directions



Responsible authors: K. Berger, A. Haensler & J. Luther-Mosebach

Soils

Year of sampling	Hectare plots sampled	SOTER unit
2005	25 (R1–25)	ZA1738
Soilscape	**Dominant soil group(s)**	**Reference group richness**
n.a.	Leptosol	6
Soil unit richness	**Soil unit evenness**	**Soil ecotype richness**
16	0.825	20
Parametric space	**pH**	**Electrical conductivity**
4.96	6.4 (5.0–8.2)	57 (15–6380) $\mu S \cdot cm^{-1}$
Organic carbon		
0.54% (0.23–3.96%)		

Due to the rocky character of the area, the majority of profiles on the Observatory are Leptosols, followed by Cambisols on the lower slopes and Fluvisols along the dry river structures. Soils with fluvic properties in certain locations are enriched with soluble salts allowing the qualifier 'Salic' and, in some cases, the classification as a Solonchak. The Cambisols, characterised by profiles deeper than 25 cm, loamier textures, and signs of clay translocation from top- to subsoil are assumed to be the oldest soil units on the Observatories in general. A younger and more coarsely textured profile is classified as Arenosol. The differentiation of the soil units into Leptosols and Cambisols is mainly based on depth of bedrock as well as the content of coarse rock fragments. In addition to these soil physical properties, the qualifiers 'Dystric' and 'Eutric' stress the wide range of soil chemical properties in the Leptosols.

The pH values exhibit a wide range and some variations with depth, mainly characterised by an increase in the second horizon. The low median values of the electrical conductivity increase with depth but reflect the non-salty character of the environment in the Observatories. However, higher values were found in salt-enriched patches.

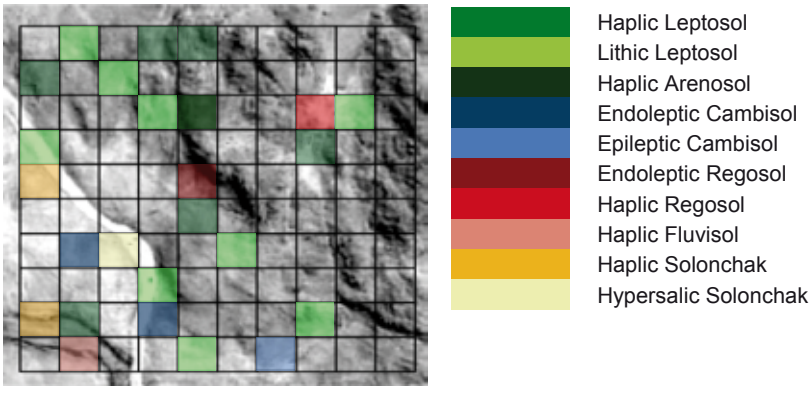
A high variability combined with a general decrease with depth is observable in organic carbon, reflecting the varying amounts of humus accumulation, which is due to different site conditions. The proportion of fine particles (clay and silt) was low with a slight increase with depth. The texture is mainly characterised by silty and loamy sand. With regard to the sand fraction, the samples are predominantly coarse sands characterising the typical weathering product of gneissic granitic bedrock. The median rooting space of 10% represents the overall shallow and rocky character of the area, but single deeper profiles, especially those located in the valley, lead to a wide range of rooting space.

In general, the high pedodiversity of the Observatory is related to both the total range of soil properties, indicating an even distribution except for the silt and clay percentage, and to the variance in rooting space, which is dominated by the overall silty sand and shallow character of the soils.

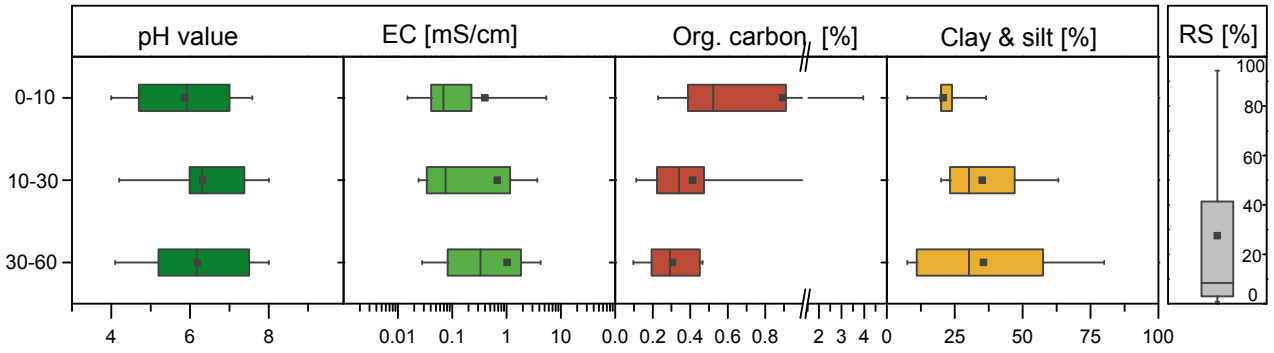
On a smaller scale, a less visible but ecologically highly important soil feature is responsible for the diversity of site conditions: the availability of water is crucial and overrides most of the soil chemical difference in a semiarid system like this. Although the area is dominated by Leptosols and therefore seems to be homogenous regarding the physical conditions in the shallow soils, significant differences occur at the microscale. Due to different weathering behaviour and micro-tectonic features such as faults and fissures, a range of different Leptosols can be distinguished with respect to their bedrock facies and size of rock fragments. Four different water supply types can be separated. The basic differentiation is from type 1 with large boulders generating high run-off and a strongly heterogeneous 'rock-garden' structure to the most homogenous site conditions in the Leptosols, categorised as type 4. Here, the small-scale pattern of cracks and fissures combined with the vertical orientation of most fissures generates a homogenous distribution of water and results in a less diverse pattern of plant species. Additionally, a better accessibility might result in stronger grazing impact on these sites.

During a field survey in September 2005, several recent erosion features were identified. The local community reported an extraordinary thunderstorm with

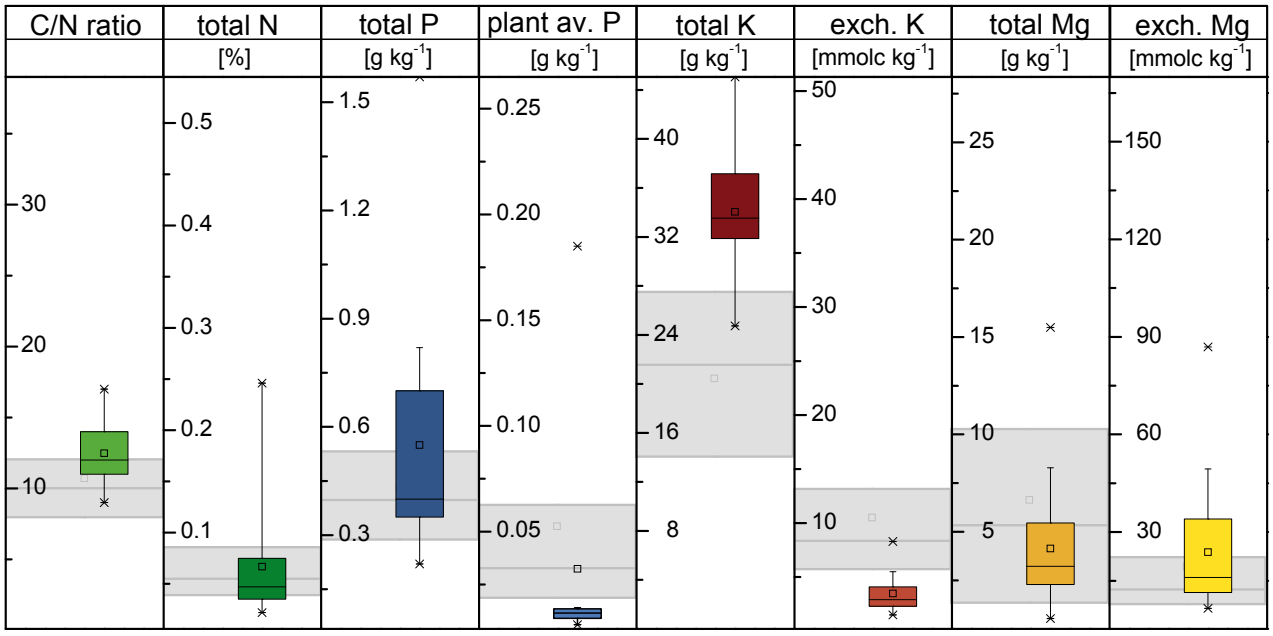
Map of soil profiles



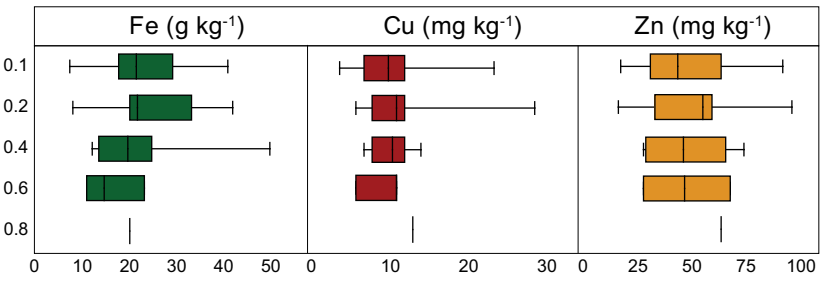
Soil characteristics



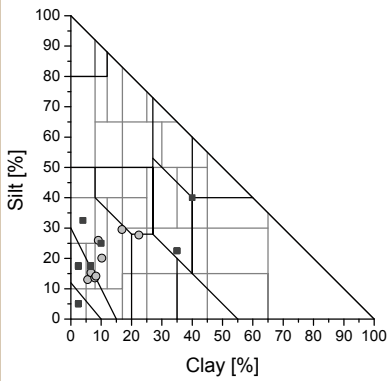
Soil nutrients



Soil micronutrients



Soil texture triangle

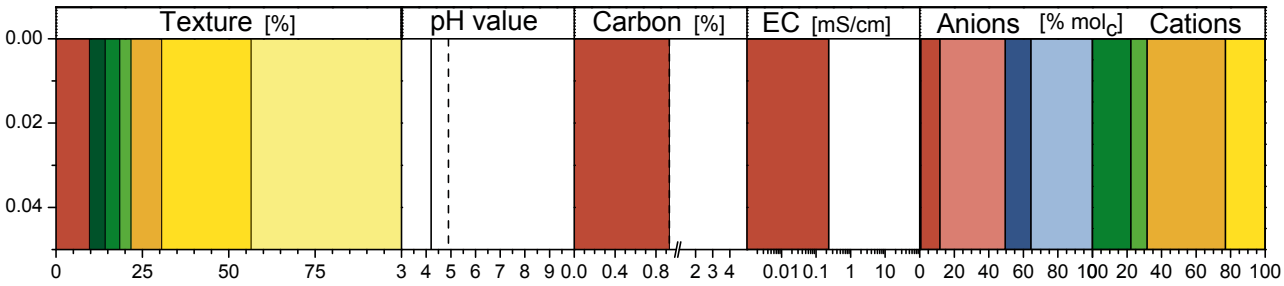


heavy precipitation in early April 2005. This unusual event of around 80 mm (BIOTA weather data compare with Electronic Appendix) created heavy run-off leading to sheet and gully erosion. This thunderstorm showed how vulnerable these winter rainfall adapted ecosystems are to strong rain events. In particular, the soil surface with frequent bare patches and succulent vegetation is only adapted to low intensity winter rainfall typical of this area. Erosion hardly takes place under slowly dripping but long lasting rain events, allowing almost complete infiltration of water. In the case of heavy summer rainfall events, neither the often bare soil nor the vegetation can reduce the intensity and enhance infiltration as is the

case for grasses in savannas with a more homogenous and denser structure. However, denser grass covers are atypical in winter rainfall regimes and occur rarely. Soil erosion is therefore a considerable problem with changing rainfall regimes and maintaining soil resources would be a difficult task. Therefore, stronger precipitation events are likely to decrease the amount of water available for the ecosystem because of higher run-off rates and increasing aridity.

Reference profile (H94)

The **Lithic Leptosol (Dystric)** is the typical soil unit found on slopes, rocky areas, and even on slightly inclined plains. The shallow bedrock and a high content of rock fragments (90%) in the upper 5 cm causes a small-scale heterogeneity of available soil resources, but potentially offering limited water storage capacity in the soil. In this profile, the gneissic-granitic bedrock in 6 cm depth exhibits few signs of weathering; it is only penetrable by roots along few fissures. The soil surface is covered about 90% with coarse rock fragments. The fine earth of the non-calcareous soil is composed of loamy sand with a dominance of medium sand. The pH value and the electrical conductivity are both very low. Organic carbon is comparatively high with 0.9%.



Texture

- Fine silt
- Medium silt
- Coarse silt
- Clay
- Fine sand
- Medium sand
- Coarse sand

- pH ($CaCl_2$)
- pH (H_2O)
- Organic carbon
- Inorganic carbon
- Electrical conductivity

Water soluble ions

- Cloride
- Sulfate
- Nitrate
- Hydrocarbonate
- Fluoride, Bromide, Nitrite
- Calcium
- Magnesium
- Potassium
- Sodium

Responsible authors: U. Wisch, A. Petersen, A. Gröngröft & D. Mager

Biological soil crusts

Sampling period(s)	Hectare plots sampled	Types of soil crusts
2002	3 (R1–R3)	1
Crust thickness	**Cover**	**Carbon [weight %]**
< 3 mm	about 3%	n.a.
Nitrogen [weight %]	**Chlorophyll *a* [mg/m²]**	**Chlorophyll *a+b* [mg/m²]**
n.a.	4	5

Due to intensive grazing and trampling impact, hardly any biological soil crusts were found, contrary to the neighboring Observatory S25 (Remhoogte). Merely initial light-coloured crusts occur, of which only small pieces can be removed. These crusts contain extremely low number of cyanobacterial genera and no green algae at all. The soil is characterised by clay bubbles in its structure (so-called "Schaumboden"). The scarce presence of biological soil crusts is also related to significantly low chlorophyll content.

Cyanobacteria
Chroococcidiopsis sp.
Leptolyngbya compacta
Leptolyngbya foveolarum
Leptolyngbya cf. *schmidlei*
Leptolyngbya sp.
Nostoc cf. *commune*

Biological soil crust characteristics

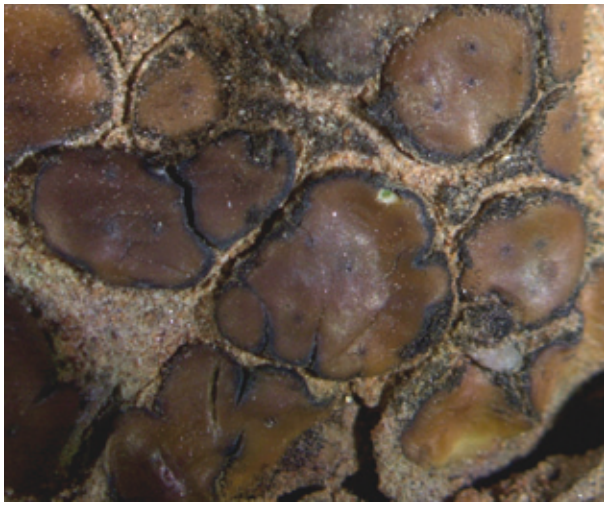
	H81	H87	H96
Soil characteristics	brown sand with fine particles and small stones	light brown sand, small stones, feldspars, structure of clay bubbles	reddish-brown sand; unweathered granite particles, small stones, clay bubbles
Crust characteristics	very small agglomerated soil particles; BSC particles not identifiable	thick soil agglomerations, slightly darker colouration, but no obvious BSC components	very small agglomerated soil particles; clay bubbles; no obvious BSC components
Chlorophyll a [mg/m²]	0.37	6.32	4.45
Chlorophyll a+b [mg/m²]	0.91	8.56	5.48

Responsible authors: B. Weber, K. Deutschewitz, S. Dojani, T. Friedl, T. Darienko, K. Mohr & B. Büdel

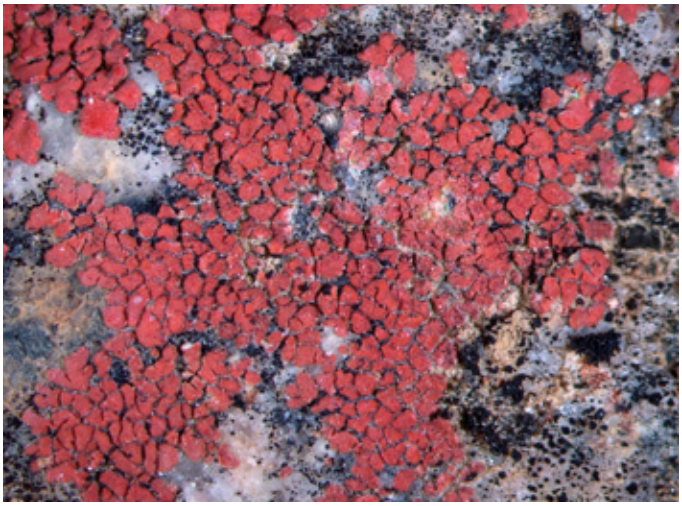
Lichens

Sampling period(s)	Hectare plots sampled	Cover
2001, 2002	10 (R1–R10)	0%
Total species richness	**Species richness on soil [1 km²]**	**Species richness on rock [1 km²]**
19	7 (37%)	12 (63%)
Species richness on plants [1 km²]	**Species richness on soil [1000 cm²]**	
n.a.	0.6 (0–3)	

This Observatory hosts a low number of lichen species in comparison to other Observatories in Namaqualand because of lower air humidity due to its greater distance from the coast. Furthermore, this Observatory is subjected to considerable anthropogenic impacts. Lichens on soils are mostly squamulose and they only grow in sheltered spaces between rocks or below shrubs. Throughout the Observatory, sites covered by soil lichens are rare and no lichens were observed in the investigated hectare plots. The absence of soil lichens is due to unsuitable soil types (sandy soils with low pH and a high incidence of rocks) and to grazing impacts.



Placidium squamulosum. Photo: L. Zedda & G. Rambold.



Caloplaca haematodes. Photo: L. Zedda & G. Rambold.

List of Taxa

Terricolous (on soil):

Buellia sp. 01 (M-0038990)
Collema coccophorum
Peccania sp.
Placidium squamulosum
Placidium tenellum
Psora crenata
Psora sp. 01 (M-0039129)

Saxicolous (on rock):

Acarospora spp. (2)
Buellia spp. (2)
Caloplaca cinnabarina
Caloplaca haematodes
Rinodina sp.
Xanthomaculina hottentotta
Xanthoparmelia spp. (4)

Epiphytic (on plants):

No records

Responsible authors: L. Zedda & G. Rambold

Vascular plants

Sampling period(s)	Hectare plots sampled	Biome
2001–2009	20 (R1–R20)	Succulent Karoo
Vegetation unit (level 1)	**Vegetation unit (level 2)**	**Identification rate**
Namaqualand Hardeveld Bioregion	SKn 3 Namaqualand Blomveld	61% – 91% – 91%
Cumulative family richness	**Dominant families (cover)**	**Dominant families (richness)**
53	Aizoaceae, Asteraceae, Poaceae	Asteraceae, Aizoaceae, Crassulaceae
Cumulative species richness (1 km²)	**Species richness (1000 m²)**	**Species richness (100 m²)**
557 – 286	56.3 (7–89)	30.2 (0–56)
***z*-value**	**Species richness change per year (1000 m²)**	**Evenness (1000 m²)**
0.270 (0.000–0.590)	0.69	0.487 (0.127–0.871)
Evenness (100 m²)	**Simpson (1000 m²)**	**Simpson (100 m²)**
0.522 (0.106–0.744)	0.710 (0.092–0.929)	0.706 (0.097–0.920)

The Observatory Paulshoek comprises a sequence of four habitat types: ephemeral rivers, plains, slopes, and mountains. The land is used communally as rangeland, mainly for sheep and goats, with high stocking rates. There are also some feral donkeys, which roam freely. The grazing regime can be characterised as being heavily and continuously grazed, which has led to soil erosion and significant degradation of the vegetation. Plant cover is open to sparse with a mean cover of 23%. The cumulative species richness (1 km²) of 557 is one of the highest along the BIOTA transect. Also, the maximum β-diversity at medium scales (1000–10000 m²), measured as z-values, is amongst the highest along the transect.

Water supply, soil depth and texture, rock cover, and grazing pressure appear to be the differentiating ecological factors for plant growth conditions on the Observatory. Compared to the mountains, the easily accessible plains and slopes are more strongly affected by degradation caused by grazing pressure. Due to selective grazing of preferred forage plants, the diverse succulent dwarf shrub community tends to be replaced by a few toxic shrub species such as *Galenia africana*. The heavy grazing also results in the replacement of perennial shrubs by annuals and geophytes. This results in the homogenisation of the plant species composition between the plains and lower slopes and it therefore becomes difficult to distinguish two communities. The rocky hills are characterised by a higher proportion of taller, non-succulent shrubs with fynbos affinities. Tall shrubs and sedges occur in the riverbeds. Three vegetation units can be distinguished according to the habitat type (i.e. ephemeral rivers, degraded flats and slopes, and mountains) on which they occur at the Observatory.

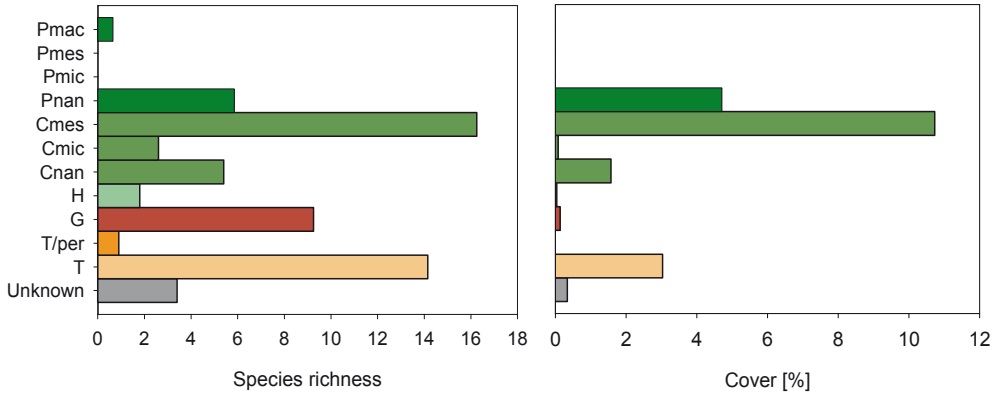
Outside the growing season, when the annuals vanish, the vegetation on plains and slopes is of relatively low grazing value due to the high proportion of unpalatable shrubs. Therefore, resources are scarce during summer, and in bad rainfall years even in winter. Farmers in the area face large and often unpredictable fluctuations in forage resources for their livestock and income.

The *Dicerothamnus rhinocerotis-Carpobrotus edulis* community (unit 1) grows along water courses and spreads into the riverbeds. The ephemeral water courses (riviers) reliably contain water for several months each year during the rainy season. Soils are deep Fluvisols, rich in coarse sands. Due to these favourable hydric conditions, the total plant cover is around 40%, which is the highest cover value compared to the other communities on this observatory. Besides the tall shrub *Dicerothamnus rhinocerotis* and the creeping *Carpobrotus edulis*, the perennial grass *Stipagrostis namaquensis* appears to be a dominant species on some river plots. The perennial shrubs *Gomphocarpus fruticosus* and *Lycium* spp. also belong to this community.

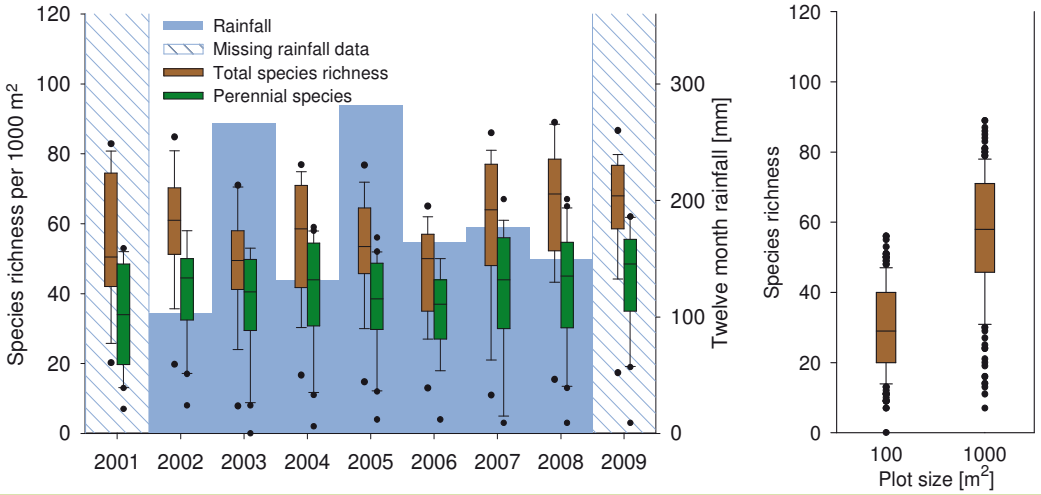
The species this community is named after are traditionally used by the local population. Renosterbos (*Dicerothamnus rhinocerotis*) is used for a variety of ailments, but especially for flu. The sweet-sour fleshy fruits of Veldvy (*Carpobrotus edulis*) are eaten by humans and animals, and are used to make jam.

Ephemeral species are characteristic of this community, indicating that the habitat is subject to regular disturbance due to flooding and livestock trampling. Therophytes occurring with high abundances are *Polygonum kitaibelianum*, *Erodium cicutarium*, *Mesembryanthemum guerichianum*, *Oncosiphon grandiflorum*, *Lasiopogon micropoides*, *Leysera tenella* and *Lepidium desertorum*.

Life forms



Species richness



Graminoid growth forms were encountered less frequently in the heavily grazed ephemeral river at the Observatory compared to the less heavily grazed plant community on the ephemeral river of the neighbouring Observatory Remhoogte. The sedges *Scirpoides dioecus* and *Cyperus* spp., and the grasses *Stipagrostis namaquensis*, *Ehrharta longiflora*, and *Bromus pectinatus* only occurred on some plots within this community.

Some of the riverbanks and adjacent plains are used for cropping because the soils are deep, coarse fragments are rare, and the water supply is good. During the years that arable land is left fallow, ephemeral species such as *Atriplex semibaccata*, *Leysera tenella*, *Oncosiphon grandiflorum*, and *Schismus barbatus* take over, reaching cover values of up to 30%.

The *Stachys rugosa-Pteronia incana* community (unit 2) occurs on mountains with variable aspects and steep slopes. Soils are Leptosols with a high proportion of rocky outcrops and blocks. Compared to the plains and lower slopes, this community is more diverse in perennial species. This is due to the diversity of habitat structures and to lower grazing pressure. Livestock struggle to access the sometimes very steep slopes. Total plant cover is approximately 25%, which is fairly high considering that much of the soil surface consists of rock.

Pteronia incana forms the dominant component of the shrub cover. This species occurs optimally in the mountains but is also present in the other communities. In contrast, the Lamiaceae shrub *Stachys rugosa* is exclusively found on the mountains.

Besides *Pteronia incana*, the creeping succulent shrubs *Ruschia viridifolia* and *Polymita albiflora* are dominant features of this community. An increased proportion of tall shrubs with fynbos affinities, such as *Lebeckia sericea* and *Rhus undulata*, is also evident within this community. Other diagnostic species are *Crassula brevifolia* subsp. *brevifolia*, *Arctotis laevis* and *Antizoma miersiana*, although they are also found in the slope community in association with rocky outcrops and boulders.

Water supply from large boulders and rocky outcrops generate high run-off

Classification table (2008)

Column		Cover	All	1	2	3
Number of relevés			**20**	**4**	**4**	**12**
Mean cover [%]			22.8	40.7	26.4	15.7
Mean species richness (1000 m²)			58.5	40.0	66.3	71.8
Inclination [°]			10.5	1.0	23.0	9.4
Mean soil pH			5.86	7.36	4.95	5.80
Mean electrical conductivity [µS·cm^{-1}]			460	2485	47	92
Organic carbon [%]			0.80	1.02	0.83	0.73
Nitrogen [%]			0.06	0.07	0.06	0.06
Fine material			51.9	93.3	18.8	49.1
Gravel			6.1	93.3	6.5	6.6
Stones 2-6 cm			8.7	4.3	7.3	12.1
Stones 6-20 cm			7.8	0.1	7.0	10.7
Stones 20-60 cm			6.3	0.2	9.0	7.5
Blocks			4.5	0.1	12.8	3.3
Rock outcrops			14.6	0.1	38.8	10.8
Unit 1: Dicerothamnus rhinocerotis-Carpobrotus edulis community						
T	Atriplex semibaccata	0.25	25	100	.	8
T	Erodium cicutarium	0.06	35	100	.	25
T	Lepidium desertorum	0.02	25	100	25	.
Pnan	Gomphocarpus fruticosus ssp. fruticosus	0.30	15	75	.	.
Cnan	Carpobrotus edulis	7.18	20	75	.	8
Cmes	Berkheya onobromoides	0.03	10	50	.	.
T	Ehrharta longiflora	0.02	10	50	.	.
T	Oncosiphon grandiflorum	2.05	50	100	25	42
T	Amsinckia calycina	0.15	10	50	.	.
Hper	Scirpoides dioecus	0.13	10	50	.	.
T	Medicago polymorpha var. vulgaris	0.06	10	50	.	.
Pnan	Stipagrostis namaquensis	5.25	10	50	.	.
T	Poaceae sp. 14859	0.02	10	50	.	.
T	Polygonum kitaibelianum	0.30	10	50	.	.
T	Amellus microglossus	0.08	25	75	25	8
Unit 2: Stachys rugosa-Pteronia incana community						
Pnan	Stachys rugosa	0.23	20	.	100	.
Cmes	Crassula brevifolia ssp. brevifolia	0.29	30	.	100	17
Cmac	Arctotis laevis	0.12	35	.	100	25
Pnan	Zygophyllum foetidum	0.37	15	.	75	.
Pnan	Microloma sagittatum	0.01	15	.	75	.
Pnan	Rhus undulata	1.44	40	.	100	33
Cmes	Polymita albiflora	3.24	40	.	100	33
Pnan	Antizoma miersiana	0.32	40	.	100	33
H	Ehrharta calycina	0.01	20	.	75	8
Cmic	Tetragonia fruticosa	0.02	50	.	100	50
T	Zaluzianskya peduncularis	0.01	10	.	50	.
Unit 3: Galenia africana community						
G	Babiana attenuata	0.01	45	.	.	75
Cmic	Galenia meziana	0.03	60	.	25	92
Cnan	Hypertelis salsoloides var. salsoloides	0.01	60	.	25	92
Hper	Lotononis falcata	0.01	40	.	.	67
Cmes	Crassula muscosa var. obtusifolia	0.01	35	.	.	58
Cnan	Aptosimum indivisum	0.01	35	.	.	58
T	Manulea cheiranthus	0.01	35	.	.	58
G	Oxalis sp. 116797	0.01	30	.	.	50
G	Moraea serpentina	0.01	65	.	50	92
Hper	Aizoon canariense	0.01	50	.	25	75
Cmes	Crassula subaphylla var. virgata	0.01	45	.	25	67
G	Oxalis foveolata	0.01	45	.	25	67

continued on next page

and the development of small temporal water rills favour species usually found along ephemeral rivers, such as the shrub *Dicerothamnus rhinocerotis* and the annual *Lepidium desertorum*. The mountain habitat is the last refuge where the palatable shrub *Ruschia robusta*, a typical grazing decreaser, can still be found on this Observatory.

The *Galenia africana* community (unit 3) is representative of the heavily grazed plains and slopes. Total plant cover is sparse (approximately 15 %) and the proportion of bare patches is therefore high. The shrub canopy is dominated by the toxic shrub *Galenia africana*. Further the scarce perennial shrub cover consists of the Asteraceae *Eriocephalus microphyllus* var. *pubescens*, *Pteronia incana*, *Pentzia incana*, the succulent Aizoaceae *Ruschia fredericii*, and a number of unpalatable species such as *Chrysocoma ciliata*, *Lycium cinereum*, and *Euphorbia mauritanica*.

The herbaceous layer shows a spectacular display of colourfully flowering. It is dominated by a variety of Asteraceae such as *Leysera tenella*, *Ursinia nana* subsp. *nana*, *Helichrysum leontonyx*, *Gazania heterochaeta*, and *Trichogyne lerouxiae*. Frequently occurring geophytes are *Moraea serpentina*, *Bulbine praemorsa*, and *Trachyandra tortilis*.

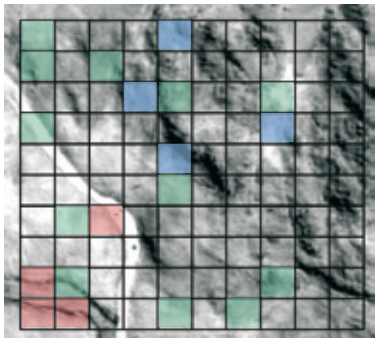
This community possesses no unique plant species but can be distinguished from the other communities by the dominance of *Galenia africana* and the absence of plant species characteristic of the ephemeral river and mountain habitats.

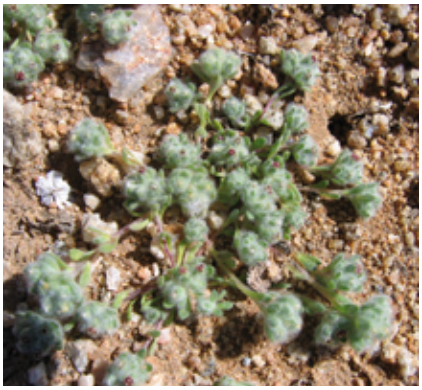
This community provides good fodder resources during winter in good rainfall years, but outside the growing season and in bad rainfall years, fodder resources are scarce and the grazing value of this community is poor.

Unit 1, H62, 2008.
Photo: W.Hanke.

Unit 2, H04, 2008.
Photo: W. Hanke.

Map of vegetation units





Lasiopogon micropoides a typical annual. Photo: W. Hanke.

Ruschia viridifolia. Photo: U. Schmiedel.

Chrysocoma ciliata. Photo: C. Mayer.

Classification table (continued)

Column		Cover	All	1	2	3
Number of relevés			**20**	**4**	**4**	**12**
G	Ornithoglossum vulgare	0.01	45	.	25	67
H	Chaetobromus involucratus ssp. dregeanus	0.02	60	25	25	83
Cmic	Drosanthemum albens	0.02	70	50	25	92
Cmes	Hirpicium alienatum	0.03	80	.	100	100
T	Trichogyne lerouxiae	0.14	80	50	50	100
Most frequent companions						
Cmes	Galenia africana	4.39	100	100	100	100
T	Helichrysum leontonyx	0.08	95	75	100	100
T	Heliophila variabilis	0.02	95	75	100	100
Pnan	Lycium cinereum	0.12	90	100	50	100
T	Ursinia nana ssp. nana	0.02	90	50	100	100
Cmes	Chrysocoma ciliata	0.14	85	25	100	100
T/Hper	Leysera tenella	2.46	80	100	75	75
Cmes	Ruschia viridifolia	2.46	80	25	100	92
Cmes	Eriocephalus africanus var. paniculatus	0.62	80	50	100	83
Pnan	Lycium ferocissimum	0.30	80	75	75	83
H	Ehrharta barbinodis	0.02	80	25	100	92
T	Zaluzianskya benthamiana	0.02	80	75	75	83
Cmes	Pteronia incana	1.41	75	.	100	92
T	Schismus barbatus	1.11	75	100	25	83
G	Bulbine praemorsa	0.01	70	.	100	83
Cmes	Eriocephalus microphyllus var. pubescens	1.18	65	.	75	83
n.a.	Ruschia fredericii	0.24	65	25	50	83
Cmes	Pentzia incana	0.22	65	25	75	75
T	Lasiopogon micropoides	0.18	65	100	25	67
Cmes	Euphorbia decussata	0.18	65	.	100	75
Cmes	Hermannia amoena	0.05	65	.	100	75
Hper	Gazania heterochaeta	0.02	65	.	75	83
Cmes	Hermannia cuneifolia var. cuneifolia	0.01	65	.	100	75
Pmac	Pelargonium carnosum	0.01	65	50	75	67
Cmes	Tripteris sinuata var. sinuata	0.01	60	25	75	67
Hper	Chlorophytum crassinerve	0.01	60	.	75	75
G	Trachyandra tortilis	0.01	55	25	25	75
Pnan	Euphorbia mauritanica	0.85	50	.	50	67
Cmes	Zygophyllum retrofractum	0.20	50	50	.	67
Cnan	Sceletium exalatum	0.07	50	.	75	58
Pnan	Asparagus capensis	0.02	50	.	75	58
T	Diascia namaquensis	0.01	50	50	25	58
Cmes	Crassula muscosa var. muscosa	0.01	50	.	75	58
G	Androcymbium sp. 116728	0.01	50	25	25	67
G	Albuca cooperi	0.01	50	25	25	67
Pnan	Lebeckia sericea	1.39	45	.	75	50
G	Oxalis obtusa	0.05	45	.	50	58
Cnan	Crassula sericea var. sericea	0.05	45	.	75	50
T	Mesembryanthemum guerichianum	0.04	45	75	25	42
T	Pentaschistis airoides ssp. airoides	0.01	45	.	50	58
G	Oxalis sp. 116682	0.03	40	.	50	50
Hper	Cyphia longiflora	0.02	40	.	50	50
T	Cotula leptalea	0.02	40	25	75	33
Cnan	Crassula cotyledonis	0.02	40	25	25	50
G	Massonia depressa	0.01	40	25	25	50
Cnan	Pelargonium sp. 116707	0.01	40	.	50	50
G	Moraea bifida	0.01	40	.	25	58
T	Dorotheanthus sp. 14847	0.01	40	25	25	50
Cmes	Thesium lineatum	0.04	35	.	50	42
T	Gazania tenuifolia	0.04	35	50	.	42
Cmes	Galenia sarcophylla	0.01	35	.	25	50
T	Senecio arenarius	0.01	35	25	50	33
T	Crassula vaillantii	1.01	30	.	25	42

Unit 2, H10, 208. Photo: W. Hanke.

Unit 3, H61, 2008. W. Hanke.

Responsible authors: W. Hanke & J. Luther-Mosebach

Vertebrates

Total species richness	Reptile species richness	Bird species richness
12	n.a.	12
Large mammal species richness	Small mammal species richness	
n.a.	n.a.	

Birds

Passeriformes	**Perching birds**
Lanius collaris	Fiscal Shrike
Motacilla capensis	Cape Wagtail
Prinia maculosa	Karoo Prinia
Pycnonotus capensis	Cape Bulbul
Cisticola subruficapillus	Grey-backed Cisticola
Cercomela schlegelii	Karoo Chat
Cercotrichas coryphaeus	Karoo Scrub-Robin
Galerida magnirostris	Large-billed Lark
Parisoma layardi	Layard's Tit-Babbler
Telophorus zeylonus	Bokmakierie
Pteroclidiformes	**Sandgrouse**
Pterocles namaqua	Namaqua Sandgrouse
Columbiformes	**Doves and pigeons**
Stigmatopelia senegalensis	Laughing Dove

Responsible authors: W. Mey, J. Deckert, A. Hoffmann & A. Mills

Effects of grazing intensity and rainfall on plant population dynamics in the Succulent Karoo (S24.01)

[W. Hanke, J. Weber, J. Dengler & U. Schmiedel]

In this study, we analysed inter-annual population dynamics of perennial plant species at different grazing intensities and interpreted the results with respect to rainfall patterns. Data were collected on the Observatories Paulshoek (S24) and Remhoogte (S25), of which S24 is grazed with high intensity and strongly degraded, while S25 is grazed with low intensity and is in good condition. We monitored the abundances of 52 perennial plant species over seven years from 2002 to 2008.

Total number of plant individuals slightly increased over the seven years, irrespective of the grazing intensity. Population size of most species remained constant over the study period, while 14 species showed significant increase and six species significant decrease in population size. On the intensively grazed Observatory (S24), the percentage of species with significant changes in population size was higher (38%) than on the Observatory grazed with low intensity (S25; 29%). For 11 species, the trends in population size depended on grazing intensity. Following a dry period in the years 2002–2004, populations of most species showed a decline in the years 2005–2006. By contrast the Aizoaceae *Galenia africana*, a toxic degradation indicator, increased in these years, probably benefiting from decreased competition.

Weber, J. (2009.): Einfluss von Niederschlag und Beweidung auf die Populationsdynamik von Pflanzen 24–26 February 2010 in Hamburg. – http://www.botanik.uni-greifswald.de/fileadmin/workshop/2010/Post_Symposium/contrib/Poster_28.pdf

Dispersal strategies in communal versus privately-owned rangeland in Namaqualand (S24.02)

[M.W. van Rooyen]

The aim of the study was to compare the dispersal strategies in communal with privately-owned rangeland and further focused on the importance of myxospermy in arid rangelands. The study was conducted in Paulshoek (S24) and the adjacent privately owned farm, Remhoogte (S25).

The dispersal spectra of the two rangelands and the six communities were dominated by ombrohydrochory, autochory, plumed diaspores, dust diaspores, and winged diaspores. Grazing, water, and landscape seemed to be the major factors influencing the composition of different dispersal types.

Myxospermy is a trait developed by plant species from arid regions to restrict diaspore dispersal by means of an anchorage mechanism. Diaspores of these species produce copious amounts of mucilage when they are moistened and are anchored to the soil once the mucilage dries out. This study investigated the origin of the mucilaginous layer of 12 species using light and scanning electron microscopy. The mucilage production of the species investigated could best be grouped into three types: (i) epidermal and subepidermal mucilage production, (ii) wings or pappus that disintegrate and become mucilaginous, and (iii) mucilage excreting hairs. Previous systems to classify the different types of mucilage production did not recognize the mucilaginous nature of wings or a pappus.

Fotouo, H. M. (2008): Dispersal strategies in communal versus privately-owned rangeland in Namaqualand, South Africa. – MSc thesis. Pretoria: Department of Plant Science, University of Pretoria.

Fotouo H.M., van Rooyen, M.W. & van der Merwe, C.F. (submitted): Anatomical investigation of mucilaginous diaspores of selected species of Namaqualand, Succulent Karoo, South Africa. – Bothalia.

Comparison of seed bank in commercial versus communal rangeland (S24.03)

[M.W. van Rooyen]

Overgrazing is currently known to be the most important threat to the plant diversity of Namaqualand, especially in rangelands such as Paulshoek, situated in the Leliefontein Communal Reserve. The objectives of the study were to determine the size, species composition, and life form composition of the seed bank in a commercial and communal rangeland. Soils in four different habitat types were sampled south of the village along a fenceline contrast. Thirty samples per habitat were taken in the communal area of Paulshoek (S24) as well as in the bordering, less severely grazed, privately-owned farm Remhoogte (S25; commercial land).

Results obtained with the seedling emergence method indicated that overall the seed bank was larger in the commercial than in the communal area. Furthermore, habitat type had an important effect on the seed bank size and in some habitats (plains and rocky slopes) the seed bank was larger in the communal rangeland. The seed bank was dominated by annual species at both sites. Species richness of both annual and perennial species was higher in the communal rangeland.

Coetzee, C. (2006): Seed bank size and species composition in the Upland Succulent Karoo: commercial versus communal rangelands. – BSc thesis. Pretoria: University of Pretoria.

The impact of grazing on pollinators and pollination

► *See also* **Article III.5.7**.

Pufal, G. (2005): Influences on the fruit set of *Cheiridopsis imitans* and *Leipoldtia schultzei* (Aizoaceae) under different landuse conditions. – Diplom thesis in Biology. Rostock: University of Rostock.

General data

Number	Name	Alternative name(s)
S25	Remhoogte	Rooiwal
Implementation	**Country**	**Province/ region**
2001	South Africa	Northern Cape
District/ constituency	**Locality**	**Farm name**
Namakwa	Leliefontein	Remhoogte 416
Latitude	**Longitude**	**Altitude**
30.395364 S	18.275695 E	1027 m a.s.l.
Rainfall season	**Biome**	**WWF Ecoregion**
Winter	Succulent Karoo	AT1322 Succulent Karoo
Agro-Ecological Zone	**Relative intensity of land use**	**Tenure**
n.a.	Low	Private
Type and history of landuse	**Land owner**	
Farming with sheep, few horses	Private	

Remhoogte (S25)

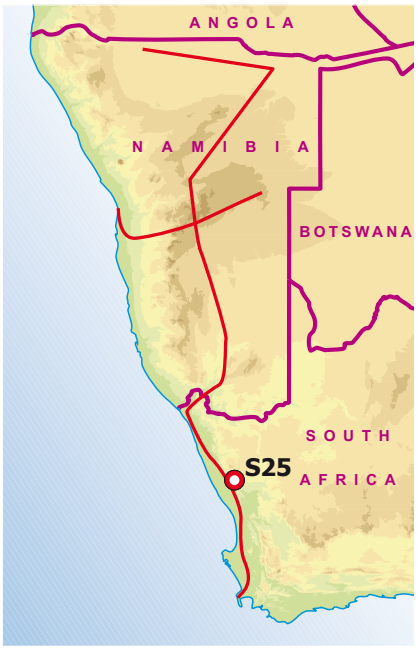
Succulent Karoo vegetation with a rivier in the foreground and rocky outcrops in the background. Photo: G. Miehlich.

The BIOTA Observatory Remhoogte (S25) is situated on the private farm Remhoogte in the Kamiesberg uplands, an escarpment (900–1500 m a.s.l.) about 50 km wide between the low-lying Sandveld in the west and the Bushmanland plateau in the east. The area is characterised by distinctive round, rocky, granite hills. The mountains are separated by valleys with sandy flats, often dissected by ephemeral water courses. The area receives an estimated mean annual rainfall of 252 mm, which falls predominantly during the winter months of May to September. Precipitation from fog and dew also plays an important ecological role for the shallow-rooting shrubs.

The vegetation is dominated by leaf-succulent dwarf shrubs. Following good winter rain, the flatlands between the mountains are covered by ephemeral plant species providing a spectacular display of colourful flowers during springtime.

The rangeland is used for farming with sheep, goats, and cattle. The grazing intensity is low to moderate, which supports a diverse succulent dwarf shrub flora, with many palatable species.

This BIOTA Observatory forms a contrasting pair with the Observatory Paulshoek (S24), which is situated on the adjacent communal land of Paulshoek. The two Observatories are divided by a fence along which is a pronounced fence-line contrast. While Remhoogte acts as a benchmark for rangeland in a good condition, the Observatory Paulshoek is



overstocked and in a strongly degraded state. The Observatory pair was established to monitor vegetation dynamics at different grazing intensities and to detect interactions with the potential impacts of climate change. The BIOTA monitoring forms part of various, interdisciplinary research activities conducted by South African scientists in the region.

Responsible authors: W. Hanke & D.H. Haarmeyer

Remote sensing and landscape

Geomorphology	Geological units	Lithological units
Pediment, slope, valley, rivier	Namaqua and Natal Metamorphic Provinces	Migmatie, gneiss, ultrametamorphic rocks
Mean EVI	**EVI absolute range**	**Mean leaf area index**
0.111 (0.097–0.133)	0.092 (2004)–0.143 (2005)	0.41

Grid map of Observatory

	0	1	2	3	4	5	6	7	8	9
0	66	48	99	90	50	93	13	16	54	69
1	74	7	31	42	63	17	35	72	64	40
2	39	34	11	5	10	61	67	89	30	55
3	2	46	57	60	15	27	73	95	76	21
4	19	84	4	82	80	12	20	47	62	100
5	85	32	49	83	41	43	53	68	98	33
6	71	59	81	75	6	1	78	58	52	86
7	38	79	8	23	9	87	26	29	25	65
8	91	28	36	24	97	94	92	18	14	37
9	56	77	96	88	51	70	3	44	22	45

1 Shallow sloped pediment with succulent shrubs
2 Gravelly, sandy slope with shrubby non-succulents
3 Rocky slopes with succulent dwarf shrubs
4 Riverbed with tall shrubby vegetation

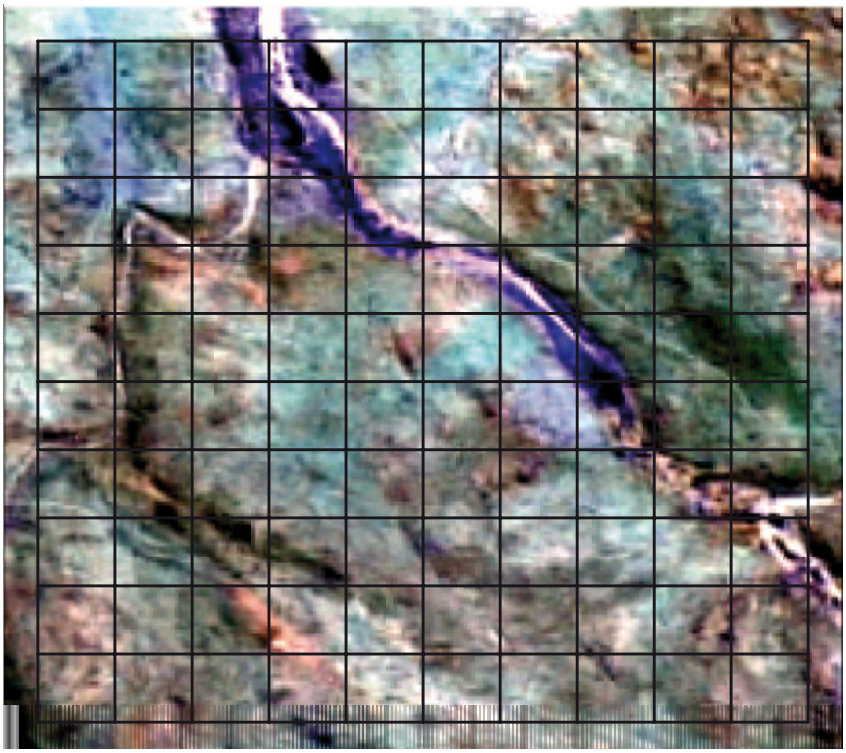
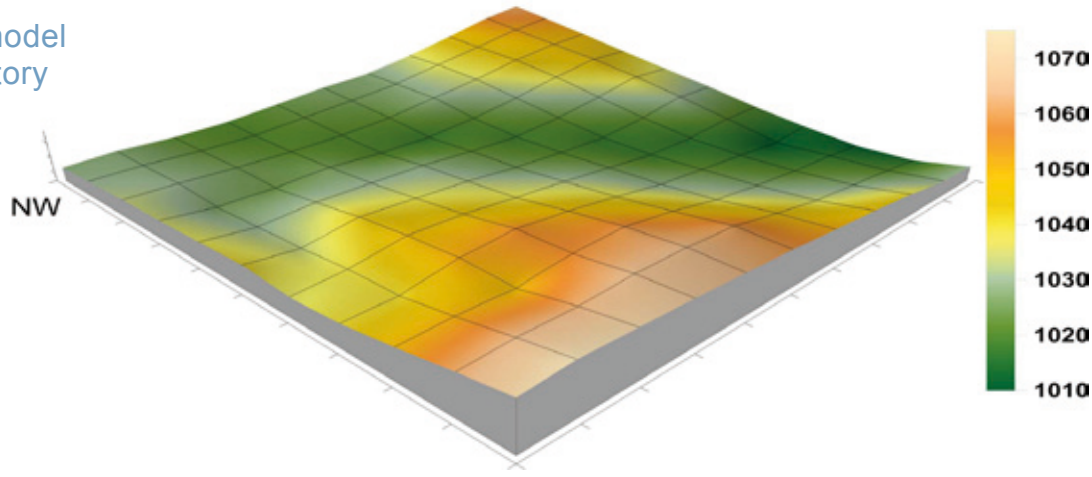


Image: SPOT, 7 October 2005

Elevation model of Observatory



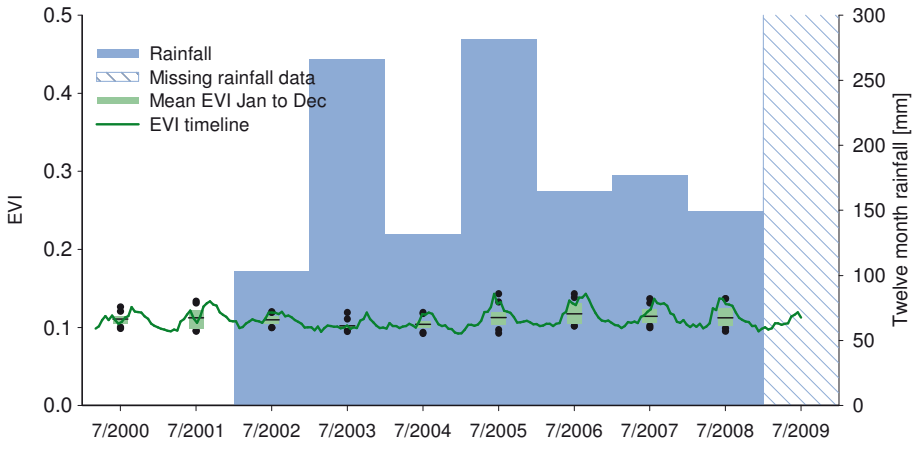
Landsat image

The drainage lines in the south-eastern parts flow to the south, and flow to the west in the other areas. The mountains are covered by more or less dense bush vegetation (light green to green-grey and blue-grey tones). Distinctive round, granite outcrops (violet-grey tones) can be detected in the north-western and south-eastern parts of the image. On the Observatory of Remhoogte, the vegetation cover is more dense (more green tones) on the Remhoogte Observatory than on the Paulshoek Observatory (north of the Remhoogte Observatory, with more blue-grey tones). Alluvial and freshwater vegetation along riverbeds or watercourses is indicated by red colours.

Scene: 177–78, acquisition date: 15 February 2007

MODIS time series

Temporal patterns of annual rainfall, vegetation cover, and phenology



Responsible authors: M. Keil & T. Labitzky

Climate

Data from BIOTA weather station

Location	Recorded period	Mean temperature
Paulshoek (S24)	2001–2009	16.9 (-1.8–40.7) °C
Mean solar radiation	**Mean wind speed**	**Mean annual precipitation**
608 (306–957) MJ·m^{-2}·month^{-1}	2.5 (9.1) m·s^{-1}	168 (98–282) mm
Mean annual potential evapotranspiration	**Interannual precipitation variability**	**Mean relative humidity**
1381 mm	108%	55% (35–78%)
Aridity index (UNEP)		
0.12 (arid)		

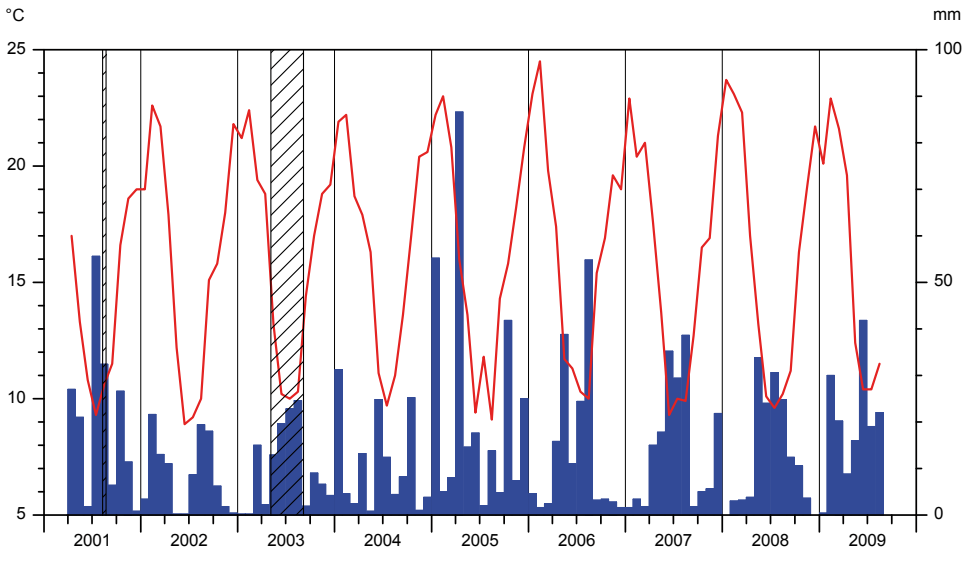
Modelled data

Mean temperature	Mean annual temperature range	Mean diurnal temperature range
15.5 (3.4–29.2) °C	11.4 °C	14.7 °C
Mean annual precipitation	**Precipitation seasonality**	**Percentage winter precipitation**
247 mm	50%	72% (winter)
Climate type	**Length of dry season**	**Aridity index (De Martonne)**
BSk	8 months	9.7 (dry)

The climate at the Observatory is characterised by arid to semi-arid conditions. Rainfall shows a moderate seasonality with more rain falling during the winter season, peaking in August. The mean annual rainfall is 168 mm, which is drier than the average rainfall recorded over the entire transect, but is the wettest within the Succulent Karoo. The comparatively high annual rainfall for this and the adjacent Observatory Remhoogte can be explained by their high elevation (1050 m a.s.l.). However, substantial interannual variability is evident. The observed near-surface air temperatures show a moderate seasonal cycle. The mean annual temperature is 16.9°C and is therefore the coldest of all Observatories, which is also related to the high elevation of the Observatory. The observed mean minimum temperature is above the freezing point, but there is still a possibility of the occurrence of frost during the months June to September. Compared to the interpolated long-term data taken from the WorldClim dataset, a markedly warmer mean annual temperature is observed at the BIOTA weather station. In particular, the station records of maximum temperatures deviate substantially from the interpolated data. For precipitation, mean annual rainfall observed at the station is markedly lower than that of the WorldClim dataset. The rainfall seasonality is also less pronounced in the BIOTA weather station data.

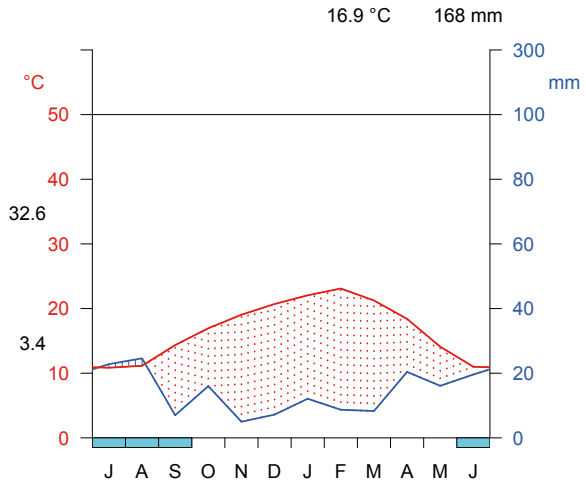
The observed near-surface winds at the Observatory are predominantly constituted of north-northwesterly and south-southeasterly flows. The north-northwesterly component is predominant during winter. Mean wind speed is highest during the early afternoon, reaching about 10 km/h. Winds during that time of the day stay fairly constant throughout the year, whereas a pronounced annual cycle is evident for the mean wind speed recorded during the evening.

Time series: rainfall and temperature

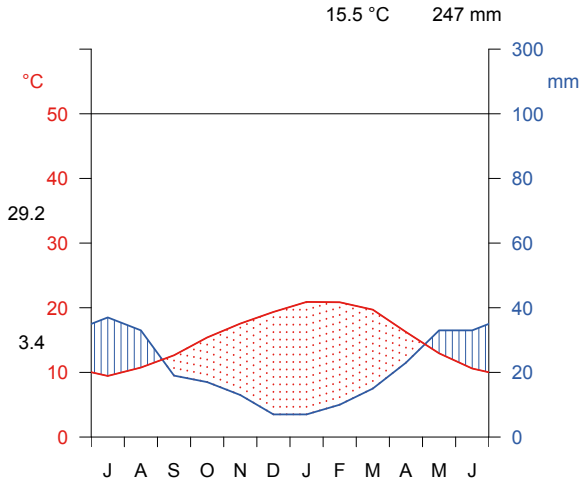


Climate diagrams

Recorded data (BIOTA)

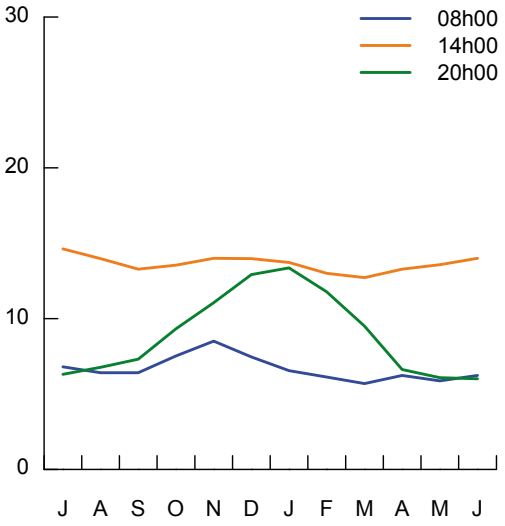


Modelled data (WorldClim)

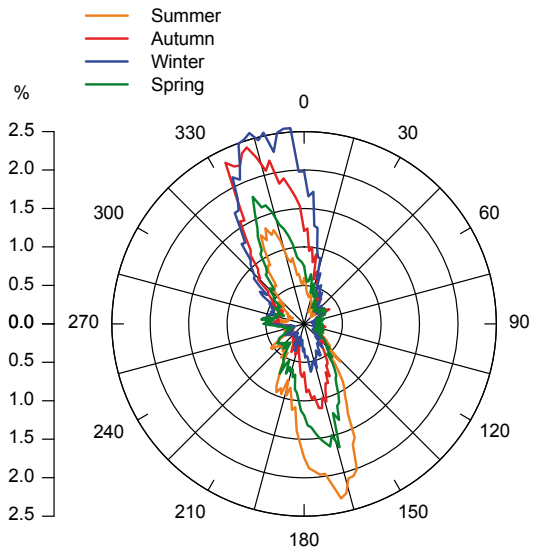


Wind diagrams

Speed



Directions



Responsible authors: K. Berger, A. Haensler & J. Luther-Mosebach

Soils

Year of sampling	Hectare plots sampled	SOTER unit
2005	25 (R1–25)	ZA1738
Soilscape	**Dominant soil group(s)**	**Reference group richness**
n.a.	Leptosol	4
Soil unit richness	**Soil unit evenness**	**Soil ecotype richness**
11	0.639	14
Parametric space	**pH**	**Electrical conductivity**
4.65	6.6 (4.9–7.8)	39 (15–3960) $\mu S \cdot cm^{-1}$
Organic carbon		
0.62% (0.06–20.70%)		

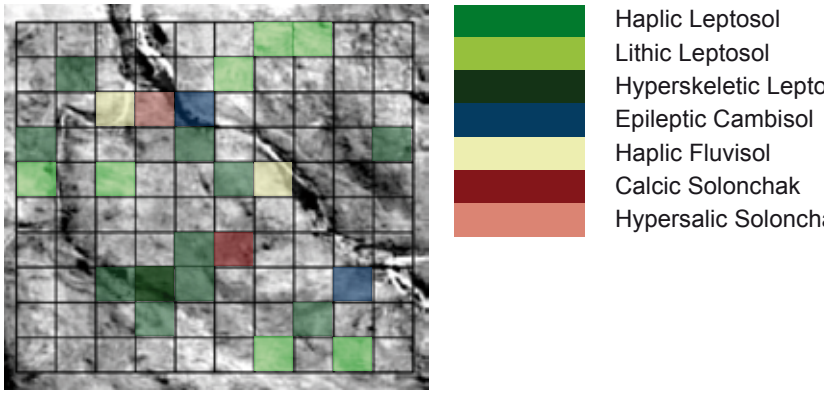
The soil properties of this Observatory are very similar to those of the neighbouring Observatory S24 (Paulshoek). The area is very rocky and thus dominated by Leptosols, deeper profiles are classified as Cambisols and, near the dry river, Fluvisols. On the only heuweltjie found, unique soil has developed characterised by biogenic accumulation of calcium carbonate and salt enrichment, and thus is classified as Calcic Solonchak.

The pH values show a wide range and some variations with depth, mainly characterised by an increase in the second and third horizon. As on Paulshoek (S24), the median values of electrical conductivity at all three depths are generally low, but their range is slightly narrower, since there are less Solonchaks on Remhoogte (S25).

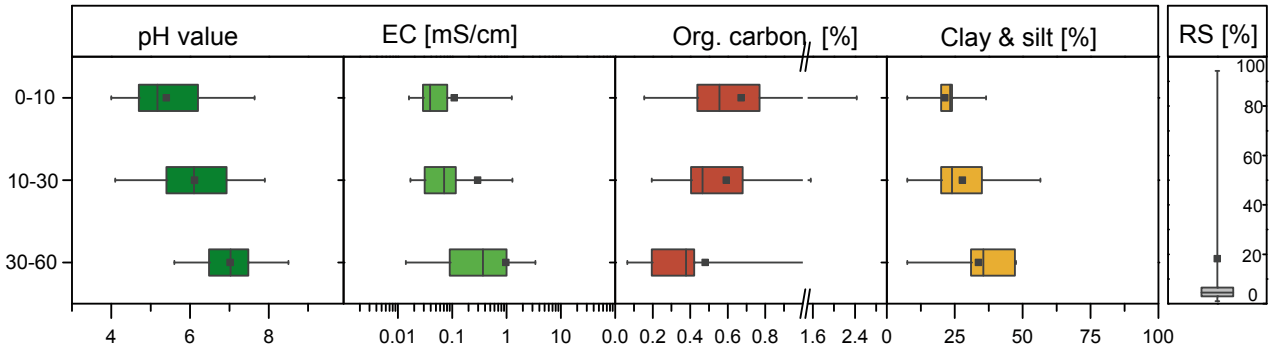
The median rooting space was low with only 5%, even lower than on Paulshoek (S24). Silt and clay content has a narrower range, generally the texture is dominated by silt, but also some Cambisols enriched with clay occur.

On this Observatory erosion is also a serious threat; further information about erosion dynamics and their relation to rainfall given for Paulshoek (S24) does apply for this Observatory.

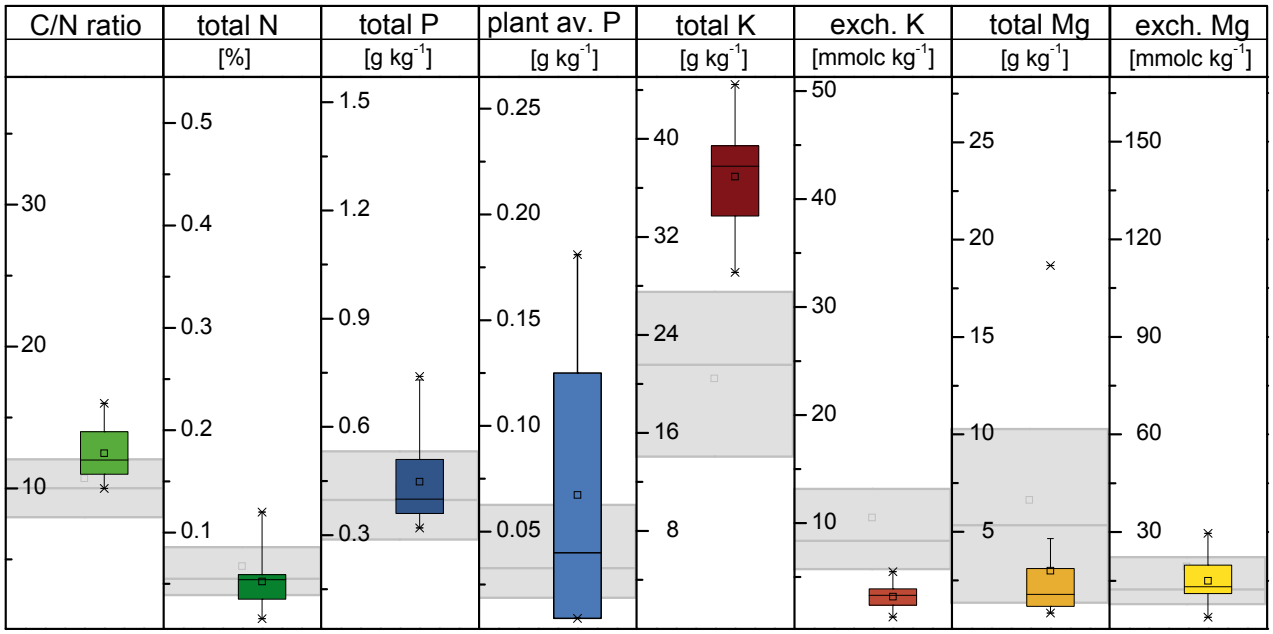
Map of soil profiles



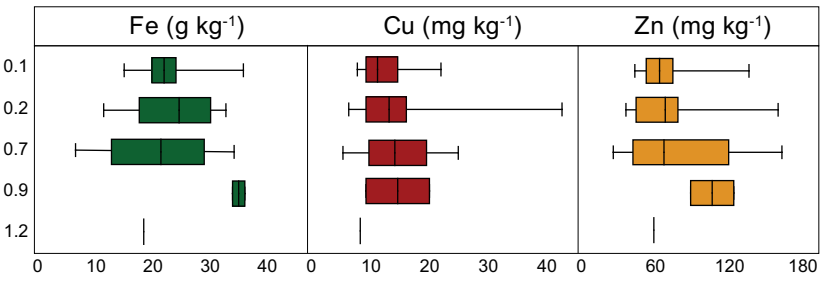
Soil characteristics



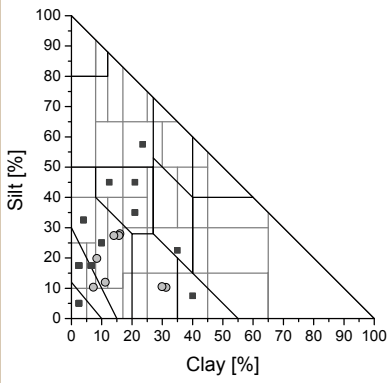
Soil nutrients



Soil micronutrients



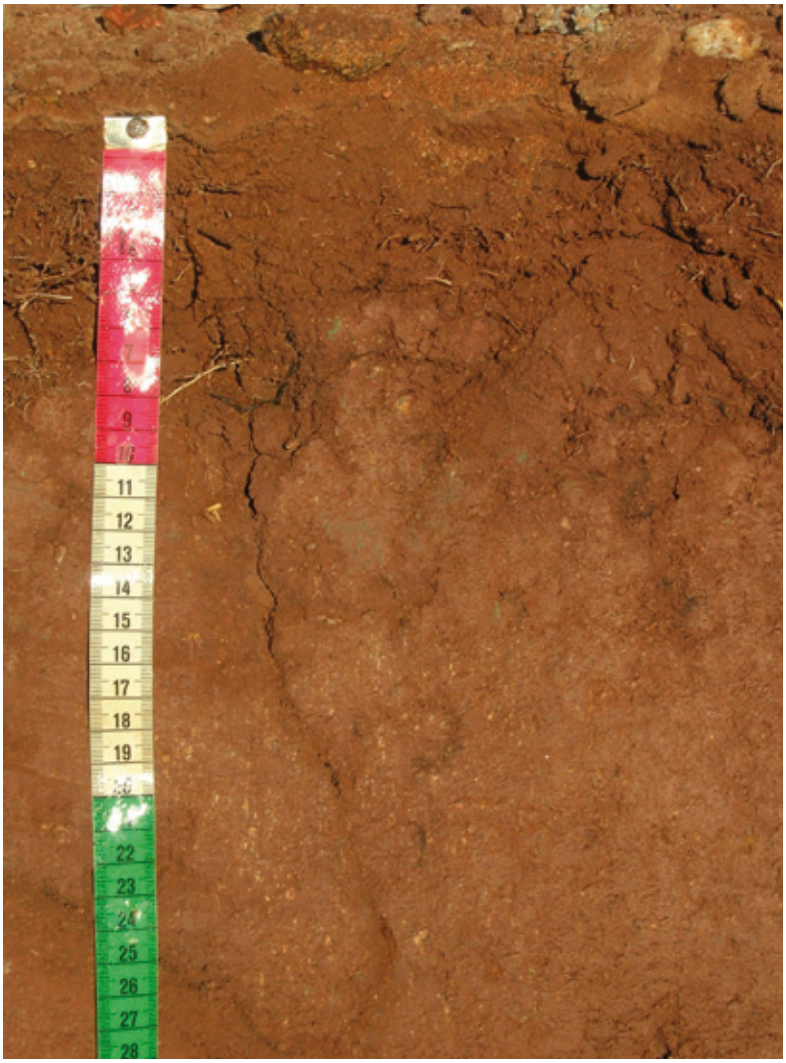
Soil texture triangle

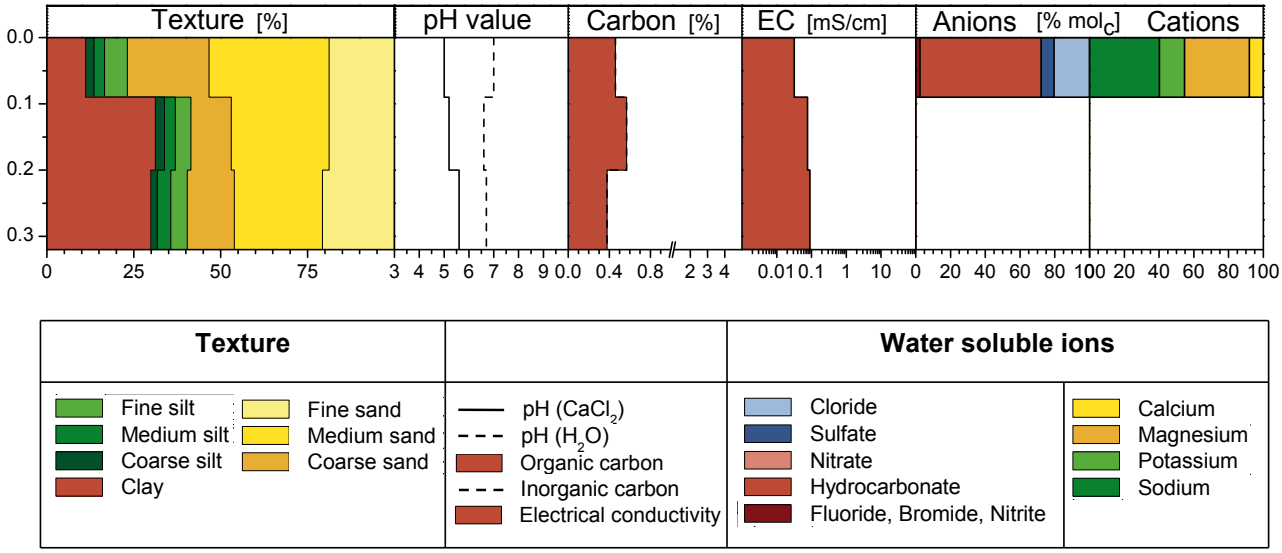


Reference profile (H78)

The Epileptic **Cambisol (Eutric, Clayic, Chromic)** is a typical example of the older and more deeply developed soils of the lower slopes. The field observations indicate that these Cambisols are predominantly found on westerly-exposed sites, which might additionally receive run-on water from higher positions. The texture of this profile is sandy clay, with the topsoil consisting of loamy sand. Clay content increased significantly from 9 to 30% from the first to the second horizon, showing clear signs of columnar macro structure. The reaction is slightly acidic in all horizons, electrical conductivity is low, and organic carbon is nearly constant and low with values of approx. 0.4%. Except for the surface cover with 50 % coarse rock fragments, such fragments make up only 5% of the volume of the whole profile.

With regard to textural changes, the total element content is relatively constant except for an increase of magnesium (from 3.5 to 7 g kg^{-1}) and a decrease of potassium (from 36.2 to 28 g kg^{-1}) with depth. Remarkable is the constancy of aluminium, which normally follows the clay trend in such substrates. This may be an indicator of different clay mineralogy in the first and second horizon.





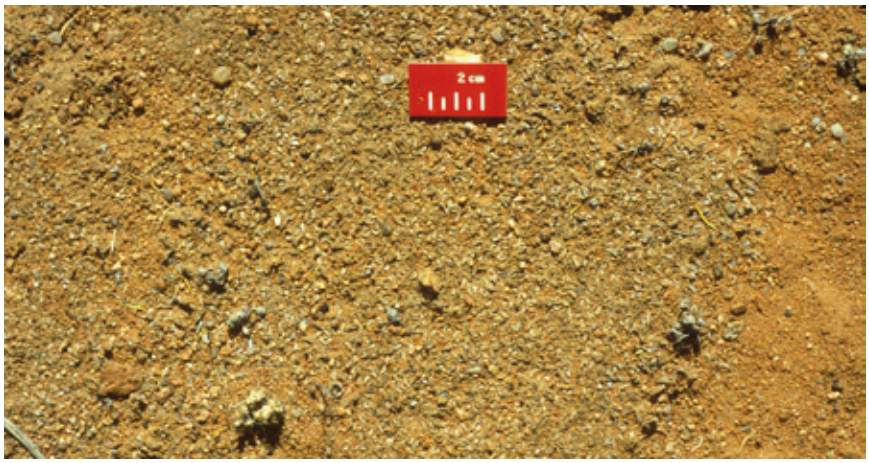
Responsible authors: U. Wisch, A. Petersen, A. Gröngröft & D. Mager

Biological soil crusts

Sampling period(s)	Hectare plots sampled	Types of soil crusts
2002	3 (R1–R3)	1, 4, 5a, 5b
Crust thickness	**Cover**	**Carbon [weight %]**
< 3 mm	about 5%	n.a.
Nitrogen [weight %]	**Chlorophyll *a* [mg/m²]**	**Chlorophyll *a+b* [mg/m²]**
n.a.	28	34

Due to only moderate grazing intensity (as compared to the intensively grazed neighbouring Observatory S24), biological soil crusts of later successional stages, such as lichen- and moss-dominated crusts (type 4 and 5), also occur on this Observatory (see photo). The high species richness corresponds to higher diversity of crust types.

Cyanobacteria
Leptolyngbya compacta
Leptolyngbya foveolarum
Leptolyngbya schmidlei
Leptolyngbya subtilissima
Nostoc commune
Phormidium aerugineo-caeruleum
Phormidium cf. *nigrum*
Porphyrosiphon lomnisczensis
Pseudanabaena minima
Pseudanabaena cf. *frigida*
Scytonema ocellatum
Symplocastrum cf. *friesii*
Tolypothrix distorta
Tolypothrix sp.
Trichocoleus sp.
Green algae
Chlorella cf. *sorokiniana*
Chlorosarcinopsis cf. *variabilis*
Scenedesmus sp. 4
Spongiochloris minor



Biological soil crust dominated by liverworts. From a distance, a greyish surface can be observed. Photo: B. Büdel.

At a closer look, individual leaflets of the liverworts can be recognised. Photo: B. Büdel.

Biological soil crust characteristics

	H30	H65	H96
Soil characteristics	Reddish-brown unweathered sand with feldspars and quartz pebbles.	Reddish-brown unweathered sand with granite particles and small stones	Reddish-brown fine sand with larger stones and quartz pebbles
Crust characteristics	Thick crust pieces; not dark coloured, BSC not obvious)	Small pieces of early stage of BSC formation	Hypolithic growth on some quartz pebbles
Chlorophyll a [mg/m²]	13.04	38.95	31.35
Chlorophyll a+b [mg/m²]	18.41	43.01	39.75

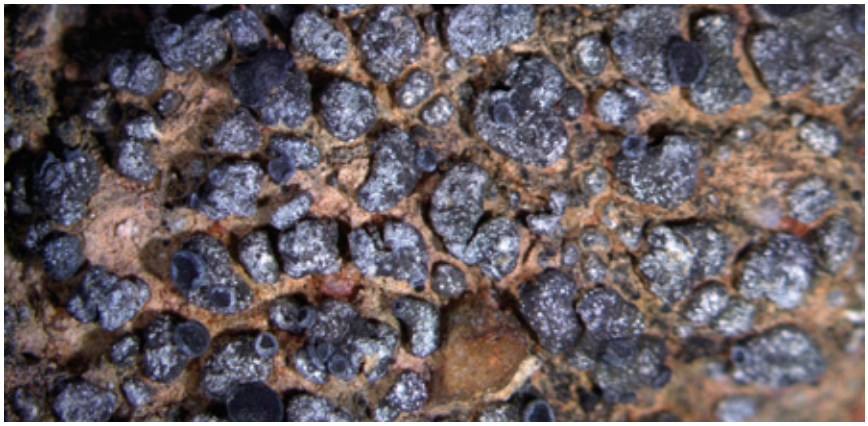
Responsible authors: B. Weber, K. Deutschewitz, S. Dojani, T. Friedl, T. Darienko, K. Mohr & B. Büdel

Lichens

Sampling period(s)	Hectare plots sampled	Cover
2001, 2002	10 (R1–R10)	2% (0–19%)
Total species richness	**Species richness on soil [1 km²]**	**Species richness on rock [1 km²]**
15	8 (53%)	7 (49%)
Species richness on plants [1 km²]	**Species richness on soil [1000 cm²]**	
n.a.	0.8 (0–5)	

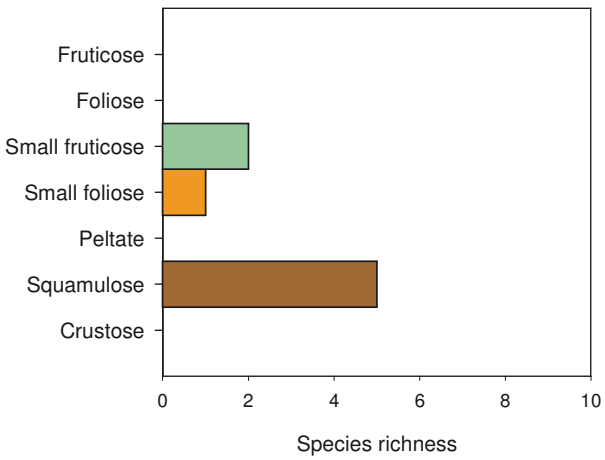
Lichen richness and species composition are similar to the neighbouring Observatory S24 (Paulshoek). However, the number of terricolous taxa and the total cover of lichens is higher compared to Paulshoek. This appears to be due to the less intensive grazing at this Observatory. Nevertheless, re-colonisation by lichens happens rather slowly. Lichens on soil are predominantly squamulose and green algal (63%), but there is a considerable cyanobacterial component (37%) too.
Lichens occur exclusively in H11 and H24, with significant cover only in H11. The most common morphological groups are MG02 and MG03. The absence of lichens in the other hectare plots is due to sandy soils with low pH and high rock cover.

Collema coccophorum. Photo: M. Schultz, L. Zedda & G. Rambold

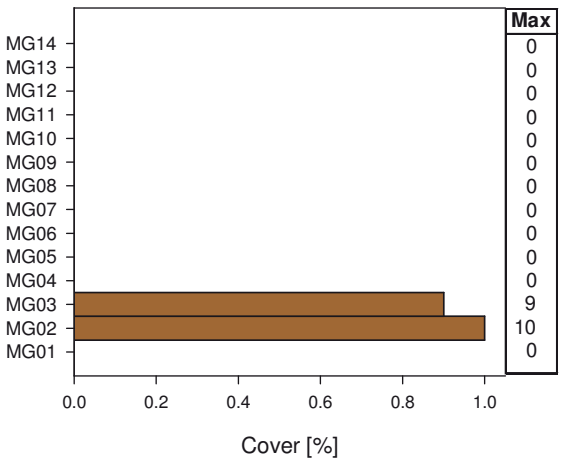


Toninia australis. Photo: L. Zedda & G. Rambold

Growth forms



Morpho groups



List of Taxa

Terricolous (on soil):

Collema coccophorum
Peccania arabica
Peccania font-queriana
Placidium squamulosum
Placidium tenellum
Psora crenata
Psora sp. 01 (M-0039003)
Toninia australis

Saxicolous (on rock):

Acarospora spp. (2)
Buellia spp. (2)
Caloplaca cinnabarina
Caloplaca haematodes
Rinodina sp.

Epiphytic (on plants):

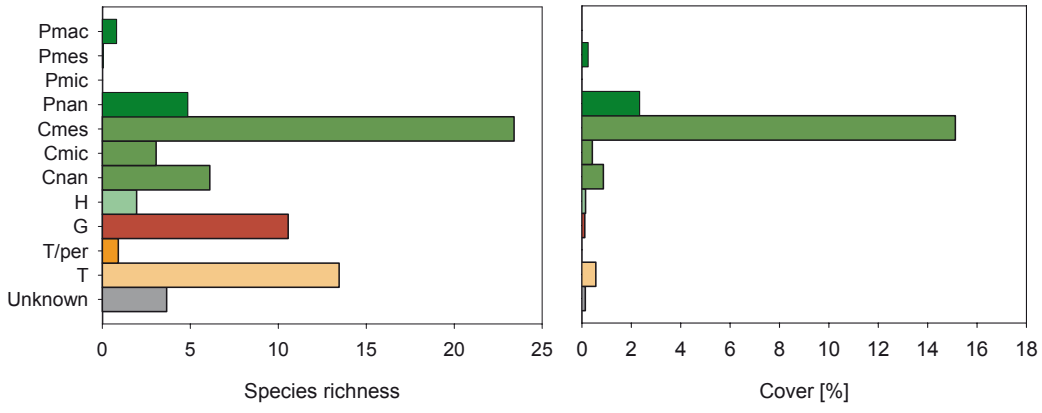
No records

Responsible authors: L. Zedda & G. Rambold

Vascular plants

Sampling period(s)	Hectare plots sampled	Biome
2001−2009	20 (R1−R20)	Succulent Karoo
Vegetation unit (level 1)	**Vegetation unit (level 2)**	**Identification rate**
Namaqualand Hardeveld Bioregion	SKn 3 Namaqualand Blomveld	64% − 91% − 92%
Cumulative family richness	**Dominant families (cover)**	**Dominant families (richness)**
54	Aizoaceae, Asteraceae, Zygophyllaceae	Asteraceae, Aizoaceae, Crassulaceae
Cumulative species richness (1 km²)	**Species richness (1000 m²)**	**Species richness (100 m²)**
562 − 296	63.1 (7−99)	31.1 (7−55)
***z*-value**	**Species richness change per year (1000 m²)**	**Evenness (1000 m²)**
0.308 (0.000−0.671)	0.52	0.539 (0.233−0.801)
Evenness (100 m²)	**Simpson (1000 m²)**	**Simpson (100 m²)**
0.571 (0.283−0.801)	0.784 (0.319−0.941)	0.774 (0.393−0.925)

Life forms



The Observatory Remhoogte comprises a sequence of four habitat types: ephemeral rivers, plains slopes, and mountains. Since the Observatory is situated on commercial farmland with moderate stocking rates and rotational grazing, a rich flora of palatable shrubs has been maintained. The species richness at different scales is amongst the highest along the transect. The plant cover is open to sparse with a mean total cover of 22%.

On sandy flats and lower slopes, the vegetation consists of a diverse dwarf shrub community with plant heights generally less than 1 m, characterised by a preponderance of succulent plants particularly in the families Aizoaceae, Asteraceae, Crassulaceae, and Euphorbiaceae. The rocky hills are characterised by a higher proportion of taller, non-succulent shrubs with fynbos affinities.

Tall sedges, trees, and grasses occur in the riverbeds.

Four vegetation units can be distinguished according to the four different habitat types on the Observatory. Water supply, soil texture, the proportion of stones, boulders, or rocky outcrops, and the soil depth are assumed to be differentiating ecological factors for plant growth. Unlike the ephemeral river habitat, which supports a well separated community, floristic change from the flats to mountains is continuous.

The plant communities at this Observatory are of high grazing value due to the high proportions of palatable perennial species, which provide fodder resources throughout the year and also in dry years.

The *Dicerothamnus rhinocerotis-Ruschia grisea* community (unit 1) occurs along water courses and spreads into the riverbeds. These ephemeral watercourses (riviers) bear water for several months each year during the rainy season. Soils are deep Fluvisols, which are rich in coarse sands.

The tree *Salix mucronata* subsp. *capensis* and the tall shrub *Dicerothamnus rhinocerotis* occur on river banks and islands present within this intact river system. Dense reed beds are formed by the segdes *Pseudoschoenus inanis*, *Scirpoides dioecus*, *Cyperus* spp. and *Juncus acutus* subsp. *leopoldii*. The ephemeral rivers are the only habitats within this landscape, which host a high proportion of grasses, such as *Stipagrostis namaquensis*, *Ehrharta longiflora*, *Bromus pectinatus*, and *Pennisetum macrourum*, giving this community a high grazing value. Ephemeral species in the riverbed indicate that the habitat is subject to regular disturbance by flooding. Highly abundant ephemerals are *Carpobrotus edulis*, *Erodium cicutarium*, *Mesembryanthemum guerichianum* and the Asteraceae *Oncosiphon grandiflorum*, *Senecio cardaminifolius*, *Senecio niveus* and *Lasiopogon micropoides*. Among the ephemerals are also several neophytic species such as *Amsinckia* spp. or *Salvia verbenaca*.

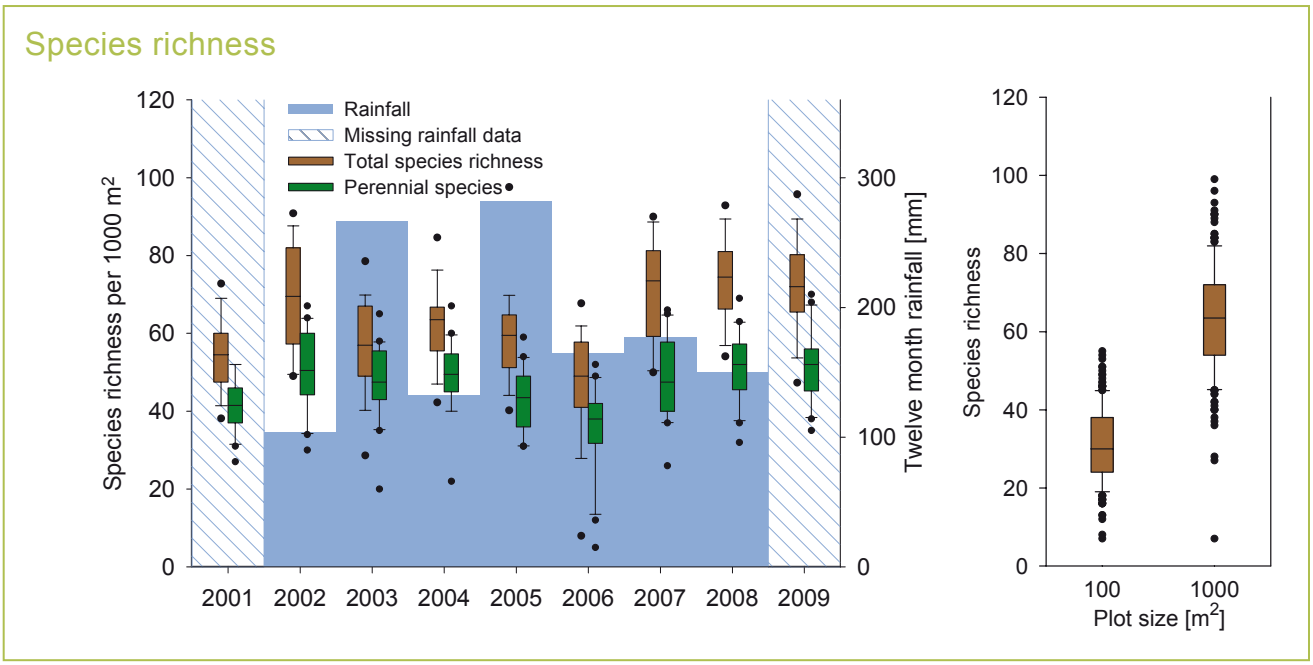
On the upper riverbanks, the shrubs, *Zygophyllum retrofractum*, *Ruschia robusta*, *Eriocephalus microphyllus* var. *pubescens*, *Lycium* spp., *Galenia africana*, and *Ruschia grisea* become dominant.

The *Lessertia diffusa-Eriocephalus microphyllus* var. *pubescens* community (unit 2) is characteristic of the Cambisols of the gently undulating plains and lower slopes, with a relatively low cover of coarse fragments (35%). The soil is slightly acidic and the texture is sandy-clay to loamy-sand. A diverse dwarf shrub community occurs in this habitat. The fine-leafed Asteraceae *Eriocephalus microphyllus* var. *pubescens* and the leaf succulent Aizoaceae *Leipoldtia schultzei* are dominant features of the shrub cover. Both species are present on the entire Observatory, but their optimum occurrence is on the plains and lower slopes. Except for the Fabaceae *Lessertia diffusa*, this community does not possess any additional species unique to the plains and lower slopes. However, it can be distinguished from the other communities by the absence of species typical of ephemeral rivers and mountains.

Other important shrubs, most of them highly palatable, are the Asteraceae *Hirpicium alienatum* and *Pentzia incana* as well as the Aizoaceae *Ruschia robusta* and *Drosanthemum glabrescens*.

Grazing intensity on this Observatory is generally low, but is highest on the easily accessible flats and lower slopes. Hence there are also a few taxa, which indicate disturbance such as *Hypertelis salsoloides* var. *salsoloides* and a variety of annual species such as *Leysera tenella*, *Manulea cheiranthus*, *Crassula umbellata*, *Gazania heterochaeta* and *Trichogyne lerouxiae*. Frequently occurring geophytes are *Moraea serpentina*, *Ornithoglossum vulgare* or *Trachyandra tortilis*.

The *Hallianthus planus-Polymita albiflora* community (unit 3) is representative of the upper slopes, with higher cover of stones and rocky outcrops, usually around 65%. Floristically, this vegetation unit is the transition between lower slopes and mountains. The leaf



succulent *Leipoltdia schultzei* decreases and is replaced by the creeping succulent dwarf shrub *Polymita albiflora*, which is favoured by coarse soil fragments. The fine-leafed Asteraceae *Eriocephalus microphyllus* var. *pubescens* and *Pteronia ciliata* dominate the shrub cover. The community can be distinguished from the neighbouring communities by *Hallianthus planus*, which does not have high cover values, but occurs reliably and exclusively on the upper slopes. Tall shrubs of fynbos affinity such as *Lebeckia sericea*, *Wiborgia monoptera* or *Rhus undulata* begin to occur, indicating the transition to the mountain vegetation (unit 4).

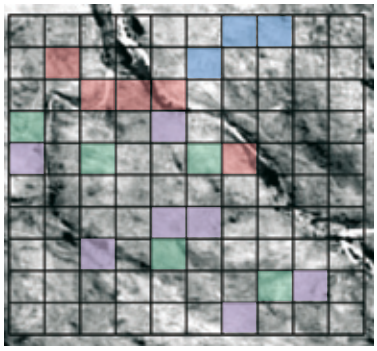
The *Polymita albiflora-Zygophyllum sessilifolium* community (unit 4) is representative of the mountain habitat. Soils supporting this community are Leptosols with a high proportion of coarse fragments in the form of rocky outcrops and boulders. The community is highly diverse due to the diversity of habitat structures such as rock interstices and erosion rills. *Eriocephalus microphyllus* var. *pubescens* and *Polymita albiflora* are dominant features of the shrub canopy. Increased proportions of tall shrubs of fynbos affinity such as *Lebeckia sericea*, *Wiborgia monoptera* or *Rhus undulata* is evident here. The community can be distinguished from the slopes community (unit 3) by the species *Zygophyllum sessilifolium*. There are a number of other diagnostic species exclusively found on the mountains, but they are rare and do not occur constantly. Among these are *Stipagrostis zeyheri*, *Crassula cotyledonis* and *Anacampseros filamentosa* subsp. *namaquensis*. Water supply from large boulders and rocky outcrops generate high water run-off and support the development of small water courses, which support species usually found in the ephemeral river community (unit 1), such as *Senecio cardaminifolius* or *Oncosiphon suffruticosum*.

Unit 1, H23, 2008. Photo: W. Hanke.

Unit 1, H24, 2008. Photo: W. Hanke.

Unit 2, H07, 2008. Photo: W. Hanke.

Map of vegetation units



Unit 3, H40, 2008. Photo: W. Hanke.

Unit 4, H64, 2008. Photo: W. Hanke.

Classification table (2008)

Column	Cover	All	1	2	3	4
Number of relevés		**20**	**5**	**3**	**5**	**7**
Mean cover [%]		21.9	27.5	22.9	16.0	21.8
Mean species richness (1000 m²)		73.9	74.2	77.7	69.2	75.4
Inclination [°]		7.8	3.4	5.7	9.8	11.4
Mean soil pH		5.39	6.50	5.33	4.83	5.03
Mean electrical conductivity [µS·cm^{-1}]		130	87	36	59	238
Organic carbon [%]		0.79	0.58	0.46	0.52	1.22
Nitrogen [%]		0.1	0.05	0.04	0.04	0.07
Fine material [%]		48.0	70.2	65.2	40.1	30.5
Gravel [%]		11.8	15.0	9.3	13.2	9.6
Stones 2-6 cm [%]		7.1	3.8	2.1	11.6	8.5
Stones 6-20 cm [%]		10.3	6.9	4.3	16.4	11.0
Stones 20-60 cm [%]		3.5	0.5	5.1	1.3	6.5
Blocks [%]		1.0	0.0	0.0	0.0	2.5
Rock outcrops [%]		18.2	3.5	13.5	17.2	31.4
Unit 1: Dicerothamnus rhinocerotis-Ruschia grisea community						
Cmic	Ruschia grisea	0.74	25	100	.	.	.
Cnan	Carpobrotus edulis	2.26	20	80	.	.	.
T	Lasiopogon micropoides	0.07	25	80	.	.	14
Pnan	Dicerothamnus rhinocerotis	0.38	25	80	.	.	14
Cmes	Senecio niveus	0.03	15	60	.	.	.
T	Senecio cardaminifolius	0.02	45	100	33	.	43
T	Oncosiphon suffruticosum	0.10	35	80	.	.	43
T	Ehrharta longiflora	0.01	20	60	.	.	14
T	Erodium cicutarium	0.07	20	60	.	.	14
T	Bromus pectinatus	0.63	20	60	.	.	14
T	Mesembryanthemum guerichianum	0.01	20	60	.	.	14
Pnan	Lycium ferocissimum	0.30	55	100	.	20	71
T	Oncosiphon grandiflorum	0.04	35	80	33	20	14
Cmes	Felicia filifolia	0.01	20	60	33	.	.
T	Grielum humifusum	0.01	20	60	33	.	.
Unit 2: Lessertia diffusa-Eriocephalus microphyllus var. pubescens community						
Hper	Lessertia diffusa	0.01	25	20	100	20	.
T	Manulea cheiranthus	0.01	10	.	67	.	.
T	Crassula umbellata	0.01	10	.	67	.	.
Cnan	Hypertelis salsoloides var. salsoloides	0.01	30	60	100	.	.
G	Oxalis sp. 116682	0.01	35	40	100	.	29
G	Androcymbium sp. 116728	0.01	35	80	100	.	.
Cnan	Conicosia elongata	0.01	15	20	67	.	.
G	Trachyandra tortilis	0.01	40	20	100	40	29
G	Ornithoglossum vulgare	0.01	40	40	100	20	29
Unit 3: Hallianthus planus-Polymita albiflora community						
Cnan	Hallianthus planus	0.01	25	.	.	100	.
Cnan	Crassula columnaris ssp. prolifera	0.01	35	.	33	100	14
Cmes	Ruschia crassisepala	0.08	15	.	.	60	.
Cnan	Conophytum calculus ssp. vanzeylii	0.01	15	.	.	60	.
n.a.	Pharnaceum sp. SG6468	0.01	15	.	.	60	.
G	Gladiolus orchidiflorus	0.01	15	.	.	60	.
G	Bulbine sp. SG5714	0.01	30	.	.	80	29
Cnan	Crassula sp. 122258	0.09	20	.	.	60	14
Cmes	Pteronia paniculata	0.10	20	.	.	60	14
Unit 4: Polymita albiflora-Zygophyllum sessilifolium community						
Cmic	Zygophyllum sessilifolium	0.02	35	.	.	20	86
Hper	Aizoon canariense	0.01	50	.	33	40	100
Cnan	Quaqua mammillaris	0.01	15	.	.	.	43
H	Stipagrostis zeyheri	0.10	15	.	.	.	43
T/Hpe	Acanthopsis carduifolia	0.01	50	.	.	80	86

continued on next page

Classification table (continued)

		Column	Cover	All	1	2	3	4
		Number of relevés		20	5	3	5	7
		Most frequent companions						
Cmes		Eriocephalus microphyllus var. pubescens	5.11	100	100	100	100	100
Cmes		Chrysocoma ciliata	0.05	100	100	100	100	100
T		Heliophila variabilis	0.01	100	100	100	100	100
G		Oxalis foveolata	0.01	100	100	100	100	100
T		Ursinia nana ssp. nana	0.01	100	100	100	100	100
Cmes		Galenia africana	1.34	95	100	100	80	100
Cmes		Leipoldtia schultzei	0.89	95	100	100	100	86
Cmes		Tripteris sinuata var. sinuata	0.24	95	100	67	100	100
Cmes		Hirpicium alienatum	0.18	95	80	100	100	100
Cmes		Hermannia cuneifolia var. cuneifolia	0.03	95	80	100	100	100
T		Helichrysum leontonyx	0.02	95	80	100	100	100
Pnan		Lycium cinereum	0.27	90	100	100	80	86
Cmic		Tetragonia fruticosa	0.04	90	80	67	100	100
Hper		Chlorophytum crassinerve	0.01	90	80	100	80	100
Cmes		Polymita albiflora	2.95	85	60	67	100	100
Cnan		Cheiridopsis denticulata	0.23	85	100	100	60	86
T		Cotula leptalea	0.11	85	40	100	100	100
T/Hpe		Leysera tenella	0.47	80	100	67	80	71
Cmes		Euphorbia decussata	0.19	80	20	100	100	100
H		Ehrharta barbinodis	0.08	80	40	67	100	100
T		Rhynchopsidium pumilum	0.03	80	40	100	100	86
Pmac		Pelargonium carnosum	0.01	80	20	100	100	100
T		Trichogyne lerouxiae	0.01	80	100	100	80	57
T		Zaluzianskya benthamiana	0.01	80	80	100	40	100
Cmes		Crassula subaphylla var. virgata	0.01	75	100	100	60	57
Cmes		Ruschia robusta	2.20	70	100	100	60	43
Cmes		Pentzia incana	0.62	70	80	100	40	71
Cmes		Pteronia incana	0.25	70	80	33	60	86
Cmes		Crassula muscosa var. obtusifolia	0.02	70	60	67	80	71
G		Albuca cooperi	0.01	70	20	100	100	71
G		Babiana attenuata	0.01	70	40	100	80	71
G		Moraea serpentina	0.01	70	40	100	100	57
G		Oxalis sp. 116797	0.01	70	40	67	100	71
Cmes		Pteronia ciliata	0.75	65	.	33	100	100
Cmes		Eriocephalus africanus var. paniculatus	0.18	65	40	100	40	86
Cmes		Antimima subg. Clavipes sp. 116615	0.05	65	60	33	80	71
T		Pentaschistis airoides ssp. airoides	0.01	65	40	100	100	43
Hper		Cyphia longiflora	0.01	65	60	33	100	57
Cmes		Zygophyllum retrofractum	3.58	60	100	33	40	57
Cmes		Ruschia goodiae	0.42	60	20	67	60	86
Cmic		Ruschia aggregata	0.27	60	60	67	40	71
Cnan		Cheiridopsis namaquensis	0.06	60	40	100	100	29
Pnan		Asparagus capensis	0.02	60	80	67	40	57
Hper		Gazania heterochaeta	0.01	60	60	100	60	43
G		Bulbine praemorsa	0.01	60	20	67	60	86
Cmes		Septulina glauca	0.06	55	100	67	20	43
Cnan		Cephalophyllum rigidum	0.27	50	40	.	60	71
Pnan		Wiborgia monoptera	0.10	50	.	33	80	71
Cmes		Manochlamys albicans	0.05	50	60	.	40	71
Cmes		Sarcocaulon salmoniflorum	0.04	50	.	67	80	57
Cmes		Drosanthemum glabrescens	0.02	50	100	100	20	14
T		Felicia merxmuelleri	0.02	50	60	33	40	57
Cnan		Wahlenbergia oxyphylla	0.01	50	.	100	40	71
G		Moraea bifida	0.01	50	20	100	40	57
Cmes		Ruschia viridifolia	0.37	45	20	67	20	71
T		Schismus barbatus	0.14	45	80	33	20	43
Cmes		Thesium lineatum	0.13	45	20	67	40	57
H		Chaetobromus involucratus ssp. dregeanus	0.03	45	60	67	.	57
Hper		Lotononis falcata	0.01	45	40	100	40	29
Pnan		Lebeckia sericea	4.02	40	.	33	40	71

Pseudoschoenus inanis in the riverbed.
Photo: W. Hanke.

Lebeckia sericea subsp. *sericea*.
Photo: W. Hanke.

Open fruit of *Polymita albiflora*.
Photo: C. Mayer.

Leipoldtia schultzei in flower.
Photo: U. Schmiedel.

Responsible authors:
W. Hanke & J. Luther-Mosebach

Vertebrates

Total species richness	Reptile species richness	Bird species richness
10	n.a.	10
Large mammal species richness	Small mammal species richness	
n.a.	n.a.	

Black-chested Prinia (*Prinia flavicans*). Photo: J. Deckert.

Birds

Passeriformes	**Perching birds**
Nectarinia famosa	Yellow-tufted Malachite Sunbird
Oenanthe pileata	Capped Wheatear
Pycnonotus capensis	Cape Bulbul
Certhilauda curvirostris	Cape Long-billed Lark
Parus afer	Southern Grey Tit
Cercotrichas coryphaeus	Karoo Scrub-Robin
Prinia maculosa	Karoo Prinia
Emberiza capensis	Cape Bunting
Pteroclidiformes	**Sandgrouse**
Pterocles namaqua	Namaqua Sandgrouse
Columbiformes	**Doves and pigeons**
Streptopelia capicola	Ring-necked Dove

Responsible authors: J. Deckert, A. Hoffmann & A. Mills

Effects of grazing intensity and rainfall on plant population dynamics in the Succulent Karoo

► *See* **S24.01**

Dispersal strategies in communal versus privately-owned rangeland in Namaqualand

► *See* **S24.02**

The impact of grazing on pollinators and pollination

► *See also* **Article III.5.7**.

Pufal, G. (2005): Influences on the fruit set of *Cheiridopsis imitans* and *Leipoldtia schultzei* (Aizoaceae) under different land use conditions. – Diplom thesis in Biology. Rostock: University of Rostock.

General data

Number	Name	Alternative name(s)
S26	Goedehoop	Flaminkvlakte
Implementation	Country	Province/ region
2001	South Africa	Western Cape
District/ constituency	Locality	Farm name
West Coast	Van Rhynsdorp	Flaminkvlakte 111
Latitude	Longitude	Altitude
31.276713 S	18.591521 E	245 m a.s.l.
Rainfall season	Biome	WWF Ecoregion
Winter	Succulent Karoo	AT1322 Succulent Karoo
Agro-Ecological Zone	Relative intensity of land use	Tenure
n.a.	Medium	Private
Type and history of landuse	Land owner	
Farming with sheep	Private	

Goedehoop (S26)

Patchy quartz field vegetation on Goedehoop. Photo: J. Deckert.

The BIOTA Observatory Goedehoop (S26) is situated on the privately owned sheep farm Goedehoop, which is also known under the name Flaminkvlakte, about 40 km north of the small town of Vanrhynsdorp, east of the N7 National Road.

The area, known as the Knersvlakte, is a low lying, gently undulating plain (approximately 245 m a.s.l. on Goedehoop), in the Succulent Karoo Biome of southern Namaqualand. The average annual rainfall in the area is low but the plants benefit from the regular occurrence of fog and dew. The Knersvlakte is underlain by heterogeneous sediments of the Nama Group, dominated by shale, phyllite, and limestone, and is intruded by numerous quartz veins, from which the dense layer of quartz gravel originates to form the quartz fields. The quartz fields are a defining feature of the Knersvlakte. They accommodate a unique and special vegetation dominated by compact, leaf-succulent dwarf shrubs. Many species found in this special habitat are obligate quartz-field dwellers and often have a very restricted distribution range. The rich quartz field flora of the Knersvlakte thus contributes strongly to the generally high levels of diversity and endemism found in the Knersvlakte. This is the main reason for the recent establishment of a nature reserve in the Knersvlakte (see Moedverloren Observatory, S28).

The Goedehoop BIOTA Observatory was established to investigate the impacts of small stock farming and projected

climate change on the very species-rich Succulent Karoo flora of the Knersvlakte. The aim of the Observatory pair Goedehoop (S26) and Ratelgat (S27) is to monitor the impacts of commercial farming on Goedehoop and the more ecotourism-oriented management on Ratelgat.

Responsible authors: U. Schmiedel & D.H. Haarmeyer

Remote sensing and landscape

Geomorphology	Geological units	Lithological units
Hills, open valley	Nama System	Quartzite, arkose, limestone, shale, phyllite, tillite, lava, tuff
Mean EVI	**EVI absolute range**	**Mean leaf area index**
0.102 (0.087–0.125)	0.081 (2001)–0.156 (2008)	0.31

Grid map of Observatory

	0	1	2	3	4	5	6	7	8	9
0	98	84	42	9	78	94	16	15	30	10
1	58	69	11	1	89	61	86	22	66	37
2	3	97	31	52	32	7	71	55	68	43
3	25	81	36	14	51	60	76	24	2	65
4	77	87	64	92	83	8	48	56	38	72
5	19	80	90	75	63	46	33	54	67	79
6	57	6	73	74	50	49	40	35	5	17
7	44	85	100	39	18	21	13	95	27	59
8	4	96	88	20	41	47	34	62	28	70
9	26	45	82	29	12	53	91	93	23	99

1 Quartz hill with compact dwarf succulents
2 Quartz hill with shrubby vegetation
3 Quartz hill with intersection (rivier)
4 Quartz plains with compact dwarf succulents
5 Plains without quartz cover and succulent shrubs
6 Saline quartz fields with compact dwarf succulents

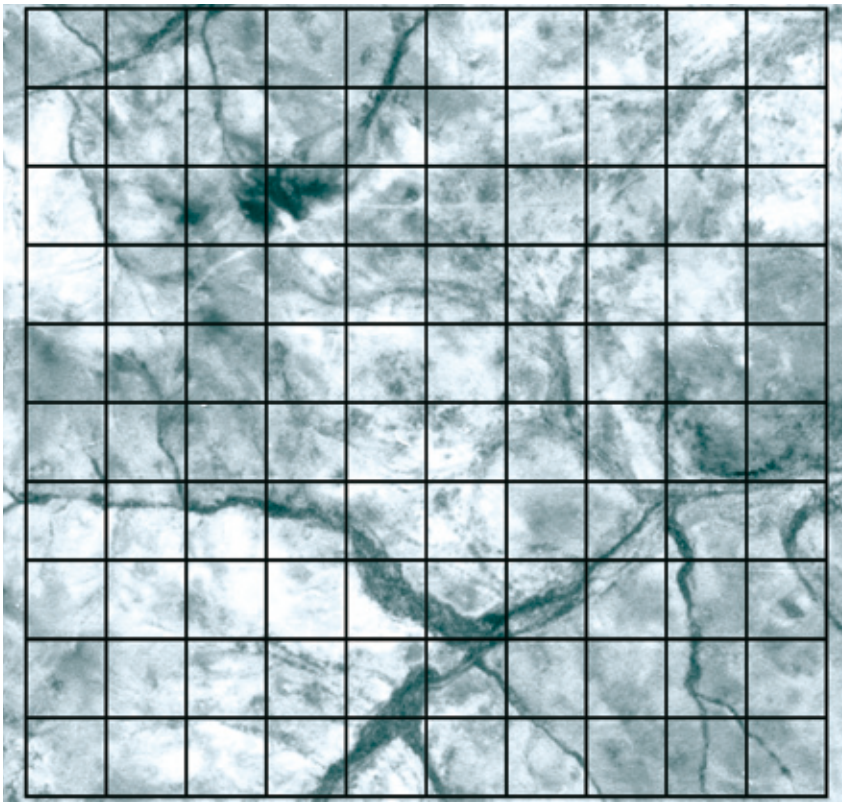
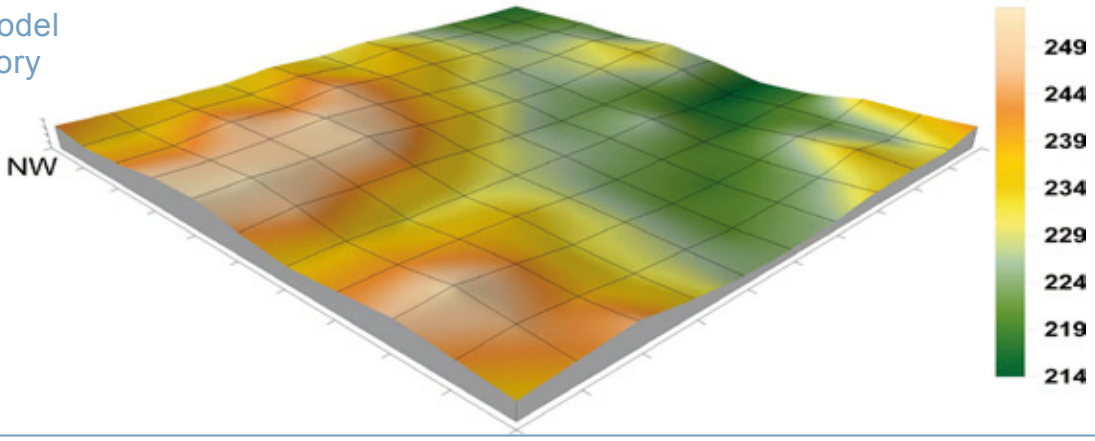


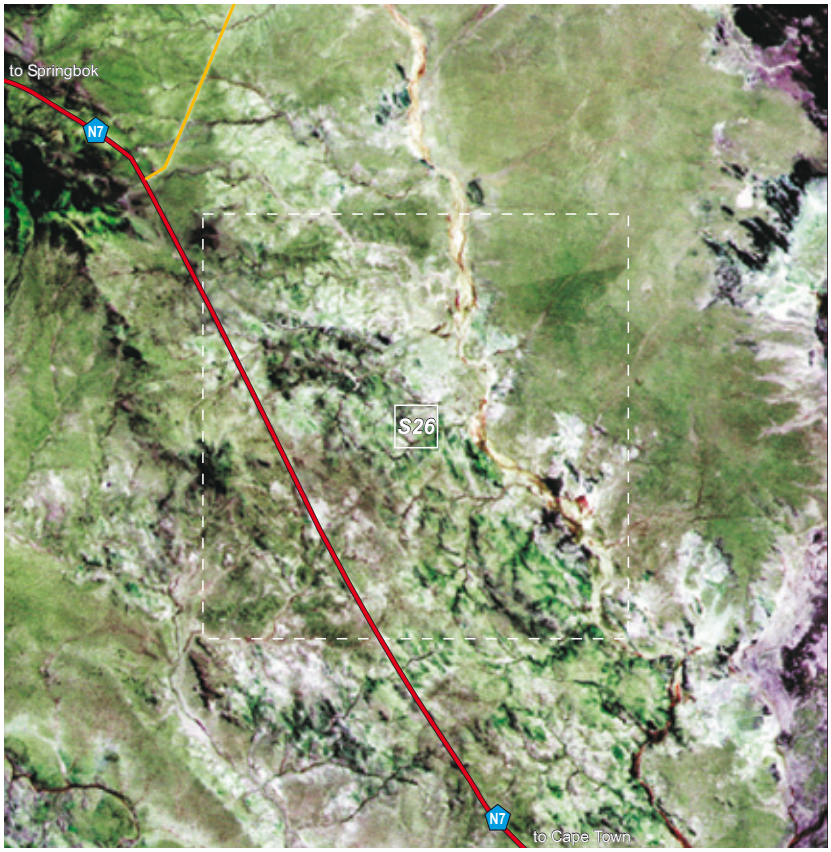
Image: aerial photograph

Elevation model of Observatory



Landsat image

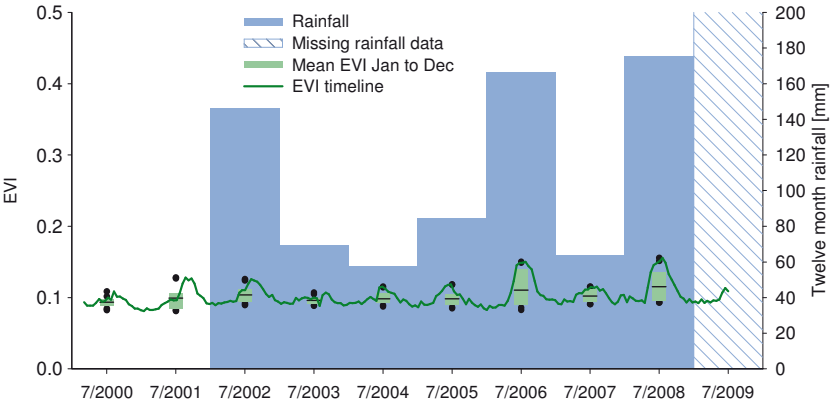
Defining features of the lithology in the Knersvlakte are the numerous intruded quartz veins and dense layers of quartz gravels, as well as shale, phyllite, and limestone rocks. The quartz fields in the Knersvlakte represent a unique flora and vegetation, dominated by leaf-succulent dwarf shrubs. The vegetation cover in the heterogeneous parts of the Knersvlakte shows up as green colours, and areas with a higher degree of bare surfaces in grey to white tones. A river valley of a tributary of the Olifants River draining to the south can be recognised in the western part of the image. In this river valley, patterns of woody vegetation are evident from the brown colours, and light-yellow to white tones indicate more open surfaces. East of the river valley, a much more homogeneous vegetation cover (succulent shrub communities on deeper homogenous loamy-sandy soils) shows up as grey-green tones. The western part of the image is crossed by the N7 national road.



Scene: 175/82, acquisition date: 07 February 2007

MODIS time series

Temporal patterns of annual rainfall, vegetation cover, and phenology



Responsible authors: M. Keil & T. Labitzky

Climate

Data from BIOTA weather station

Location	Recorded period	Mean temperature
Ratelgat (S27)	2001–2009	19.9 (3.5–46.0) °C
Mean solar radiation	**Mean wind speed**	**Mean annual precipitation**
674 (279–1050) MJ·m^{-2}·month^{-1}	3.9 (13.2) m·s^{-1}	124 (10–175) mm
Mean annual potential evapotranspiration	**Interannual precipitation variability**	**Mean relative humidity**
1549 mm	130%	58% (38–81%)
Aridity index (UNEP)		
0.08 (arid)		

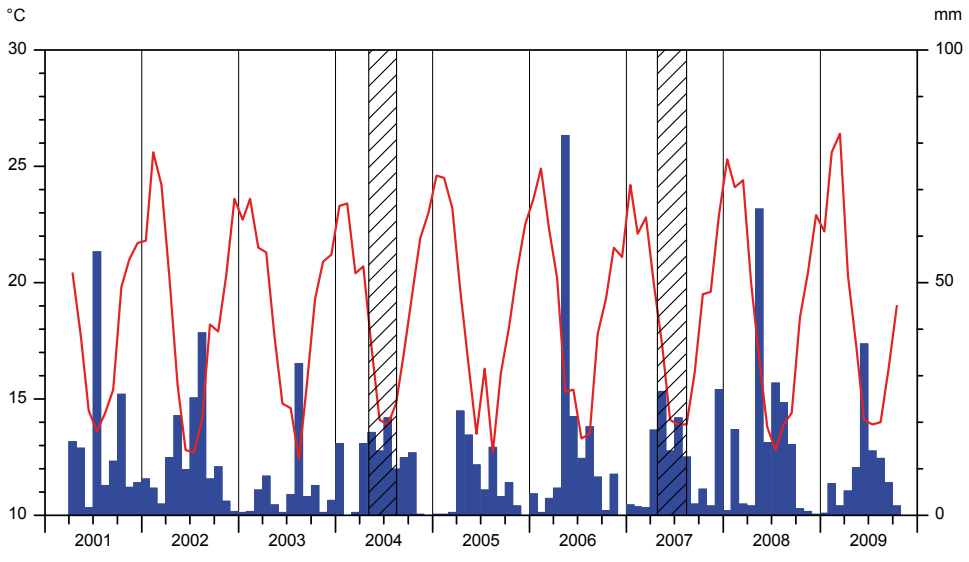
Modelled data

Mean temperature	Mean annual temperature range	Mean diurnal temperature range
18.9 (6.5–32.3) °C	10.7 °C	15.4 °C
Mean annual precipitation	**Precipitation seasonality**	**Percentage winter precipitation**
162 mm	64%	78% (winter)
Climate type	**Length of dry season**	**Aridity index (De Martonne)**
BSh	11 months	5.6 (dry)

The climate at the Observatory is characterised by arid conditions. Rainfall shows a moderate seasonality with more rain falling during the winter season, peaking in May. The mean annual rainfall over the observation period was 124 mm, which is fairly dry in comparison to the average rainfall recorded over the entire transect, but is in line with the average of the Observatories within the Succulent Karoo. However, substantial interannual variability is evident. The observed near-surface air temperatures show a moderate seasonal cycle. The mean annual temperature is 19.9°C, which approximates the average for this biome. Compared to the interpolated long-term data taken from the WorldClim dataset, a slightly warmer mean annual temperature is observed at the station. For precipitation, mean annual rainfall observed at the BIOTA weather station is markedly lower than that of the WorldClim dataset. The rainfall seasonality is also less pronounced in the station data.

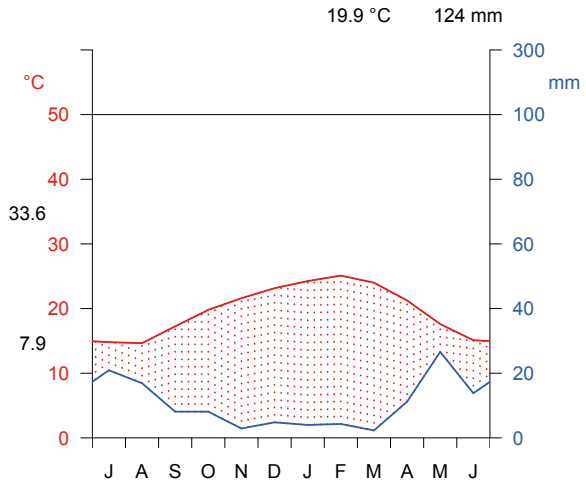
The observed near-surface winds at the Observatory are predominantly constituted of south-westerly flows, but a northerly component is also evident during winter. Mean wind speed shows a pronounced annual cycle in the evenings, and a moderate annual cycle in the mornings and early afternoons. Strongest winds occur in the evening during the summer, reaching up to about 28 km/h.

Time series: rainfall and temperature

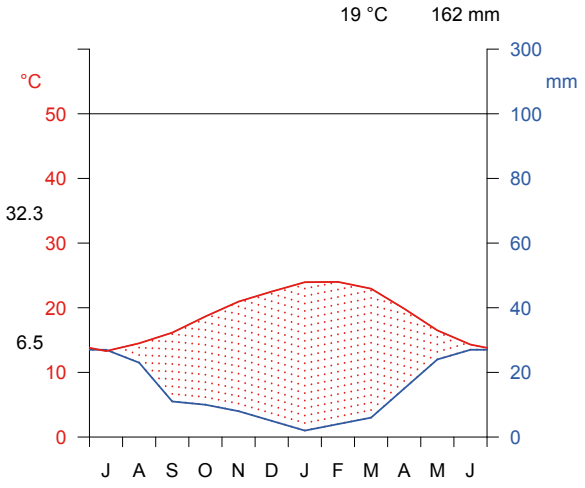


Climate diagrams

Recorded data (BIOTA)

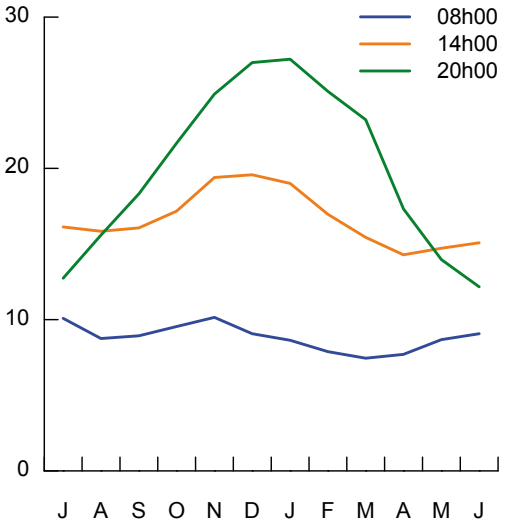


Modelled data (WorldClim)

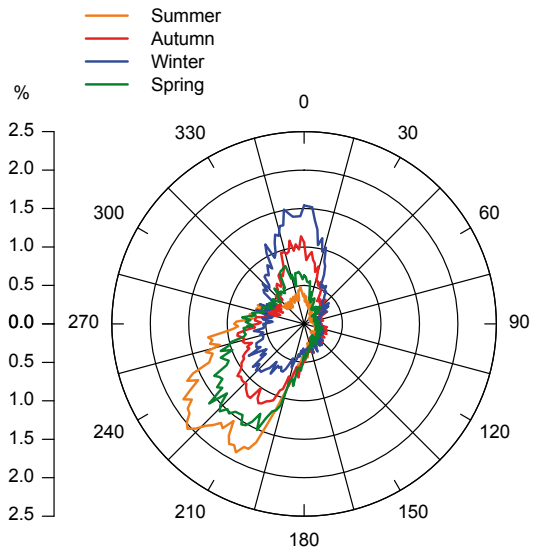


Wind diagrams

Speed



Directions



Responsible authors: K. Berger, A. Haensler & J. Luther-Mosebach

Soils

Year of sampling	Hectare plots sampled	SOTER unit
2002	25 (R1–25)	ZA2024
Soilscape	**Dominant soil group(s)**	**Reference group richness**
n.a.	Cambisol, Solonchak, Leptosol	4
Soil unit richness	**Soil unit evenness**	**Soil ecotype richness**
11	0.663	12
Parametric space	**pH**	**Electrical conductivity**
4.38	7.3 (4.0–9.0)	1140 (37–28,300) $\mu S \cdot cm^{-1}$
Organic carbon		
0.80% (0.15–1.76%)		

On this Observatory, four soil reference groups are found: Cambisol, Leptosol, Fluvisol, and Solonchak. The Solonchaks, all qualified with the prefix 'Hypersalic', are typical for salt-enriched quartz fields. Cambisols are found on less saline substrates and are characterised by an intensive red, loamy texture, often densely packed with residual quartz debris. The Endo- and Epileptic qualifiers characterise the depth of these profiles with respect to the underlying bedrock. The shallowest soil unit, Leptosols, are found on shallow phyllite and schist bedrock or larger quartz outcrops. The Leptosols are further divided by means of the Dystric and Eutric qualifiers, reflecting the wide range of base saturation. The Hypereutric Fluvisols are characterised by a high pH value and a dense shrub cover of *Galenia africana*, well visible on the aerial photography (compare Remote sensing and Landscape Section) characterised by a dark appearance. The Fluvisols are the only soil unit that can be clearly assigned to a topographical position, namely dry rivers, while the occurrence of the other soil units is only driven by small-scale changes of varying bedrock depth and enrichment of soluble salts.

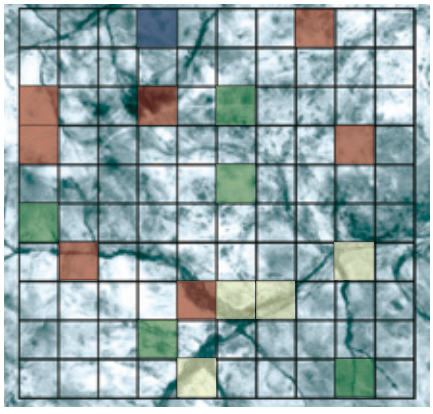
The pH values show wide ranges from very low to low. The same is true for the electrical conductivity with a median of 1 mS cm-1 indicating salt-enriched conditions, while also high proportion of non-salt affected as well as extremely saline soils occur. The degree of salinity also affects the content of organic carbon, which shows wide ranges and a strong decrease with depth. Saline sites are regularly less enriched in organic carbon. As a result, this Observatory, together with Observatory S27 (Ratelgat) is the most variable along the transect, especially with regard to soil pH and degree of salinity.

The proportion of fine particles (clay and silt) shows the lowest variability within the selected parameters and is characterised by the silty weathering products of phyllite. The median rooting space indicates the shallow and fragment-rich character of the sites except for the few dry river profiles with a high rooting space.

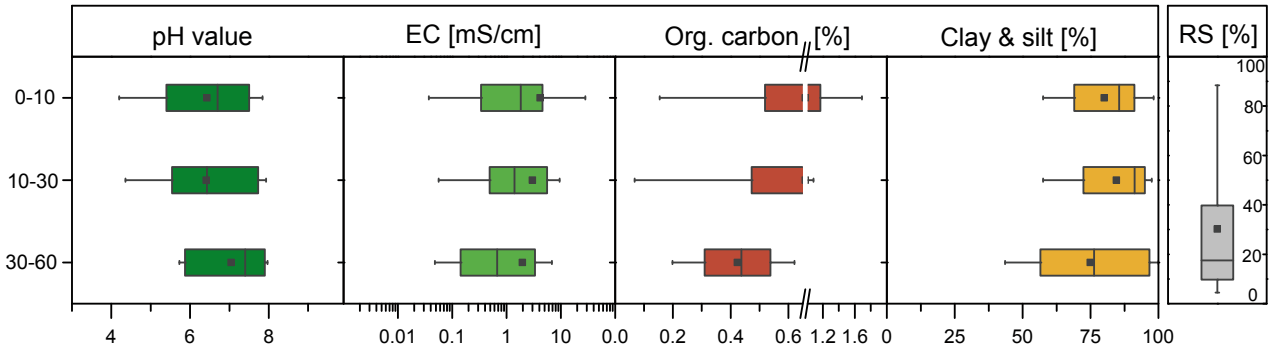
The spectrum of occurring textures is large, covering mainly silt, silt loam and sandy silt. With regard to the sand fractions, the samples predominantly consist of coarse and fine sands. The parent material (schist, phyllite) provides typical fine sand as weathering product; however, microfragments of phyllites occur as coarse sand in the analyses and thus influence the results.

The occurring quartz cover as such cannot be used as an indicator for specific soil properties, as complete quartz coverings are found on various distinct soil and vegetation units. The impression that there is a higher quartz cover in certain habitats is mainly due to the low vegetation cover on saline quartz fields, while less saline quartz-covered soils are more densely vegetated and appear less white.

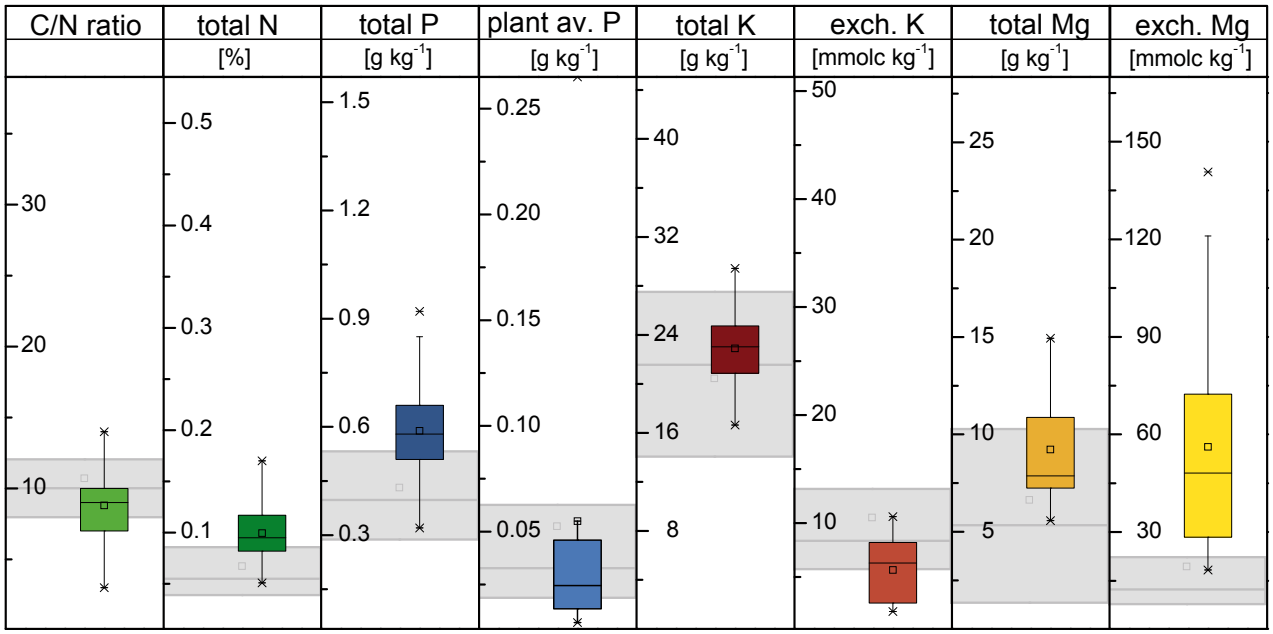
Map of soil profiles



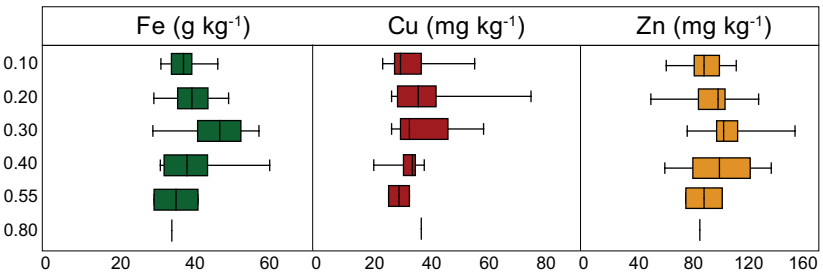
Soil characteristics



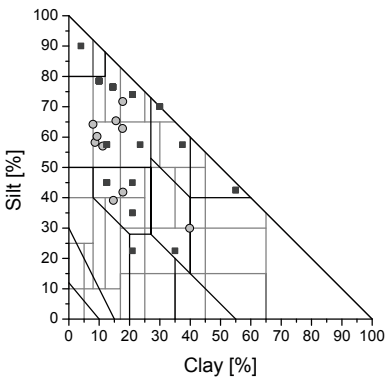
Soil nutrients



Soil micronutrients



Soil texture triangle

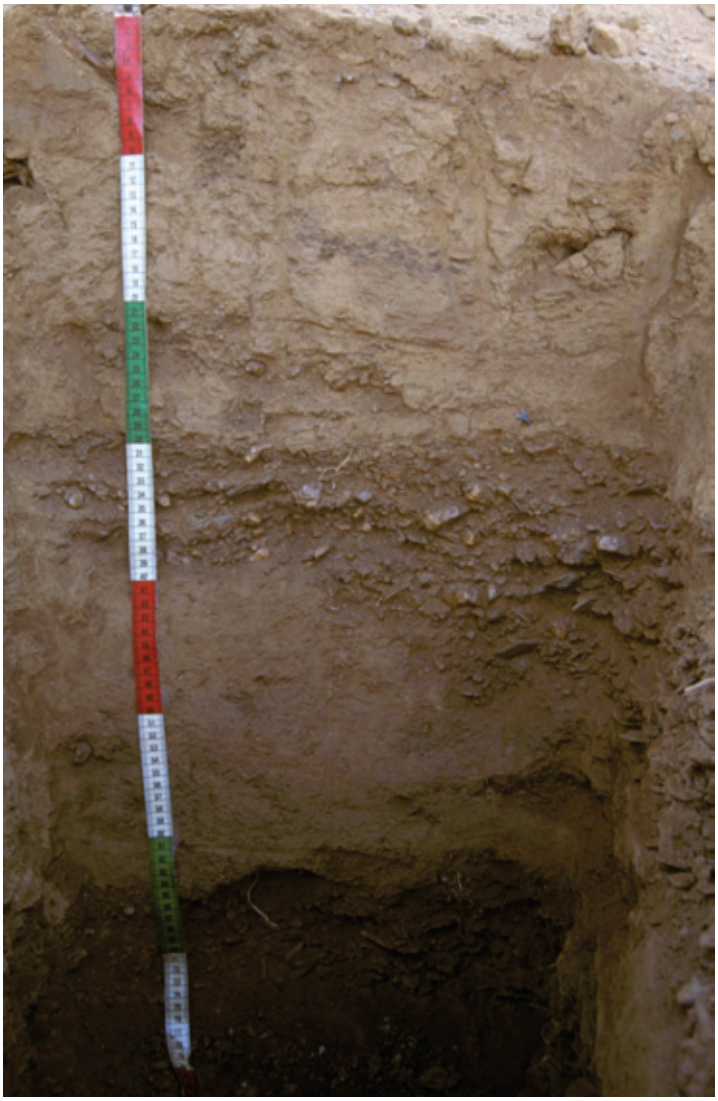


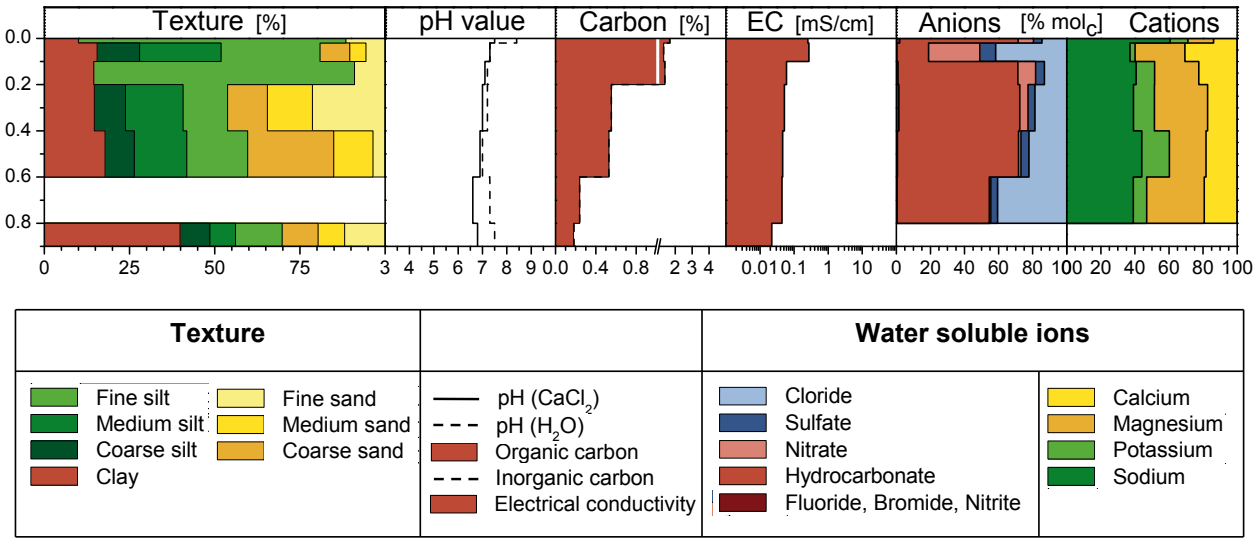
Reference profile (H68)

The occurrence of **Haplic Fluvisols** (Hypereutric) is restricted to the dry rivers dissecting both Observatories Goedehoop (S26) and Ratelgat (S27). The untypical depth of the solum shows characteristics of fluvial deposition. The low flow intensity of the dry rivers is reflected in the silt-rich texture of the soil material (similar to the bedrock derived soils on the slopes and plains). The decreasing trend of organic carbon may be a result of an in-situ accumulation of humus and is therefore an indication of a relatively high profile age.

The content of rock fragments varies from 5 to 40% due to the differences of fluvial sedimentation. The soil structure is subangular blocky, and excavation difficulty is low to moderate. Rooting is deep with up to 20 roots dm^{-2} in the topsoil and still 6–10 roots dm^{-2} at a depth of 80 cm.

The non-saline character is expressed by low electrical conductivity values of 50–90 µS cm^{-1}. The pH value is moderately high and constant with depth except for the strongly alkaline upper thin horizon. The fact that *Galenia africana* occurs very frequently has to be considered when interpreting the high pH values of the profile as this species is concurrently suspected to increase pH values (see Allsopp 1999). The total reserve of bases varies only slightly with depth around 190 cmol kg^{-1}. As electrical conductivity indicates, the amount of water-soluble salts was very low with about 5 $mmol_c$ kg^{-1} in contrast to fairly high amount of exchangeable cations (about 100 $mmol_c$ kg^{-1}).





Responsible authors: U. Wisch, A. Petersen, A. Gröngröft & D. Mager

Biological soil crusts

Sampling period(s)	Hectare plots sampled	Types of soil crusts
2002, 2003	5 (R1, R2, R4, R5, R55)	2, 4, 6
Crust thickness	**Cover**	**Carbon [weight %]**
> 4 mm	up to 15% on stable soils	2.377
Nitrogen [weight %]	**Chlorophyll *a* [mg/m²]**	**Chlorophyll *a+b* [mg/m²]**
0.054	85	112

Hypolithic communities (type 6 crusts) occur approximately under 70% of the quartz stones, covering about half of the ground of quartz fields. These hypolithic crusts are characterised by a particularly high richness of cyanobacteria. Besides this crust type, well-developed cyanobacteria-dominated crusts and lichen-dominated crusts with green algae occur on stable soils between the quartz pebbles. These crusts also occur in other areas without the characteristic quartz layer, for example next to ephemeral brooks (rivier). In alluvial fans, containing large amounts of salt and gypsum, initial cyanobacteria-dominated crusts (type 1) also occur. Apart from small filamentous cyanobacterial taxa like Pseudanabaena, larger species capable of fixing atmospheric nitrogen are found. The rich coverage of biological soil crusts is proportional with high chlorophyll values as well as relatively high soil carbon- and nitrogen content as compared to the other Observatories.

Cyanobacteria: *Nostoc* sp., *Oscillatoria tenuis, Phormidium aerugineo-caeruleum, Phormidium vulgare, Phormidium* sp., *Pseudanabaena minima, Pseudanabaena* cf. *frigida, Pseudanabaena* cf. *tenuis, Pseudanabaena* sp., *Schizothrix lardacea, Schizothrix* sp., *Scytonema ocellatum, Syplocastrum* cf. *friesii, Tolypothrix distorta, Trichocoleus* cf. *delicatulus, Trichocoleus sociatus.*

Green algae: *Myrmecia israeliensis, Nautococcus* sp., *Neochlorosarcina negevensis, Neospongiococcum* cf. *punctatum, Scenedesmus* sp. 4, *Spongiochloris minor.*

Biological soil crust characteristics

	H13	H27	H38	H68	H80
Soil characteristics	Yellow-brown silt and quartz pebbles	Yellow-brown sand and silt, small quartz pebbles	Yellow-brown silt and quartz pebbles	Yellow-brown silty sand, few small quartz pebbles	Brown silty sand, few quartz pebbles
Crust characteristics	Hypolithic growth on quartz pebbles	Thin but extended well-developed dark BSC with lichens	Hypolithic growth on some quartz pebbles	Extensive light and dark BSC with few lichens	Small pieces with thin, brittle BSC; some areas with dark BSC
Chlorophyll *a* [mg/m²]	79.83	82.71	89.02	71.33	102.26
Chlorophyll *a+b* [mg/m²]	111.24	125.02	119.32	58.49	146.02
Carbon [weight %]	4.53	1.28	1.27	2.57	2.25
Nitrogen [weight %]	0.04	0.04	0.09	0.02	0.09

In-between the widespread quartz pebbles well-established cyanobacterial crusts are present. Photo: K. Deutschewitz.

The lower side of the majority of quartz pebbles is covered with hypolithic crusts. Photo: K. Deutschewitz.

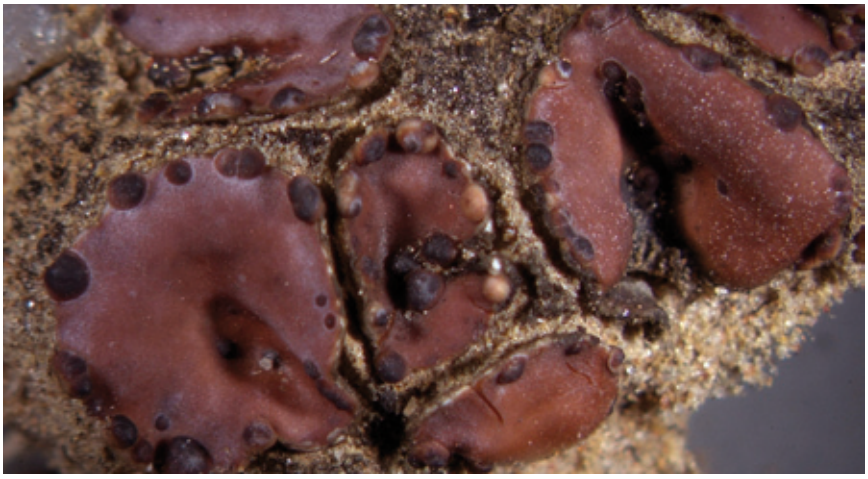
Responsible authors: B. Weber, K. Deutschewitz, S. Dojani, T. Friedl, T. Darienko, K. Mohr & B. Büdel

Lichens

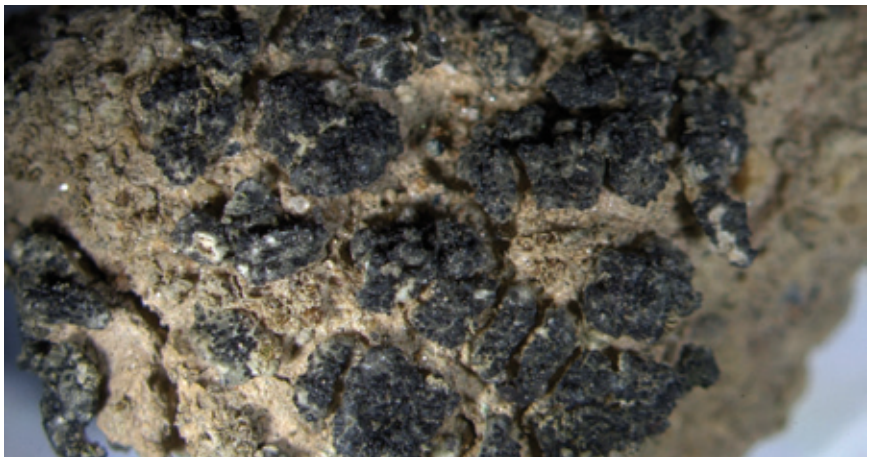
Sampling period(s)	Hectare plots sampled	Cover
2001, 2002	13 (R1−R10, R38, R80, R97)	18% (0−80%)
Total species richness	**Species richness on soil [1 km²]**	**Species richness on rock [1 km²]**
69	30 (43%)	20 (29%)
Species richness on plants [1 km²]	**Species richness on soil [1000 cm²]**	
19 (28%)	3.5 (0−10)	

This Observatory possesses an extraordinary and peculiar diversity of lichens, and is therefore one of the most interesting from a lichenological point of view. Lichens are common and abundant on all substrates and their unusually high richness is due to favourable climatic conditions. Besides a large group of globally widespread and ubiquitous species, several endemic soil-inhabiting taxa (especially *Xanthoparmelia* spp.) occur. Some species, e.g. from the genera *Buellia* and *Caloplaca*, are still undescribed. The alkaline, stable, and compact soils favour the prolific growth of terricolous lichens, whose diversity is even greater than in the lichen fields of the Namib Desert (Observatory S16/Wlotzkasbaken) and is the highest along the entire BIOTA transect. Terricolous lichens are mostly green algal taxa, with common squamulose and foliose growth habits, indicating high air humidity. Foliose taxa also indicate that disturbance by livestock trampling is low.

Lichen cover on soil is relatively high, and nine morphological groups occur in the surveyed hectare plots, mainly in H09, H25, H48, H51, H80, where three new lichen communities were identified by Zedda & Rambold (2009). High cover of quartz pebbles results in a decrease of lichen cover, probably also due to the high soil acidity associated with these areas. Lichens are not present in dry river beds as the soils are unstable. The high number of species and the presence of endemic taxa make this area unique and provide incentives for assigning it special conservation status.



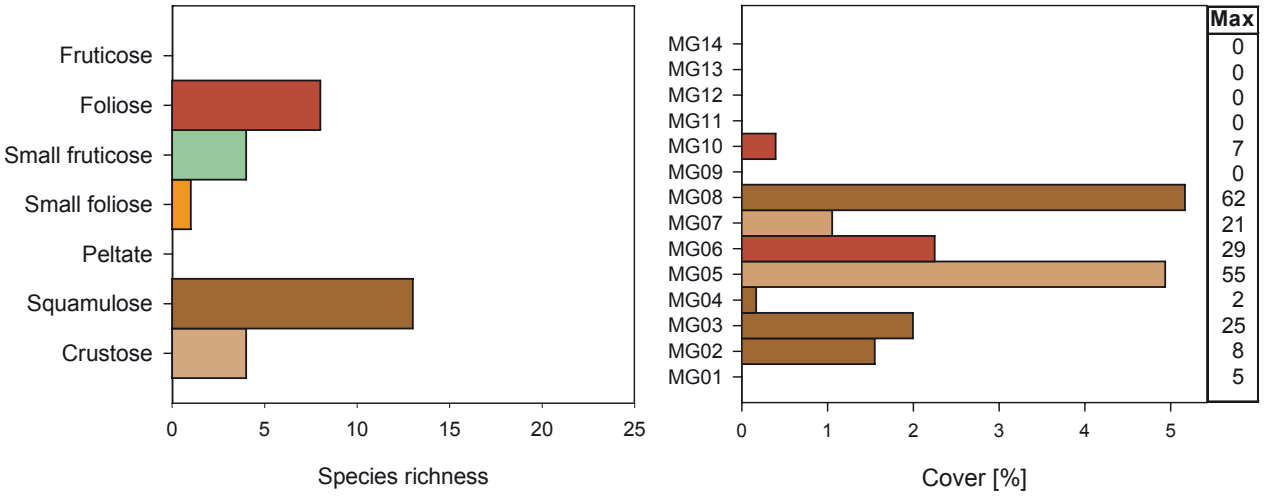
Psora crenata. Photo: L. Zedda & G. Rambold.



Toninia ruginosa subsp. *pacifica*. Photo: L. Zedda & G. Rambold.

Xanthoparmelia aff. *imitatrix*. Photo: L. Zedda & G. Rambold.

Life forms



List of Taxa

Terricolous (on soil):

Buellia sp. 01 (M-0039248)
Caloplaca sp. 01 (M-0038960)
Caloplaca sp. 02 (M-0038961)
Collema coccophorum
Diploschistes hensseniae
Eremastrella crystallifera
Heppia adglutinata
Lichinaceae sp.
Lichinella stipatula
Peccania arabica
Peccania font-queriana
Placidium squamulosum
Placidium tenellum
Psora aff. cerebriformis
Psora crenata
Psora sp. 01
Sarcogyne sp. 01 (M-0039028)
Toninia aff. ruginosa ssp. ruginosa
Toninia australis
Toninia lutosa
Toninia ruginosa ssp. pacifica
Verrucaria compacta agg.
Xanthoparmelia aff. imitatrix
Xanthoparmelia amphixanthoides
Xanthoparmelia crassilobata
Xanthoparmelia hyporhytida
Xanthoparmelia leonora
Xanthoparmelia prolata
Xanthoparmelia simulans
Xanthoparmelia sp. 01 (M-0039013)

Saxicolous (on rock):

Acarospora sp.
Acarospora strigata
Amandinea punctata
Buellia concinna var. oceanica
Buellia sp.
Caloplaca baueri
Caloplaca rubelliana
Caloplaca sp.
Diploschistes aeneus
Diploschistes austroafricanus
Diploschistes hensseniae
Lecidea sp.
Lichinella sp.
Neofuscelia
Paraparmelia
Peccania sp.
Rinodina sp.
Xanthoparmelia hottentotta
Xanthoparmelia spp. (3)

Epiphytic (on plants):

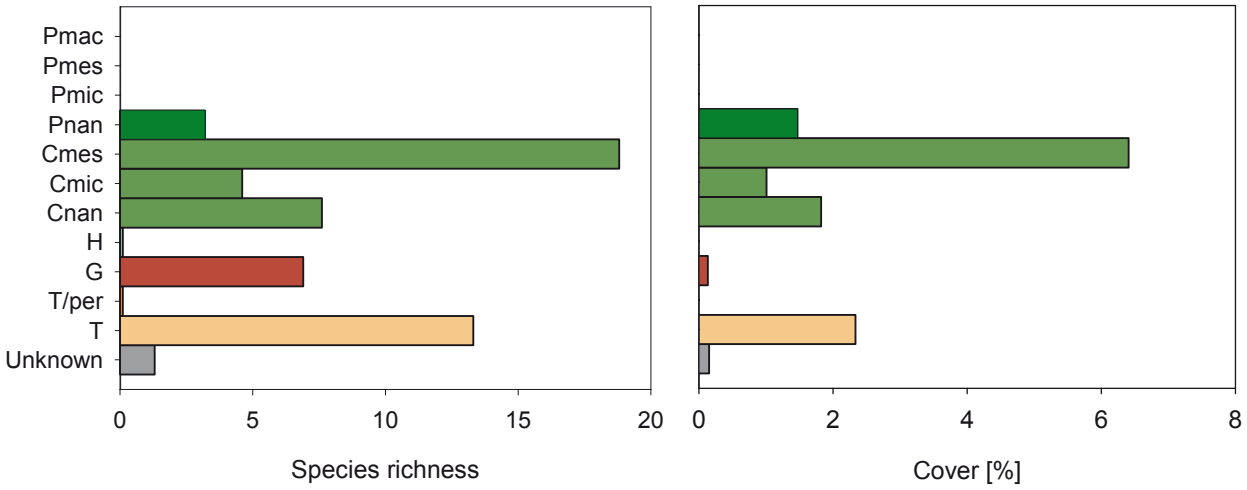
Amandinea extenuata
Arthonia sp.
Buellia spp. (2)
Calicium sp.
Caloplaca holocarpa
Caloplaca sp.
Candelaria concolor
Dirinaria complicata
Hyperphyscia pruinosa
Hyperphyscia syncolla
Lecanora sp.
Opegrapha sp.
Opegrapha varia
Physcia sp.
Rinodina plana
Rinodina pyrina
Xanthoria parietina
Xanthoria sp.

Responsible authors: L. Zedda & G. Rambold

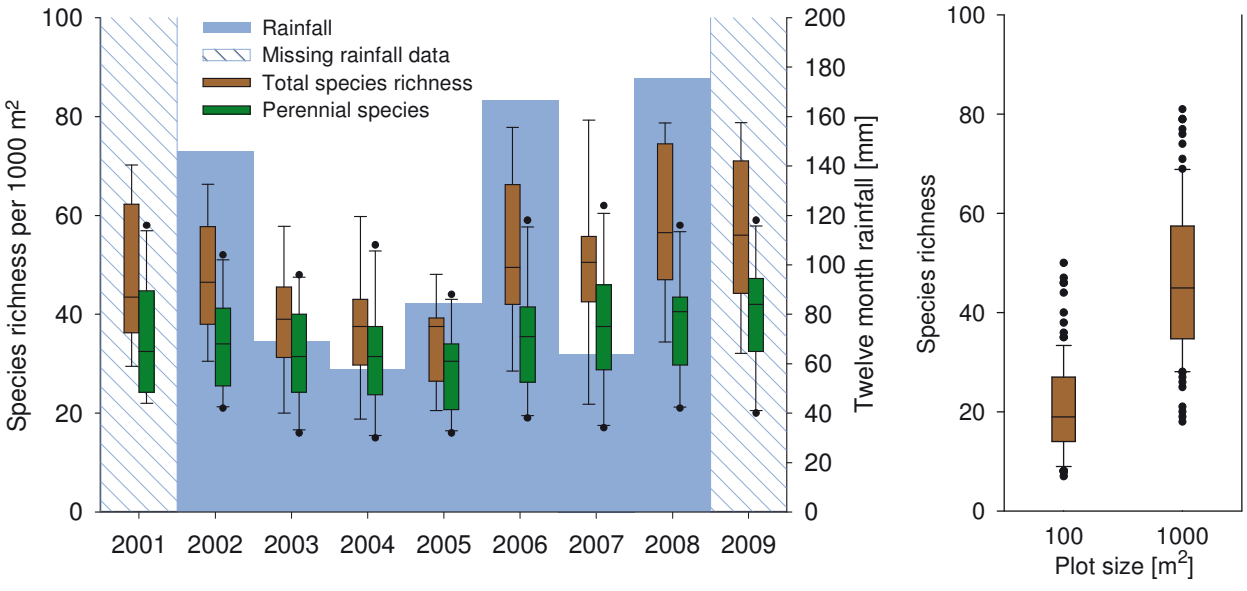
Vascular plants

Sampling period(s)	Hectare plots sampled	Biome
2001–2009	10 (R1–R9, R30)	Succulent Karoo
Vegetation unit (level 1)	**Vegetation unit (level 2)**	**Identification rate**
Knersvlakte Bioregion	SKk 3 Knersvlakte Quartz Vygieveld	79% – 92% – 91%
Cumulative family richness	**Dominant families (cover)**	**Dominant families (richness)**
38	Aizoaceae, Chenopodiaceae, Asteraceae	Aizoaceae, Asteraceae, Crassulaceae
Cumulative species richness (1 km²)	**Species richness (1000 m²)**	**Species richness (100 m²)**
302 – 207	47.0 (18–81)	21.1 (7–50)
***z*-value**	**Species richness change per year (1000 m²)**	**Evenness (1000 m²)**
0.347 (0.165–0.917)	0.50	0.617 (0.188–0.855)
Evenness (100 m²)	**Simpson (1000 m²)**	**Simpson (100 m²)**
0.594 (0.214–0.875)	0.778 (0.237–0.953)	0.706 (0.210–0.909)

Life forms



Species richness



The landscape of Goedehoop Observatory is characterised by a mosaic of large quartz fields and zonal habitats without quartz cover, which are interspersed by heuweltjies. The vegetation of the Observatory falls under the Northern Knersvlakte Vygieveld (SKk 1) and the Knersvlakte Quartz Vygieveld (SKk 3, Mucina et al. 2006). Both vegetation types are dominated by leaf-succulent dwarf shrubs typical of the Succulent Karoo but differ in their vegetation structure and species composition.

Outside the quartz fields, vegetation is characterised by taller shrubs (C mes to P), mostly Aizoaceae, Chenopodiaceae and Asteraceae. Typical species are *Ruschia subsphaerica*, *R. bolusiae Drosanthemum* spp., *Lycium* spp. and various leaf-succulent, shrubby *Asteraceae*. The circular heuweltjie patches, which are a favourable habitat for fast-growing shrubs, are typically dominated by dense stands of *Lampranthus otzentianus*, *Psilocaulon leptarthron*, and *Stoeberia frutescens* or the creeping *Cephalophyllum framesii*. In spring, after good winter rainfall, geophytes and the famous Namaqua daisies (annual species of Asteraceae) occur in high abundance.

Quartz fields are typically inhabited by very compact dwarf succulent (C nan, C mic) Aizoaceae. Dominant quartz field species that may cover large areas with high densities are the Knersvlakte endemics *Cephalophyllum spissum* and *Argyroderma fissum* (Vingervygie). Quartz fields are often dominated by a single species, whereas other species only have very low cover values. This dominance structure causes the generally low evenness values of the quartz field vegetation. The small-scale mosaic of the quartz fields has a high spatial species turnover (i.e. β-diversity), expressed as very high z-values, which are amongst the highest along the entire BIOTA transect.

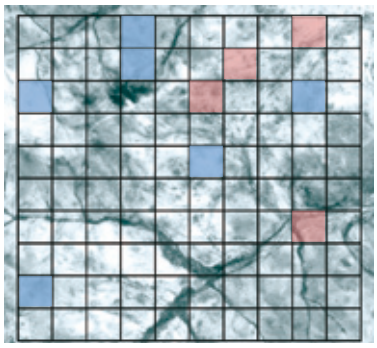
Two main vegetation units can be distinguished: the vegetation on the mosaic of zonal soils and quartz field with high soil salinity and neutral soil pH; and the vegetation occurring on the mosaic of zonal soils with acid soils (pH < 5) with less saline quartz fields (Schmiedel & Jürgens 1999). These two main

Quartz field dominated landscape of Goedehoop. Photo: U. Schmiedel

Unit 1, H61, saline quartz field with high abundance of *Mesembryanthemum fastigiatum* in the background, 2006. Photo: R. Christiaan.

Unit 2, H80, acid quartz fields with *Monilaria chrysoleuca* in the foreground, 2007. Photo: R. Christiaan.

Map of vegetation units



vegetation units are reflected in the vegetation classification.

The *Cephalophyllum framesii-Ruschia subsphaerica* community (unit 1) corresponds to the characteristic vegetation of saline quartz fields and zonal soils. Saline quartz fields are low lying, flat areas or plateaus, dominated by the Knersvlakte-endemic, compact dwarf shrub *Argyroderma fissum,* which may occur at high densities in patches. During spring of good rainfall years, the quartz fields with higher soil salinity that have only sparse perennial vegetation cover are densely covered by the succulent annual Aizoaceae *Mesembryanthemum fastigatum* and *M. nodiflorum*. Adjacent soils without quartz cover are dominated by shrubby Aizoaceae such as *Ruschia subsphaerica* and the similar looking *Antimima excedens*, both also Knersvlakte-endemics. Deeper soils that provide more favourable habitats are characterised by *Psilocaulon leptarthron* and *Drosanthemum* sp. 116576, which are frequently accompanied by the annual *Mesembryanthemum guerichianum* (Soutslaai) after good rains. This community corresponds to the *Psilocaulon leptharthron-Euphorbia muricata* alliance, described by Schmiedel (2002) for the Knersvlakte.

The *Senecio aloides-Ruschia burtoniae* community (unit 2) occurs on the mosaic of mainly acid quartz fields and zonal soils. Acid quartz fields typically occur on hill tops or around quartz outcrops and are thus covered by larger quartz gravel

Classification table (2008)

Column	Cover	All	1	2
Number of relevés		**10**	**4**	**6**
Mean cover [%]		16.1	23.0	11.5
Mean species richness (1000 m²)		58.2	69.3	50.8
Inclination [°]		5.8	5.5	6.0
Mean soil pH		6.60	6.8	6.5
Mean electrical conductivity [µS·cm^{-1}]		4085	2174	5360
Organic carbon [%]		0.71	0.8	0.64
Nitrogen [%]		0.08	0.1	0.08
Fine material [%]		15.8	31.5	5.3
Gravel [%]		55.3	61.3	51.3
Stones 2-6 cm [%]		27.9	7.0	41.8
Stones 6-20 cm [%]		0.6	0.3	0.8
Stones 20-60 cm [%]		0.3	0.0	0.5
Biotic crust		6.2	3.0	8.4
Unit 1: Cephalophyllum framesii-Ruschia subsphaerica community*				
Cnan	Cephalophyllum framesii	0.42	40	100 .
Cmes	Psilocaulon dinteri	0.19	40	100 .
T	Mesembryanthemum guerichianum	0.06	40	100 .
T	Osteospermum pinnatum var. pinnatum	0.08	50	100 17
Cmes	Drosanthemum sp. 116576	0.14	30	75 .
Cmes	Psilocaulon leptarthron	0.48	30	75 .
Cmic	Zygophyllum retrofractum	0.11	30	75 .
T	Tetragonia microptera	0.01	30	75 .
G	Androcymbium cf. capense	0.01	30	75 .
T	Schismus barbatus	0.03	60	100 33
Cmic	Drosanthemum schoenlandianum	0.13	40	75 17
T	Mesembryanthemum nodiflorum	0.03	40	75 17
Cnan	Argyroderma fissum	0.12	40	75 17
n.a.	Jamesbrittenia racemosa	0.02	20	50 .
Cmes	Antimima excedens	0.03	20	50 .
Cnan	Malephora purpureo-crocea	0.22	70	100 50
T	Helichrysum leontonyx	0.12	70	100 50
T	Tribolium utriculosum	0.01	20	50 .
T	Crassula vaillantii	0.07	20	50 .
T	Didelta carnosa	0.07	70	100 50
Cmic	Helichrysum dregeanum	0.18	20	50 .
Cmes	Ruschia subsphaerica	3.50	20	50 .
Cmes	Galenia sarcophylla	0.06	20	50 .
T	Tripteris clandestina	0.01	20	50 .
Cmes	Galenia fruticosa	0.01	20	50 .
T	Lepidium desertorum	0.13	20	50 .
Cmes	Drosanthemum deciduum	0.02	20	50 .
Cmes	Phyllobolus nitidus	0.02	20	50 .
Unit 2: Senecio aloides-Ruschia burtoniae community*				
Cnan	Senecio aloides	0.01	50	. 83
G	Bulbine sedifolia	0.01	40	. 67
G	Othonna intermedia	0.05	40	. 67
Cmes	Pteronia ciliata	0.10	30	. 50
Cmes	Pelargonium crithmifolium	0.01	30	. 50
Cmes	Monilaria chrysoleuca	0.06	30	. 50
Cnan	Conophytum calculus ssp. calculus	0.04	30	. 50
G	Moraea serpentina	0.01	30	. 50
Cnan	Anacampseros filamentosa ssp. namaquensi	0.01	30	. 50
T	Helichrysum sp. 14946	0.01	30	. 50

**only the highly diagnostic species are significant according to Fisher's exact test*

continued on next page

Classification table (continued)

Column		Cover	All	1	2
Number of relevés			**10**	**4**	**6**
Most frequent companions					
Cmes	Tripteris sinuata var. sinuata	0.05	100	100	100
T	Heliophila variabilis	0.03	100	100	100
Cmes	Drosanthemum diversifolium	0.44	90	100	83
T	Foveolina dichotoma	0.41	90	100	83
Cnan	Conophytum minutum var. pearsonii	0.04	90	75	100
G	Oxalis luteola	0.03	90	100	83
T	Mesembryanthemum fastigiatum	1.69	80	75	83
Cnan	Cephalophyllum spissum	1.33	80	75	83
Cmes	Salsola sp. 116850	0.49	80	75	83
T	Amellus microglossus	0.19	80	100	67
Cmes	Tetragonia fruticosa	0.09	80	75	83
G	Caulipsolon rapaceum	0.09	80	100	67
Cmic	Zygophyllum cordifolium	0.07	80	100	67
Cmes	Asparagus recurvispinus	0.04	80	75	83
T	Gazania lichtensteinii	0.01	80	100	67
Cnan	Crassula columnaris ssp. prolifera	0.01	80	100	67
T	Atriplex lindleyi ssp. inflata	0.01	80	100	67
Csub	Argyroderma delaetii	3.78	70	75	67
Pnan	Lycium cinereum	0.48	70	75	67
Cmes	Drosanthemum pulverulentum	0.27	70	75	67
Cnan	Conophytum subfenestratum	0.05	70	75	67
Cmes	Tetragonia verrucosa	0.03	70	50	83
T	Senecio arenarius	0.01	70	75	67
Cmes	Drosanthemum globosum	0.15	60	75	50
T	Ursinia nana ssp. nana	0.07	60	50	67
G	Albuca viscosa	0.01	60	50	67
Cmes	Ruschia bolusiae	0.21	50	75	33
Cmic	Antimima watermeyeri	0.09	50	50	50
Pnan	Lampranthus watermeyeri	0.04	50	50	50
Cmes	Pteronia glabrata	0.04	50	75	33
G	Moraea miniata	0.01	50	75	33
Cmes	Ruschia burtoniae	0.84	40	25	50
Pnan	Lycium ferocissimum	0.68	40	50	33
Cmes	Salsola sp. 116603	0.21	40	25	50
Cnan	Cephalophyllum staminodiosum	0.15	40	25	50
Cmes	Monilaria moniliformis	0.15	40	25	50
Pnan	Aridaria noctiflora ssp. noctiflora	0.09	40	50	33
Cmes	Ruschia spinosa	0.08	40	50	33
Cmes	Sarcocaulon crassicaule	0.07	40	50	33
Cmes	Phyllobolus spinuliferus	0.06	40	50	33
Cmes	Pteronia succulenta weiss	0.04	40	25	50
Cmes	Pentzia peduncularis	0.03	40	25	50
G	Bulbine fallax	0.02	40	25	50
G	Oxalis sp. 116852	0.01	40	50	33
G	Chlorophytum undulatum	0.01	40	25	50
Cnan	Tylecodon pygmaeus	0.01	40	25	50
G	Oxalis pes-caprae	0.01	40	50	33
Cmes	Galenia africana	3.57	30	50	17
Pnan	Lampranthus otzenianus	3.34	30	50	17
Cmes	Berkheya fruticosa	0.87	30	50	17
Cmes	Sarcocornia xerophila	0.21	30	25	33
Cmes	Eriocephalus namaquensis	0.18	30	25	33
Pnan	Hoplophyllum spinosum	0.14	30	25	33
Pnan	Aridaria serotina	0.12	30	50	17
Cmes	Asparagus capensis	0.11	30	25	33
T	Ehrharta triandra	0.11	30	50	17
Cmes	Thesium lineatum	0.07	30	25	33
Cmes	Hermannia cuneifolia var. glabrescens	0.05	30	50	17
Cnan	Antimima solida	0.04	30	25	33

than the saline quartz fields. Typical and locally dominating species on acid quartz fields are the shrubby *Ruschia burtoniae*, the compact dwarf shrub *Conophytum calculus* subsp. *calculus*, and *Monilaria chrysoleuca* (Bobbejaansvinger). *Senecio aloides* of the Asteraceae, a leaf-succulent dwarf shrub that mainly grows below other shrubs, does not reach high cover values but is typical of the community. This community corresponds to the *Conophytum calculus* subsp. *calculus* group, described by Schmiedel (2002) for the acid quartz fields in the Knersvlakte.

Argyroderma fissum is often found on the quartz fields of Goedehoop.
Photo. U. Schmiedel

Argyroderma patens is endemic to the quartz fields of the farms Goedhoop, Ratelgat and surroundings.
Photo: U. Schmiedel

Cephalophyllum spissum is a typical quartz field dweller of the Knersvlakte.
Photo: U. Schmiedel

Responsible authors: U. Schmiedel & J. Luther-Mosebach

Vertebrates

Total species richness	Reptile species richness	Bird species richness
13	n.a.	13
Large mammal species richness	Small mammal species richness	
n.a.	n.a.	

Birds

Passeriformes	**Perching birds**
Cercomela schlegelii	Karoo Chat
Cercotrichas coryphaeus	Karoo Scrub-Robin
Cinnyris fuscus	Dusky Sunbird
Cisticola subruficapillus	Grey-backed Cisticola
Emberiza capensis	Cape Bunting
Galerida magnirostris	Large-billed Lark
Parisoma layardi	Layard's Tit-Babbler
Parus afer	Southern Grey Tit
Serinus flaviventris	Yellow Canary
Telophorus zeylonus	Bokmakierie
Gruiformes	**Cranes, rails, coots, and allies**
Eupodotis vigorsii	Vigors´s Bustard
Neotis ludwigii	Ludwigs Bustard
Falconiformes	**Birds of prey**
Falco tinnunculus	Common Kestrel

Responsible author: W. Mey

Mating couple of stone grasshopper (family Pamphagidae) on quartz fields. Photo: U. Schmiedel.

General data

Number	Name	Alternative name(s)
S27	Ratelgat	Luiperskop
Implementation	**Country**	**Province/ region**
2001	South Africa	Western Cape
District/ constituency	**Locality**	**Farm name**
West Coast	Van Rhynsdorp	Luiperskop 211
Latitude	**Longitude**	**Altitude**
31.285881 S	18.600308 E	239 m a.s.l.
Rainfall season	**Biome**	**WWF Ecoregion**
Winter	Succulent Karoo	AT1322 Succulent Karoo
Agro-Ecological Zone	**Relative intensity of land use**	**Tenure**
n.a.	Medium	Communal
Type and history of landuse	**Land owner**	
Farming with sheep	Private	

Ratelgat (S27)

The farm Ratelgat is used for small stock farming and eco-tourism. The photo shows one of the small farm houses. Photo: J. Deckert.

The BIOTA Observatory Ratelgat (S27) is situated on the farm Ratelgat (or Luiperskop), in the Knersvlakte about 40 km north of the small town Vanrhynsdorp, east of the N7 National Road. The farm is owned by the Griqua Ratelgat Development Trust, an organisation that aids the economic and cultural development of the indigenous Griqua community of South Africa. The farm is used for small stock farming (mainly sheep) and eco-tourism but is also an important heritage site of the Griqua community.

The Knersvlakte is a low lying, gently undulating plain (approximately 240 m a.s.l. on Ratelgat), in the Succulent Karoo Biome of southern Namaqualand. The average annual rainfall in the area is very low but the plants benefit from the regular occurrence of fog and dew. The area is dominated by shale, phyllite, and limestone, and is intruded by numerous quartz veins from where the dense layer of quartz gravel, which forms the quartz patches, originates. The quartz fields are a defining feature of the Knersvlakte. They accommodate a unique and special flora dominated by compact, leaf-succulent dwarf shrubs. Many species found in this special habitat are obligate quartz-field dwellers and often have a very restricted distribution range. The rich quartz field flora of the Knersvlakte thus contributes strongly to the generally high levels of diversity and endemism found in the Knersvlakte. The quartz fields are the main reason for the recent establishment of a nature reserve in the

Knersvlakte (see Moedverloren Observatory, S28).

The BIOTA Observatory was established to investigate the impacts of the projected climate change and small-stock farming on the diverse Succulent Karoo flora of the Knersvlakte. The aim of the Observatory pair Goedehoop (S26) and Ratelgat (S27) is to monitor the impacts of commercial farming on Goedehoop and the more ecotourism-oriented management on Ratelgat.

Responsible authors: U. Schmiedel & D.H. Haarmeyer

Remote sensing and landscape

Geomorphology	Geological units	Lithological units
Hills, rivier	Nama System	Quartzite, arkose, limestone, shale, phyllite, tillite, lava, tuff
Mean EVI	**EVI absolute range**	**Mean leaf area index**
0.109 (0.094–0.144)	0.088 (2001)–0.176 (2008)	0.30

Grid map of Observatory

	0	1	2	3	4	5	6	7	8	9
0	16	96	67	8	60	86	84	97	98	82
1	32	99	100	64	42	77	18	88	94	81
2	56	54	63	75	57	92	27	43	12	49
3	45	69	76	47	50	10	89	35	5	2
4	44	51	62	31	26	91	78	20	23	11
5	59	83	87	93	48	36	40	3	72	34
6	9	70	28	13	73	41	53	66	19	79
7	58	25	33	6	24	85	37	71	15	1
8	14	7	30	38	22	29	80	39	95	65
9	74	52	61	46	4	90	17	55	68	21

1 Quartz hill with compact dwarf succulents
2 Quartz / non-quartz mosaic
3 Quartz hill with rivier
4 Plains without quartz cover and succulent shrubs
5 Quartz fields with shrubby vegetation

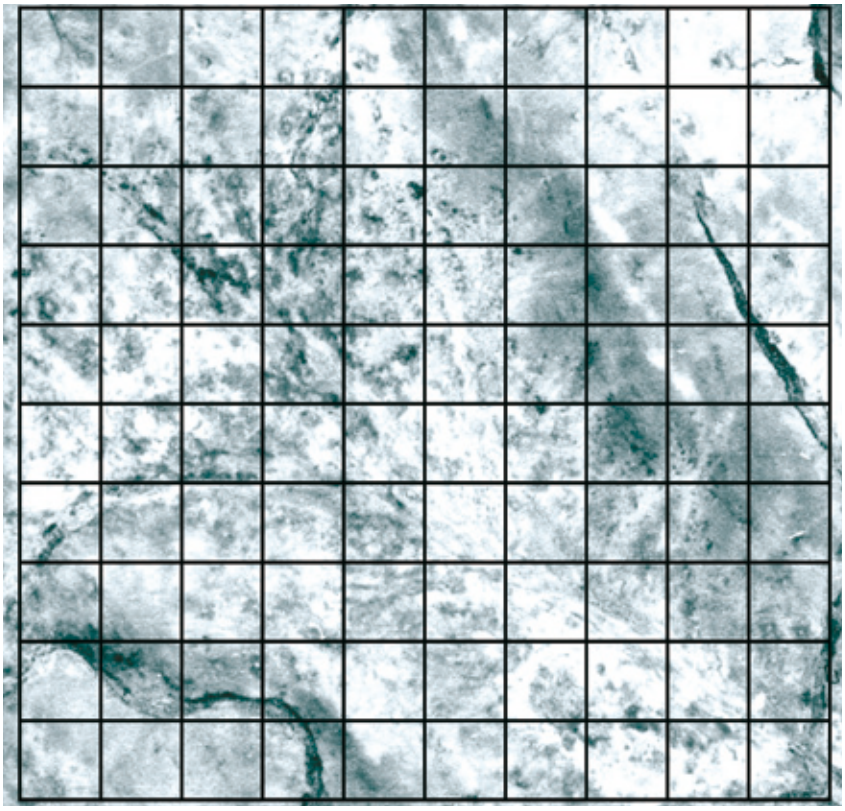
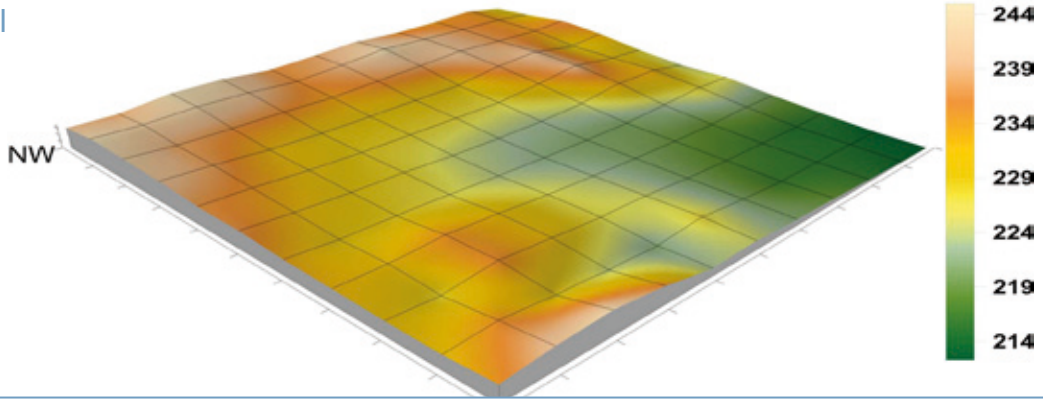


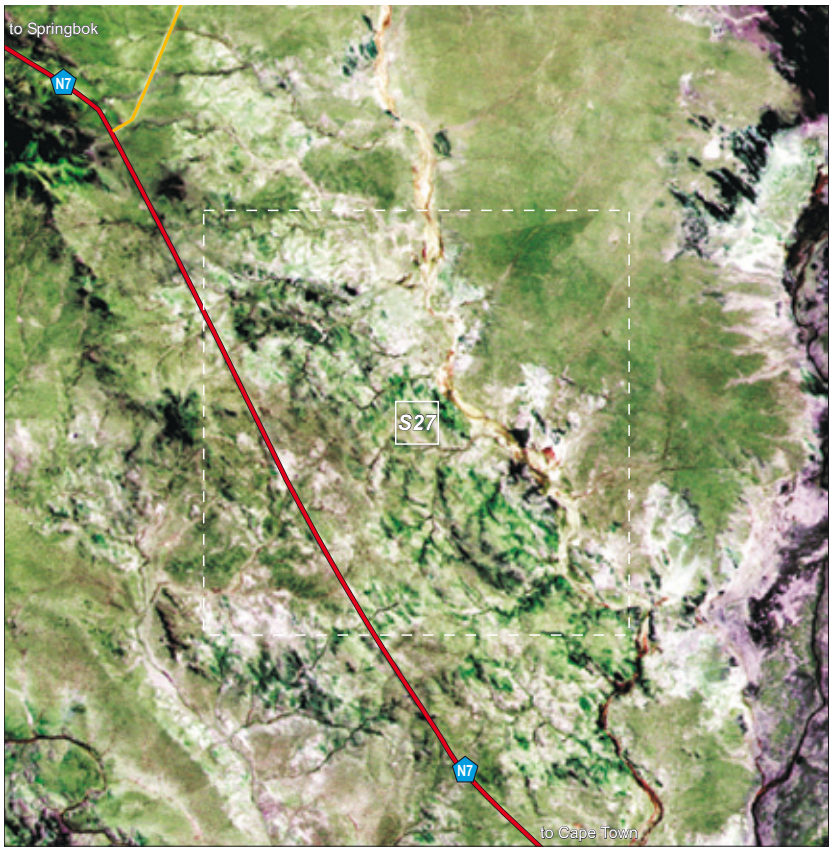
Image: aerial photograph

Elevation model of Observatory



Landsat image

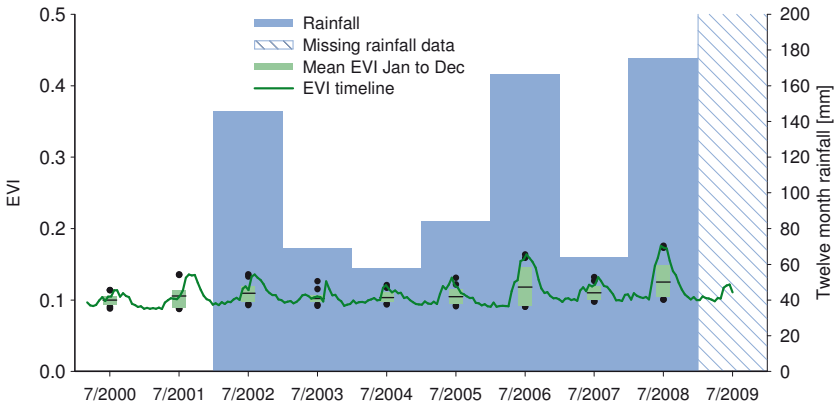
Defining features of the lithology in the Knersvlakte are the numerous intruded quartz veins and dens layers of quartz gravels, as well as shale, phyllite, and limestone rocks. The quartz fields in the Knersvlakte represent a unique flora and vegetation, dominated by leaf-succulent dwarf shrubs. The vegetation cover in the heterogeneous parts of the Knersvlakte shows up as green colours, and areas with a higher degree of bare surfaces in grey to white tones. A river valley of a tributary of the Olifants River draining to the south can be recognised in the western part of the image. In this river valley, patterns of woody vegetation are evident from the brown colours while light yellow to white tones indicate more open surfaces. East of the river valley, a much more homogeneous vegetation cover (succulent shrub communities on deeper homogenous loamy-sandy soils) shows up as grey-green tones. The western part of the image is crossed by the N7 national road.



Scene: 175/82, acquisition date: 07 February 2007

MODIS time series

Temporal patterns of annual rainfall, vegetation cover, and phenology



Responsible authors: M. Keil & T. Labitzky

Climate

Data from BIOTA weather station

Location	Recorded period	Mean temperature
Ratelgat (S27)	2001–2009	19.9 (3.5–46.0) °C
Mean solar radiation	**Mean wind speed**	**Mean annual precipitation**
674 (279–1050) MJ·m^{-2}·month^{-1}	3.9 (13.2) m·s^{-1}	124 (10–175) mm
Mean annual potential evapotranspiration	**Interannual precipitation variability**	**Mean relative humidity**
1549 mm	130%	58% (38–81%)
Aridity index (UNEP)		
0.08 (arid)		

Modelled data

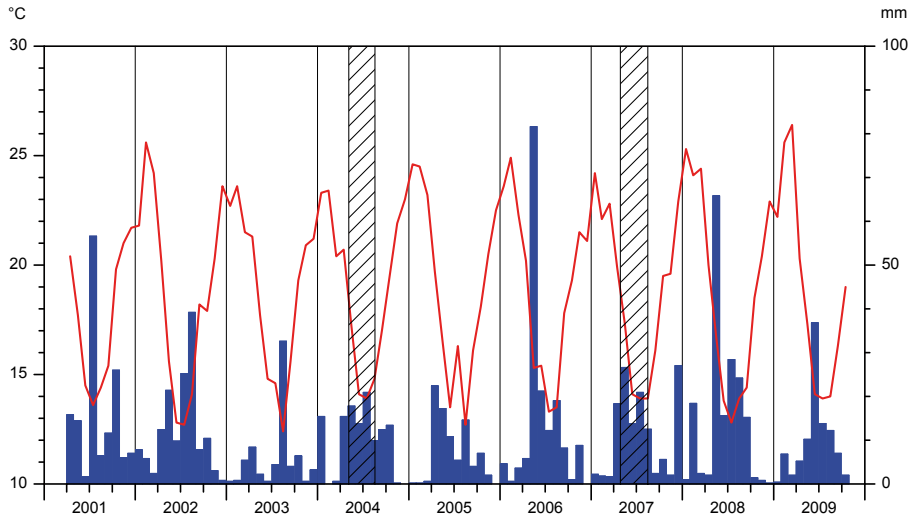
Mean temperature	Mean annual temperature range	Mean diurnal temperature range
19.1 (6.6–32.5) °C	10.7 °C	15.5 °C
Mean annual precipitation	**Precipitation seasonality**	**Percentage winter precipitation**
159 mm	62%	78% (winter)
Climate type	**Length of dry season**	**Aridity index (De Martonne)**
BSh	11 months	5.5 (dry)

The climate at the Observatory is characterised by arid conditions. Rainfall shows a moderate seasonality with more rain falling during the winter season, peaking in May. The mean annual rainfall over the observation period was 124 mm, which is fairly dry in comparison to the average rainfall recorded over the entire transect, but is in line with the mean values of the Observatories within the Succulent Karoo. However, substantial interannual variability is evident.

The observed near-surface air temperatures show a moderate seasonal cycle. The mean annual temperature is 19.9°C, which approximates the average for this biome. Compared to the interpolated long-term data taken from the WorldClim dataset, a slightly warmer mean annual temperature is evident at the BIOTA weather station. For precipitation, mean annual rainfall observed at the station is markedly lower than that of the WorldClim dataset. The rainfall seasonality is also less pronounced in the station data.

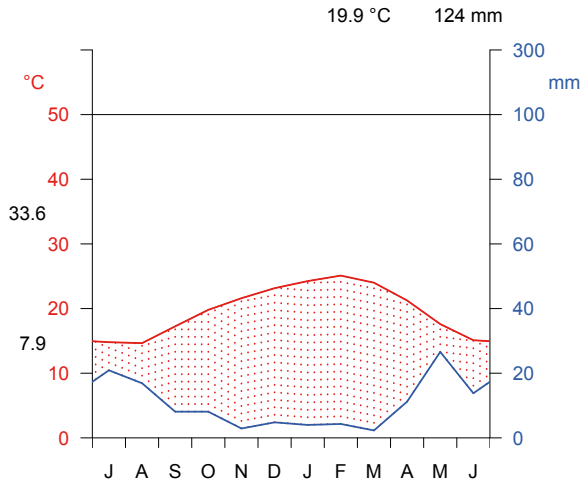
The observed near-surface winds at the Observatory are predominantly constituted of south-westerly flows, but a northerly component is also evident during winter. Mean wind speed shows a pronounced annual cycle in the evenings, and a moderate annual cycle in the mornings and early afternoons. Strongest winds occur in the evenings during summer, reaching up to 28 km/h.

Time series: rainfall and temperature

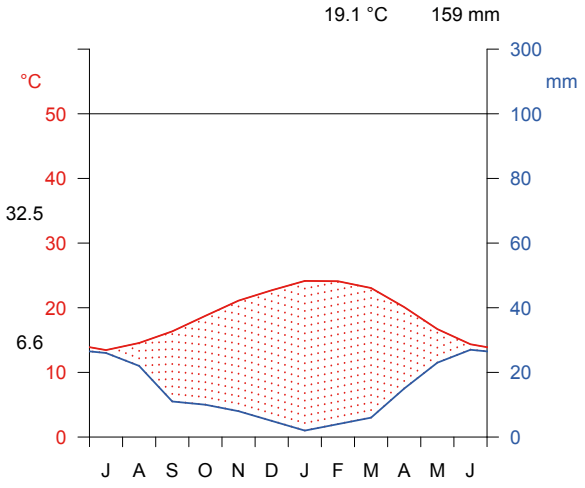


Climate diagrams

Recorded data (BIOTA)

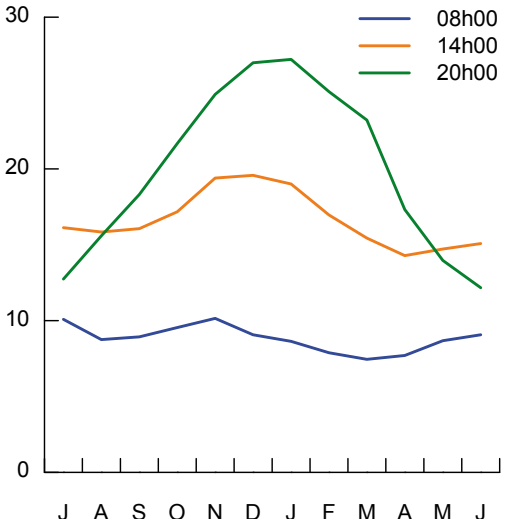


Modelled data (WorldClim)

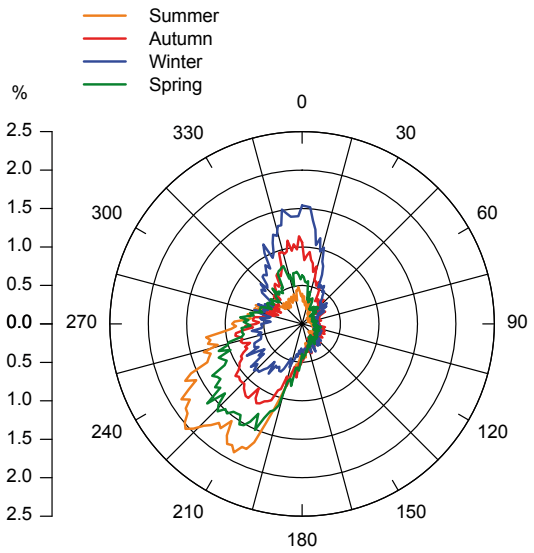


Wind diagrams

Speed



Directions



Responsible authors: K. Berger, A. Haensler & J. Luther-Mosebach

Soils

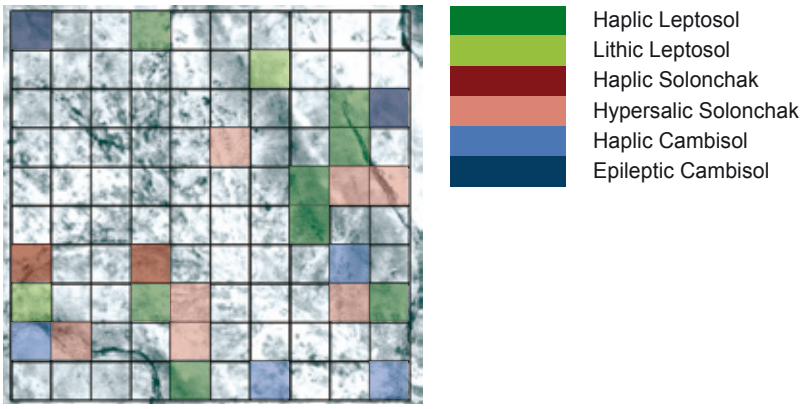
Year of sampling	Hectare plots sampled	SOTER unit
2002	25 (R1–25)	ZA2024
Soilscape	**Dominant soil group(s)**	**Reference group richness**
n.a.	Leptosol, Soloncha, Cambisol	3
Soil unit richness	**Soil unit evenness**	**Soil ecotype richness**
13	0.716	13
Parametric space	**pH**	**Electrical conductivity**
4.40	7.2 (4.0–9.1)	1365 (40–10,780) $\mu S \cdot cm^{-1}$
Organic carbon		
0.65% (0.27–1.56%)		

On this Observatory, soils of the reference groups Cambisol, Leptosol, and Solonchak are found. On the saline quartz fields, Solonchaks are dominant, as on Observatory S26 (Goedehoop). On less saline substrates, Cambisols predominate. Leptosols as the unit with the shallowest soils are found on phyllite and schist bedrock or larger quartz outcrops.

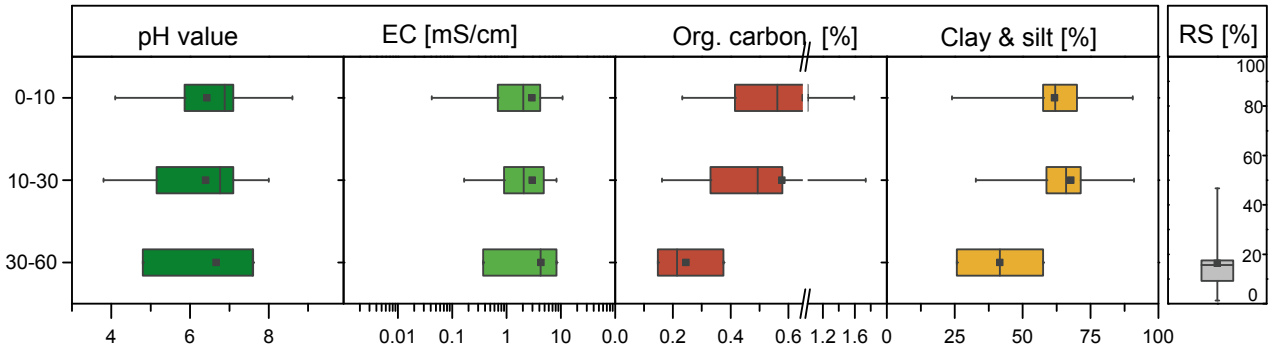
As on Goedehoop (S26), the pH and electrical conductivity values show a wide range. Electrical conductivity is slightly higher than on Goedehoop while concentrations of organic carbon are slightly lower. Since Solonchaks occurred more often on this Observatory than on Goedehoop, these differences can be well explained by the higher soil salinity.

Due to the sandier facies of the phyllites and schists on this Observatory, the soils exhibit lower amounts of fine particle percentage (clay and silt) than on the neighbouring Observatory. The median rooting space indicates the shallow and fragment-rich character of the site.

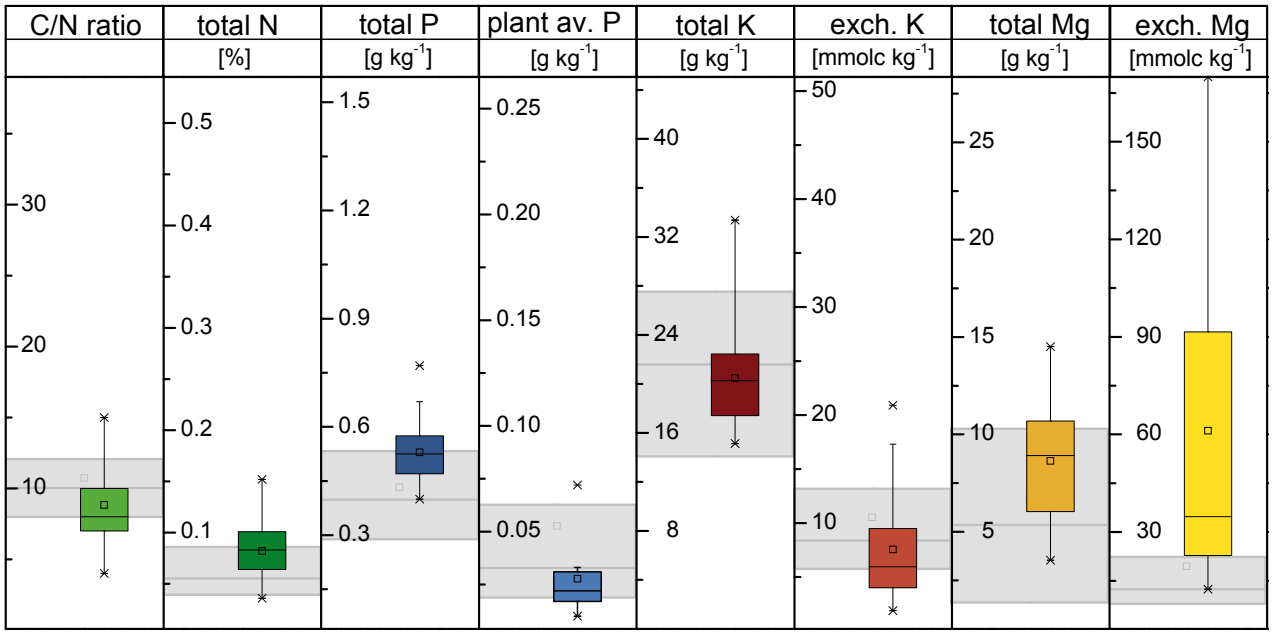
Map of soil profiles



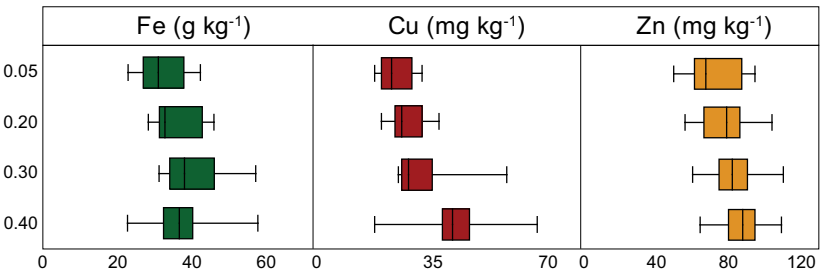
Soil characteristics



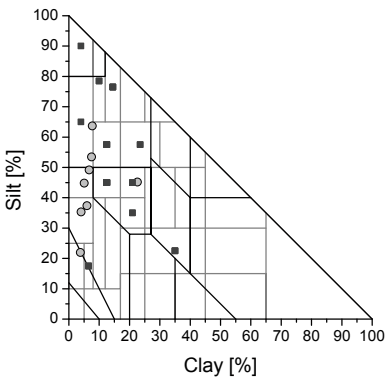
Soil nutrients



Soil micronutrients



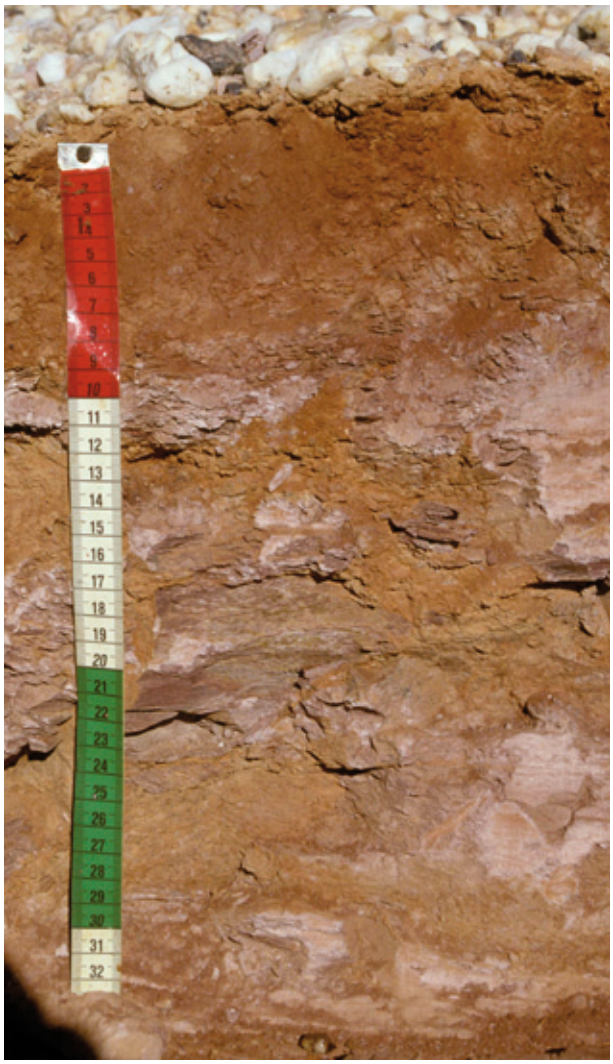
Soil texture triangle

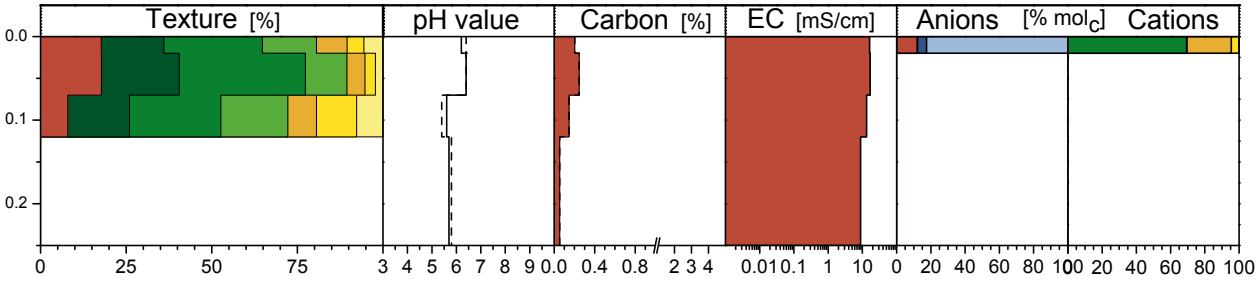


Reference profile (H20)

The **Hypersalic Solonchak (Chloridic, Yermic)** is a typical example for the shallow and extremely saline soils on weathered phyllite within the quartz fields. The profile was situated on a north-westerly exposed slope with approximately 10% inclination. Below the dense cover of quartz gravel follows a horizon with a loose structure of high silt content that is free of coarse rock fragments. This texture continues towards the subsoil while the content of porous rock fragments from the underlying phyllite increases. The clay content is relatively low and, except for the soil surface, no quartz fragments occur in the profile. Soil structure is loosely subangular-blocky with a low excavation difficulty in the top 12 cm. Below that, the transition to the bedrock begins, with rock fragments similar to the underlying parent material but strongly weathered.

The extremely saline soil has electrical conductivity values of around 10 mS cm^{-1}, decreasing with depth. Similarly, the pH value changes from low to very low with depth. Organic carbon is low, representing reduced biological activity. This is underlined by the lack of plants due to extreme osmotic potentials of > 3 MPa, resulting also in a low root density of 6–10 roots dm^{-2}. The total element content shows a strong decrease in calcium, while other elements increase slightly. Water soluble and exchangeable ions are extremely high (500 and 650 $mmol_c\ kg^{-1}$ respectively in the topsoil) and are dominated by sodium and chloride due to the soil's salinity. The significant decrease in calcium is probably induced by aeolian input of material with higher calcium content in the first horizon. However, due to the absence of calcium carbonate, the input of material with a distinct geochemistry should go along with changes in other elements as well. This is not the case and the origin of the calcium thus remains an open question.





Texture		Water soluble ions	
Fine silt	Fine sand	pH ($CaCl_2$)	Cloride	Calcium
Medium silt	Medium sand	pH (H_2O)	Sulfate	Magnesium
Coarse silt	Coarse sand	Organic carbon	Nitrate	Potassium
Clay		Inorganic carbon	Hydrocarbonate	Sodium
		Electrical conductivity	Fluoride, Bromide, Nitrite	

Responsible authors: U. Wisch, A. Petersen, A. Gröngröft & D. Mager

Biological soil crusts

Sampling period(s)	Hectare plots sampled	Types of soil crusts
2002	3 (R2, R3, R15)	2, 4, 6
Crust thickness	**Cover**	**Carbon [weight %]**
3–4 mm	up to 15% on stable soils	1.935
Nitrogen [weight %]	**Chlorophyll *a* [mg/m²]**	**Chlorophyll *a+b* [mg/m²]**
0.073	88	125

Despite the frequent occurrence of hypolithic crusts, species richness of cyanobacteria in this Observatory is significantly lower than in the neighbouring Observatory S26, and no green algal species were found to occur. This is most probably related to higher grazing and thus trampling intensity at this Observatory. Besides crust type 6, well-developed cyanobacteria-dominated crusts and lichen-dominated crusts with green algae occur on stable soils between quartz pebbles.

Cyanobacteria
Leptolyngbya foveolarum
Leptolyngbya sp.
Phormidium chlorinum
Porphyrosiphon lomnisczensis
Pseudanabaena minima
Pseudophormidium cf. *hollerbachianum*
Schizothrix sp.
Tolypothrix bouteillei
Tolypothrix sp.

No **green algae** found

Biological soil crust characteristics

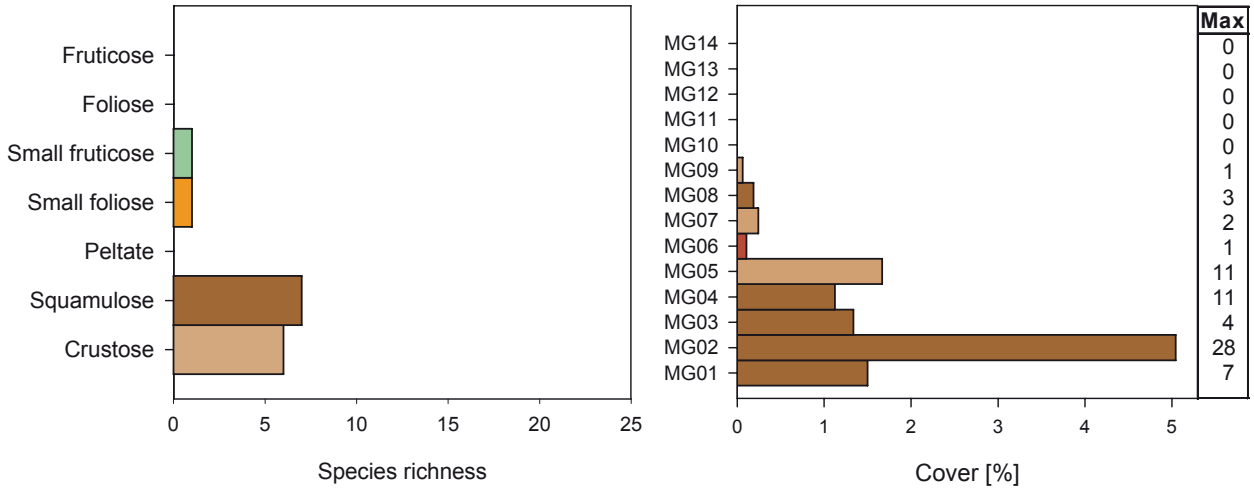
	H39	H57	H78
Soil characteristics	Brown silty sand with very small pebbles and wood pieces	Brown silty sand with pebbles and plant root pieces	Dark yellow-brown silt or sand, rare pebbles; air holes
Crust characteristics	Widespread light colored BSC combined with abiotic crust	Hypolithic crust and light crust, perhaps abiotic	Widespread dark BSC with lichens
Chlorophyll a [mg/m²]	82.89	123.64	56.95
Chlorophyll a+b [mg/m²]	124.45	170.09	80.27
Carbon [weight %]	1.88	2.51	1.42
Nitrogen [weight %]	0.16	0.03	0.03

Responsible authors: B. Weber, K. Deutschewitz, S. Dojani, T. Friedl, T. Darienko, K. Mohr & B. Büdel

Lichens

Sampling period(s)	Hectare plots sampled	Cover
2001, 2002	10 (R1–R10)	10% (0–41%)
Total species richness	**Species richness on soil [1 km²]**	**Species richness on rock [1 km²]**
52	18 (35%)	20 (38%)
Species richness on plants [1 km²]	**Species richness on soil [1000 cm²]**	
14 (27%)	3 (0–9)	

Life forms



List of Taxa

Terricolous (on soil):

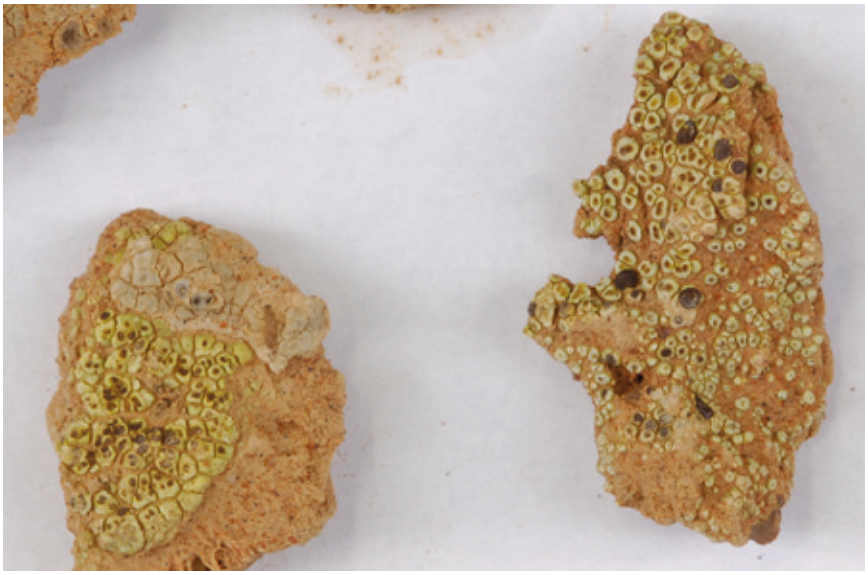
Acarospora sp. 01 (M-0039109)
Buellia sp. 01 (M-0039123)
Buellia sp. 02 (M-0038546)
Caloplaca sp. 01 (M-0039121)
Caloplaca sp. 02 (M-0039119)
Collema coccophorum
Eremastrella crystallifera
Diploschistes hensseniae
Lichinaceae sp.
Placidium squamulosum
Placidium tenellum
Psora crenata
Toninia australis
Toninia lutosa
Verrucaria compacta
Xanthoparmelia leonora
Xanthoparmelia simulans
Xanthoparmelia sp.

Saxicolous (on rock):

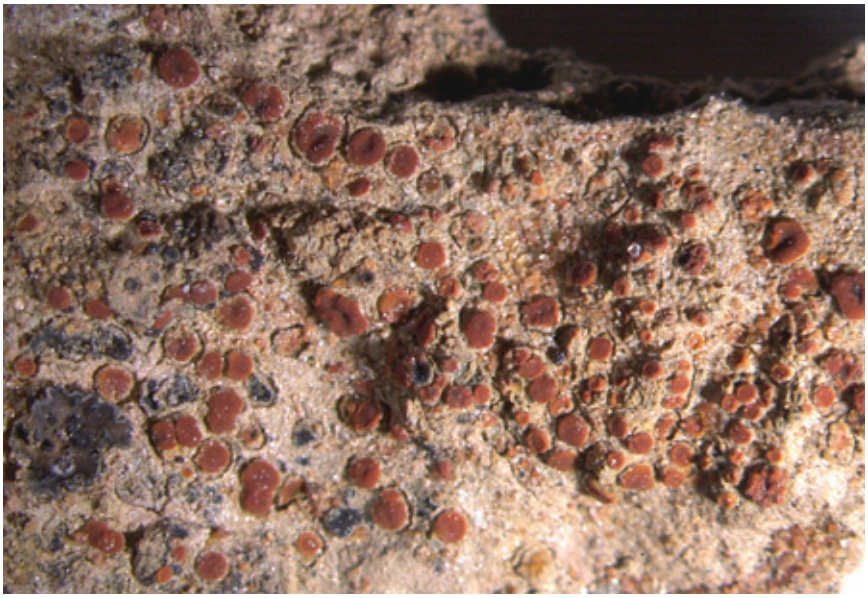
Acarospora sp.
Acarospora strigata
Aspicilia sp.
Buellia spp. (3)
Caloplaca aff. rubelliana
Caloplaca sp.
Diploschistes aeneus
Diploschistes austroafricanus
Diploschistes hensseniae
Xanthomaculina hottentota
Xanthoparmelia spp. (8)

Epiphytic (on plants):

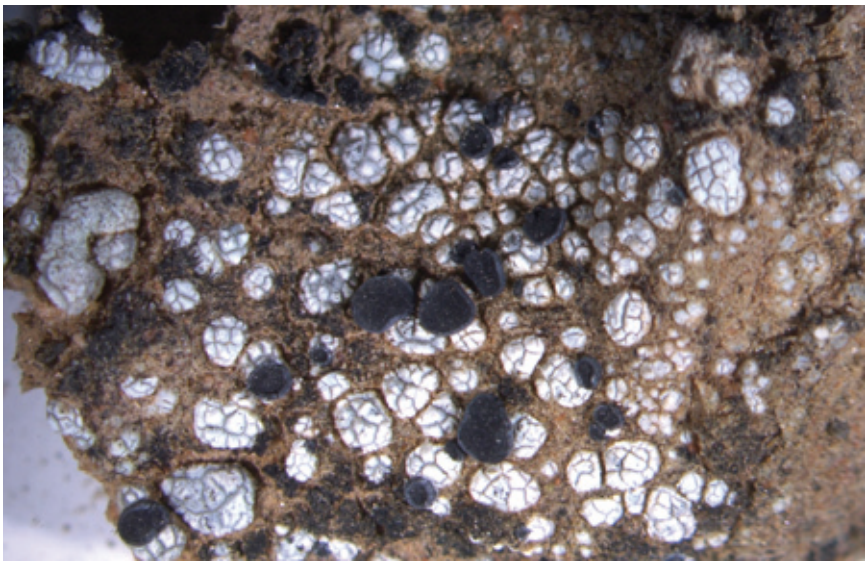
Amandinea extenuata
Buellia sp.
Caloplaca holocarpa s.l.
Caloplaca sp.
Candelaria concolor
Candelariella vitellina
Hyperphyscia syncolla
Lecanora sp.
Ramalina celastri
Teloschistes chrysophthalmus
Xanthoria dissectula
Xanthoria karrooensis
Xanthoria sp.
Xanthoria turbinata



Acarospora sp. Photo: L. Zedda & G. Rambold.



Caloplaca sp. Photo: L. Zedda & G. Rambold.



Toninia lutosa. Photo: L. Zedda & G. Rambold.

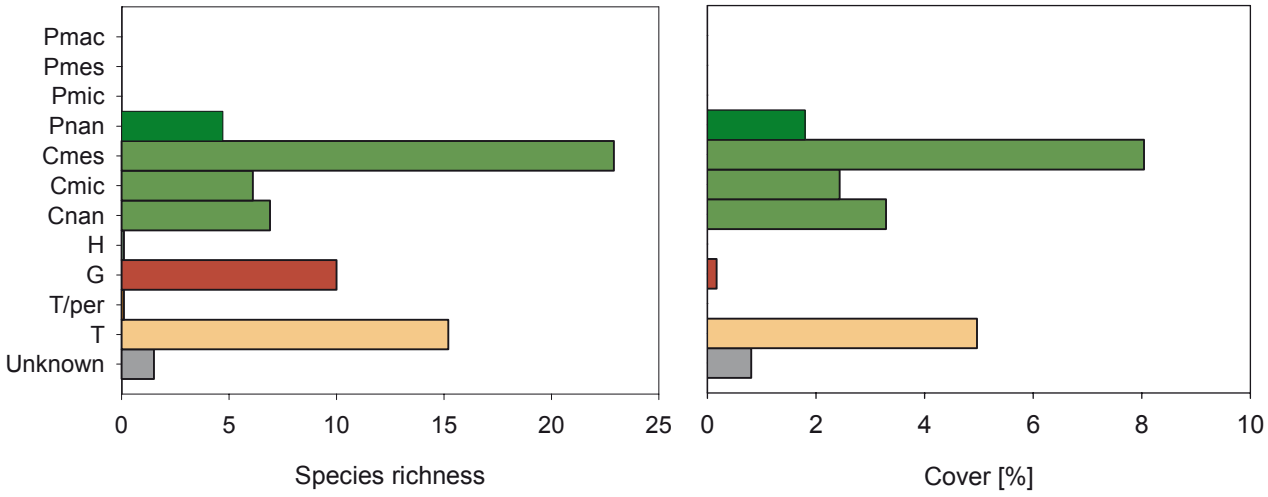
Lichens occur abundantly on all major substrates at this Observatory. Nevertheless, total richness is lower than at the twin Observatory S26 (Goedehoop), especially of soil-inhabiting lichens (18 at Ratelgat vs. 30 at Goedehoop), whereas lichen diversity on rocks and barks is similar at both sites. The differences in soil lichen diversity can probably be explained by differences in soil type as the climatic conditions are similar at both Observatories (Zedda & Rambold 2009). A further distinction between these two Observatories is the lower cover of soil lichens at Ratelgat. The morphological groups MG06, MG05, MG07, MG08 and MG10, which possess rare and often taxa endemic to Namaqualand, are missing, whereas they are abundant on Goedehoop. Only ubiquitous species representing especially MG02 are abundant. Lichen hotspots are found in the hectare plots H35, H57, H70 and H79, which have a lower cover of quartz pebbles and soils with higher average alkalinity.

Responsible authors:
L. Zedda & G. Rambold

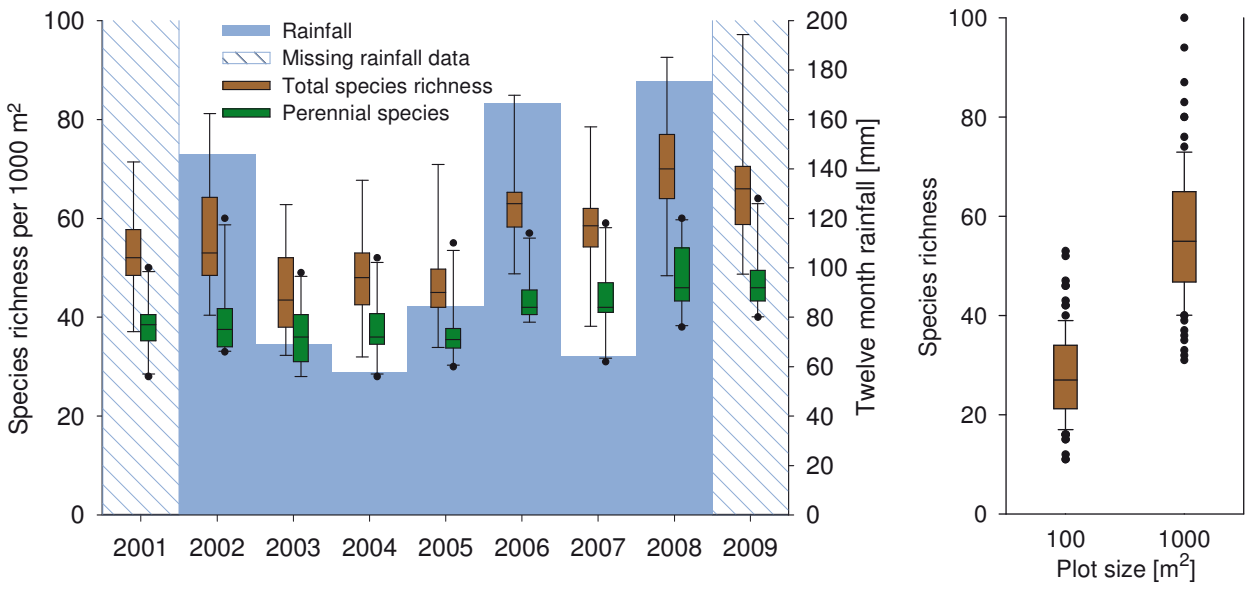
Vascular plants

Sampling period(s)	Hectare plots sampled	Biome
2001–2009	10 (R1–R10)	Succulent Karoo
Vegetation unit (level 1)	**Vegetation unit (level 2)**	**Identification rate**
Knersvlakte Bioregion	SKk 3 Knersvlakte Quartz Vygieveld	80% – 93% – 93%
Cumulative family richness	**Dominant families (cover)**	**Dominant families (richness)**
36	Aizoaceae, Asteraceae, Chenopodiaceae	Aizoaceae, Asteraceae, Crassulaceae
Cumulative species richness (1 km²)	**Species richness (1000 m²)**	**Species richness (100 m²)**
285 – 206	56.4 (31–100)	28.1 (11–53)
***z*-value**	**Species richness change per year (1000 m²)**	**Evenness (1000 m²)**
0.303 (0.176–0.541)	1.01	0.629 (0.342–0.870)
Evenness (100 m²)	**Simpson (1000 m²)**	**Simpson (100 m²)**
0.624 (0.883–0.883)	0.817 (0.463–0.954)	0.767 (0.358–0.936)

Life forms



Species richness



The vegetation of the BIOTA Observatory Ratelgat falls under the Northern Knersvlakte Vygieveld (SKk 1) and the Knersvlakte Quartz Vygieveld (SKk 3, Mucina et al. 2006). The Observatory is characterised by a patchy small-scale mosaic of quartz fields and zonal soils without quartz cover (Schmiedel & Jürgens 1999). In contrast to the neighbouring Observatory Goedehoop (S26), the quartz fields here are smaller and less clearly distinguished from the zonal soils. The dominant families in terms of species richness and plant cover are the Aizoaceae and Asteraceae. Vegetation is dominated by leaf-succulent dwarf shrubs. Medium sized shrubby growth forms (C mes, C mic) are the most species-rich and abundant but compact dwarf shrubs (C nan) may also reach very high cover values. The richness of perennial species over all plots is higher and shows lower variance than on the neighbouring Goedehoop Observatory (S26), where the clear differences between quartz patches and zonal soils causes a higher variance. The more homogeneous vegetation pattern at Ratelgat Observatory also results in a lower β-diversity and thus lower z-values than on the Goedehoop Observatory.

The zonal, loamy-sandy soils are dominated by the mat-forming, creeping *Cephalophyllum framesii* (Rankvye), the shrubby, sparsely leaved *Drosanthemum globosum*, and *Ruschia subsphaerica*. After good rainfall, the zonal soils are densely covered by the annual *Asteraceae Didelta carnosa* (Perdebloom) and *Foveolina dichotoma* (Knoppieopslag). Large areas are dominated by acid quartz fields and slopes with poorly weathered shale, which are covered by homogeneous stands of *Ruschia burtoniae*. Two main vegetation types can be distinguished: a mosaic of zonal soils and quartz field with high soil salinity and neutral soils; and a mosaic of less saline quartz fields and zonal soils with low pH (i.e. soil pH < 5). The vegetation classification reflects these mosaic patterns.

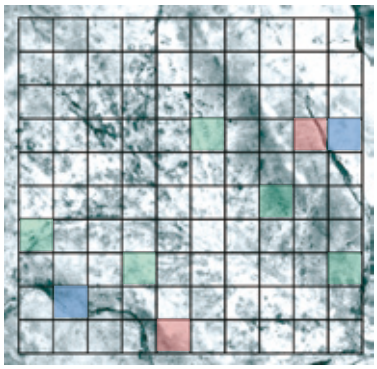
The *Hirpicium alienatum-Ruschia burtoniae* community (unit 1) is characterised by homogeneous stands of *Ruschia burtoniae* (with cover values up to 10%), which is accompanied by

Unit 1, H94, 2004. Photo: R. Christiaan.

Unit 2, H81, with dense stands of *Galenia africana* (Kraalbos) in the dry riverbed, 2008. Photo: R. Christiaan.

Unit 3, H79, with *Drosanthemum diversifolium* in flower, 2006. Photo: R. Christiaan.

Map of vegetation units



many other species that reach only very low cover values (< 1%). *Hirpicium alienatum* (Haarbos) is a very palatable, non-succulent shrub that does not reach high cover values but occurs with high consistency. The community occurs on soils that are covered by quartz gravel (2–6 cm) or poorly weathered shale bedrock on slopes and hilltops. The soil salinity is low, which is typical for these acid quartz fields (soil pH < 4.5) and soils have the highest values for organic carbon amongst all plots. This community corresponds to the *Conophytum calculus* subsp. *calculus* group, described by Schmiedel (2002) for the acid quartz fields in the Knersvlakte.

The *Tripteris hyosereoides-Ruschia burtoniae* community (unit 2) is typical of dry riverbeds that cut through the quartz field landscape. Most of the diagnostic species are annuals such as the tall *Asteraceae Tripteris hyosereoides* (Dassiegousblom) and the invasive species *Amsinckia retrosa* (Neukbos), which may occur in high densities after good rainfall. However, the dominant species are *Galenia africana* (Kraalbos), occurring along the dry rivers, and *Ruschia burtoniae*, which covers the quartz fields or shale slopes adjacent to the rivers.

The *Antimima solida-Cephalophyllum spissum* community (unit 3) occurs on a mosaic of saline quartz fields and zonal soils. These soils possess a much higher cover of biological soil crusts than those where the other two communities occur. The dominant species on zonal soils are *Ruschia subsphaerica*, *R. bolusiae*, *Drosanthemum globosum*, *Cepha-*

Classification table (2008)

Column		Cover	All	1	2	3
Number of relevés			**10**	**2**	**2**	**6**
Mean cover [%]			22.9	13.8	29.6	23.7
Mean species richness (1000 m²)			70.2	57.0	83.5	70.2
Inclination [°]			6.4	14.0	5.0	4.0
Mean soil pH			6.291	4.21	6.97	6.852
Mean electrical conductivity [µS·cm^{-1}]			3005	743	5251	3011
Organic carbon [%]			0.76	1.40	0.57	0.58
Nitrogen [%]			0.08	0.10	0.07	0.07
Fine material [%]			47.7	4.0	35.5	70.0
Gravel [%]			33.4	41.5	40.0	27.6
Stones 2-6 cm [%]			15.2	50.0	13.0	2.2
Stones 6-20 cm [%]			0.8	1.5	1.5	0.2
Stones 20-60 cm [%]			0.1	0.5	0.0	0.0
Blocks [%]			0.0	0.0	0.0	0.0
Rock outcrops [%]			2.8	2.5	10.0	0.0
Soft litter [%]			1.6	0.5	6.0	0.3
Biotic crust [%]			27.3	5.5	5.0	45.0
Unit 1: Hirpicium alienatum-Ruschia burtoniae community						
Cmes	Microloma sagittatum	0.03	20	100	.	.
Cmes	Asparagus capensis	0.12	30	100	.	17
Cmes	Hirpicium alienatum	0.45	20	100	.	.
Unit 2: Tripteris hyosereoides-Ruschia burtoniae community						
T	Tripteris hyoseroides	0.06	20	.	100	.
Cnan	Peliostomum virgatum	0.02	20	.	100	.
T	Ehrharta triandra	0.18	20	.	100	.
T	Amsinckia retrorsa	0.02	20	.	100	.
Unit 3: Antimima solida-Cephalophyllum spissum community						
Pnan	Lampranthus otzenianus	0.54	60	.	.	100
Cmes	Galenia sarcophylla	0.35	60	.	.	100
T	Tetragonia microptera	0.10	50	.	.	100
Cnan	Antimima solida	0.31	70	.	50	83
G	Caulipsolon rapaceum	0.15	70	.	50	100
T	Tripteris clandestina	0.01	70	.	50	100
Most frequent companions						
T	Didelta carnosa	0.30	100	100	100	100
T	Amellus microglossus	0.24	100	100	100	100
Cmes	Tetragonia fruticosa	0.22	100	100	100	100
G	Oxalis pes-caprae	0.02	100	100	100	100
T	Foveolina dichotoma	3.06	90	50	100	100
Cnan	Cephalophyllum framesii	1.47	90	100	50	100
Cmes	Salsola sp. 116850	0.78	90	100	50	100
Cmic	Drosanthemum schoenlandianum	0.72	90	100	50	100
Cmes	Tripteris sinuata var. sinuata	0.44	90	100	100	83
Cmes	Drosanthemum globosum	0.38	90	100	50	100
Pnan	Aridaria serotina	0.22	90	100	100	83
Cmic	Zygophyllum cordifolium	0.20	90	50	100	100
Cmes	Asparagus recurvispinus	0.08	90	50	100	100
T	Heliophila variabilis	0.05	90	100	100	83
G	Oxalis luteola	0.05	90	100	100	83
G	Chlorophytum undulatum	0.02	90	100	50	100
Cnan	Cephalophyllum spissum	1.78	80	50	50	100
Cmes	Ruschia bolusiae	0.99	80	50	50	100
Cnan	Malephora purpureo-crocea	0.33	80	.	100	100
Cmes	Psilocaulon dinteri	0.24	80	.	100	100
Pnan	Lycium cinereum	0.23	80	50	100	83
T	Osteospermum pinnatum var. pinnatu	0.18	80	.	100	100
T	Mesembryanthemum guerichianum	0.15	80	50	100	83
T	Gazania lichtensteinii	0.12	80	50	50	100

continued on next page

Classification table (continued)

Column		Cover	All	1	2	3
Number of relevés			**10**	**2**	**2**	**6**
T	Ursinia nana ssp. nana	0.11	80	100	50	83
T	Helichrysum leontonyx	0.11	80	50	100	83
Pnan	Lampranthus watermeyeri	0.07	80	100	100	67
T	Senecio arenarius	0.01	80	50	100	83
G	Moraea miniata	0.01	80	100	100	67
Cmes	Ruschia burtoniae	2.97	70	100	100	50
Cmes	Crassula subaphylla var. virgata	0.01	70	50	50	83
Cmes	Drosanthemum diversifolium	0.58	60	.	50	83
T	Oncosiphon suffruticosum	0.37	60	.	100	67
Cmic	Zygophyllum retrofractum	0.31	60	.	50	83
Cmes	Salsola zeyheri	0.31	60	.	100	67
Pnan	Aridaria noctiflora ssp. noctiflora	0.17	60	50	50	67
Csub	Argyroderma delaetii	0.15	60	.	50	83
Cmes	Hermannia cuneifolia var. glabrescens	0.13	60	100	100	33
Cmes	Phyllobolus spinuliferus	0.10	60	.	50	83
Cmes	Pteronia glabrata	0.09	60	100	50	50
Cmes	Brownanthus ciliatus	0.07	60	100	50	50
T	Atriplex lindleyi ssp. inflata	0.04	60	.	100	67
Cnan	Conophytum minutum var. pearsonii	0.03	60	100	50	50
G	Oxalis sp. 116852	0.03	60	.	50	83
G	Albuca cooperi	0.01	60	100	100	33
Cmes	Crassula muscosa var. muscosa	0.01	60	100	100	33
G	Trachyandra tortilis	0.01	60	.	50	83
Cmes	Crassula expansa ssp. pyrifolia	0.01	60	50	.	83
Cnan	Conophytum subfenestratum	1.42	50	.	50	67
Cmes	Ruschia subsphaerica	1.32	50	.	50	67
Cmes	Drosanthemum sp. 116844	0.63	50	50	100	33
Cmes	Berkheya fruticosa	0.34	50	50	100	33
Cmes	Phyllobolus splendens	0.27	50	50	50	50
Cmic	Antimima watermeyeri	0.25	50	100	50	33
Cmes	Drosanthemum pulverulentum	0.17	50	50	50	50
Cmes	Galenia fruticosa	0.08	50	.	50	67
Cmes	Galenia africana	2.08	40	100	100	.
Pnan	Lycium ferocissimum	0.80	40	50	100	17
Cmes	Monilaria chrysoleuca	0.56	40	.	50	50
Cmes	Eriocephalus namaquensis	0.53	40	100	50	17
Cmes	Phyllobolus nitidus	0.36	40	.	.	67
T	Schismus barbatus	0.21	40	.	100	33
Cmes	Crassula muscosa var. obtusifolia	0.05	40	.	50	50
Cmic	Galenia meziana	0.04	40	100	50	17
T	Tribolium utriculosum	0.03	40	100	.	33
G	Cyanella hyacinthoides	0.02	40	.	100	33
T	Nemesia ligulata	0.01	40	.	100	33
G	Lapeirousia pyramidalis	0.01	40	100	50	17
G	Androcymbium cf. capense	0.01	40	50	50	33
Cnan	Anacampseros filamentosa ssp. nam	0.01	40	50	.	50
G	Othonna intermedia	0.01	40	100	.	33
G	Albuca viscosa	0.01	40	100	50	17
G	Ornithogalum suaveolens	0.01	40	.	50	50
Cnan	Crassula columnaris ssp. prolifera	0.01	40	.	50	50
G	Bulbine succulenta	0.01	40	.	50	50
G	Lachenalia sp. 262/29	0.01	40	.	50	50
T	Bromus pectinatus	1.76	30	.	100	17
Cmes	Arenifera stylosa	0.68	30	50	.	33
Cmes	Drosanthemum sp. 116576	0.35	30	.	.	50
Cmes	Antimima excedens	0.23	30	.	.	50
T	Mesembryanthemum fastigiatum	0.10	30	50	50	17
Cmes	Ruschia sp. 123721	0.10	30	.	.	50
Cmes	Leipoldtia schultzei	0.10	30	.	50	33
Cmes	Tetragonia verrucosa	0.07	30	50	50	17
Cmes	Lycium oxycarpum	0.07	30	50	50	17
T	Poaceae sp. 15036	0.04	30	.	50	33

lophyllum framesii (Rankvye), and the Knersvlakte-endemic, compact dwarf shrub *Antimima solida*. The Knersvlakte-endemic, compact dwarf shrub *Cephalophyllum spissum* is dominant on quartz fields.

Conophytum calculus subsp. *calculus* is restricted to quartz fields. Photo: U. Schmiedel.

The dwarf shrub *Ruschia burtoniae* often dominates acid quartz fields in the Knersvlakte. Photo: U. Schmiedel.

Flower of *Ruschia burtoniae* in August 2004. Photo: U. Schmiedel.

Responsible authors: U. Schmiedel & J. Luther-Mosebach

Vertebrates

Total species richness	Reptile species richness	Bird species richness
11	n.a.	11
Large mammal species richness	Small mammal species richness	
n.a.	n.a.	

Birds

Passeriformes	**Perching birds**
Corvus albus	Pied Crow
Prinia maculosa	Karoo Prinia
Chersomanes albofasciata	Spike-heeled Lark
Cisticola subruficapillus	Grey-backed Cisticola
Serinus flaviventris	Yellow Canary
Cercomela schlegelii	Karoo Chat
Emberiza capensis	Cape Bunting
Galerida magnirostris	Large-billed Lark
Gruiformes	**Cranes, rails, coots, and allies**
Eupodotis vigorsii	Vigors´s Bustard
Neotis ludwigii	Ludwigs Bustard

Responsible author: W. Mey

Site-specific studies

Impact of disturbance and restoration potential of quartz field vegetation (S27.01)

[S. Etzold]

Subject of this study was the impact of disturbance on vegetation, phytodiversity, and habitat conditions of quartz fields and the development of suitable restoration measures. Applied methods include vegetation ecological and population dynamical analyses, seed bank investigations and the establishment and evaluation of restoration experiments. The study was carried out on the Observatories Ratelgat (S27), Moedverloren (S28), and on the farm Quaggaskop.

The vegetation analysis revealed differences in the susceptibility inside and outside of quartz fields and between quartz field communities, which correlated well with the specialisation degree of the respective species. On the disturbed quartz fields, a shift in vegetation from the highly specialised quartz field vegetation to shrubby vegetation with dominance of opportunists was observed, probably caused by an alteration of soil features. Highly significant was the absence of the quartz stones on the disturbed sites, which has essential impact on microclimate and water supply for the quartz field species, and changed chemical soil properties.

The longevity of the quartz field species, the low recruitment rate, and the weakly developed seed bank characterise a system that is rather geared towards persistence than towards colonisation. Disturbance of such a derivative and complex system is likely to have a severe impact on the underlying finely tuned processes and are presumed to be restored, if ever possible, only with high investment and intervention.

This was confirmed by the restoration experiments with a very slow recovery rate of the disturbed quartz fields. However, scattered quartz stones had a positive effect on the disturbed bare areas, highlighting the high importance of the quartz stones for the quartz field species. Restoration efforts are considered to be extremely demanding due to the patchiness of the quartz fields which leads to a high number of specific requirements in a small spatial area.

Etzold, S. (2006): Dynamics in quartz field vegetation in the Knersvlakte/South Africa – with special reference to disturbance and restoration. – Diplom thesis in Biology. Hamburg: University of Hamburg.

How does grazing intensity affect different vegetation types in the Knersvlakte? (S27.02)

[D.H. Haarmeyer, U. Schmiedel, J. Dengler, B.M. Bösing]

The Knersvlakte in the Succulent Karoo Biome (South Africa) is known for its high plant diversity and endemism. In

the course of establishing a conservation area there, we assessed baseline data for future management. We investigated the effects of grazing on the vegetation in terms of species diversity and composition as well as reproduction of selected species. Data were sampled on four adjacent farms, including Ratelgat, on which the Observatory S27 lies. The farms were ungrazed, moderately, or intensively grazed by sheep and goats. The data were collected in 27 quartz and 24 non-quartz plots, representing two major habitat types of the region. Within each of the 1000-m² plots, 100 subplots of 400 cm² size were sampled.

Analyses of variance (ANOVAs) revealed that species richness and abundance of endemic species on quartz fields decreased with grazing. Abundance of annuals did not increase significantly due to grazing. Fidelity analyses indicated that species composition differed between grazing intensities and that the ungrazed and moderately grazed plots both contained unique locally endemic habitat specialists. Reproduction of two endemic dwarf shrubs, *Drosanthemum schoenlandianum* and *Argyroderma fissum* (both Aizoaceae), increased under moderate grazing, which in the case of *D. schoenlandianum* was interpreted as an effect of grazing. We attribute the low number of seedlings and annuals on the moderately grazed farm to lower seasonal rainfall on these plots. From the conservation perspective, none or moderate grazing appear to be necessary to preserve plant diversity and vegetation patterns, and their underlying processes.

Haarmeyer, D.H. (2009): Effects of domestic livestock on the vegetation of the Knersvlakte, South Africa. – Diplom thesis in Biology. Hamburg: University of Hamburg.

Haarmeyer, D.H., Schmiedel, U., Dengler, J., Bösing, B.M. (2010): How does grazing intensity affect different vegetation types in arid Succulent Karoo, South Africa? Implications for conservation management. – Biological Conservation **143**: 588–596.

The role of domestic herbivores in endozoochorous plant dispersal in the Knersvlakte (S27.03)

[D.H. Haarmeyer, B.M. Bösing, U. Schmiedel, J. Dengler]

Herbivores can act as dispersal vectors by purposely or accidentally ingesting ripe fruits, and thus endozoochory is one determining factor for plant distribution patterns. The objective of our study was to investigate to what extent plants of major taxonomic groups of the Knersvlakte are endozoochorously dispersed. On three different farms in the central Knersvlakte (including the Observatory farm Ratelgat), dung of domestic herbivores was collected and analysed by the seedling-emergence method. The resulting species composition was compared to the standing vegetation of thirty-four 1000-m² plots, each recorded on one hundred 400-cm² subplots.

Our results show that domestic livestock facilitated the dispersal of taxa characteristic of the Knersvlakte, in particular Aizoaceae. Among this family, the local endemic dwarf shrub *Drosanthemum schoenlandianum* emerged with the highest frequency in dung (14.5% of all seedlings). For the Asteraceae, which are frequent in the standing vegetation of the Knersvlakte, however, endozoochorous dispersal by livestock was only of minor importance. Conservation planning should consider these dispersal patterns on behalf of future population dynamics. The complete exclusion of livestock might change current processes and thus alter vegetation patterns.

Haarmeyer, D.H. (2009): Effects of domestic livestock on the vegetation of the Knersvlakte, South Africa. – Diplom thesis in Biology. Hamburg: University of Hamburg.

Haarmeyer, D.H., Bösing, B.M., Schmiedel, U., Dengler, J. (2010): The role of domestic herbivores in endozoochorous plant dispersal in the arid Knersvlakte, South Africa. – South African Journal of Botany **76**: 359–364.

Effects of domestic livestock grazing on small mammal communities in the Knersvlakte (S27.04)

[B.M. Bösing, D.H. Haarmeyer, U. Schmiedel, J. Dengler]

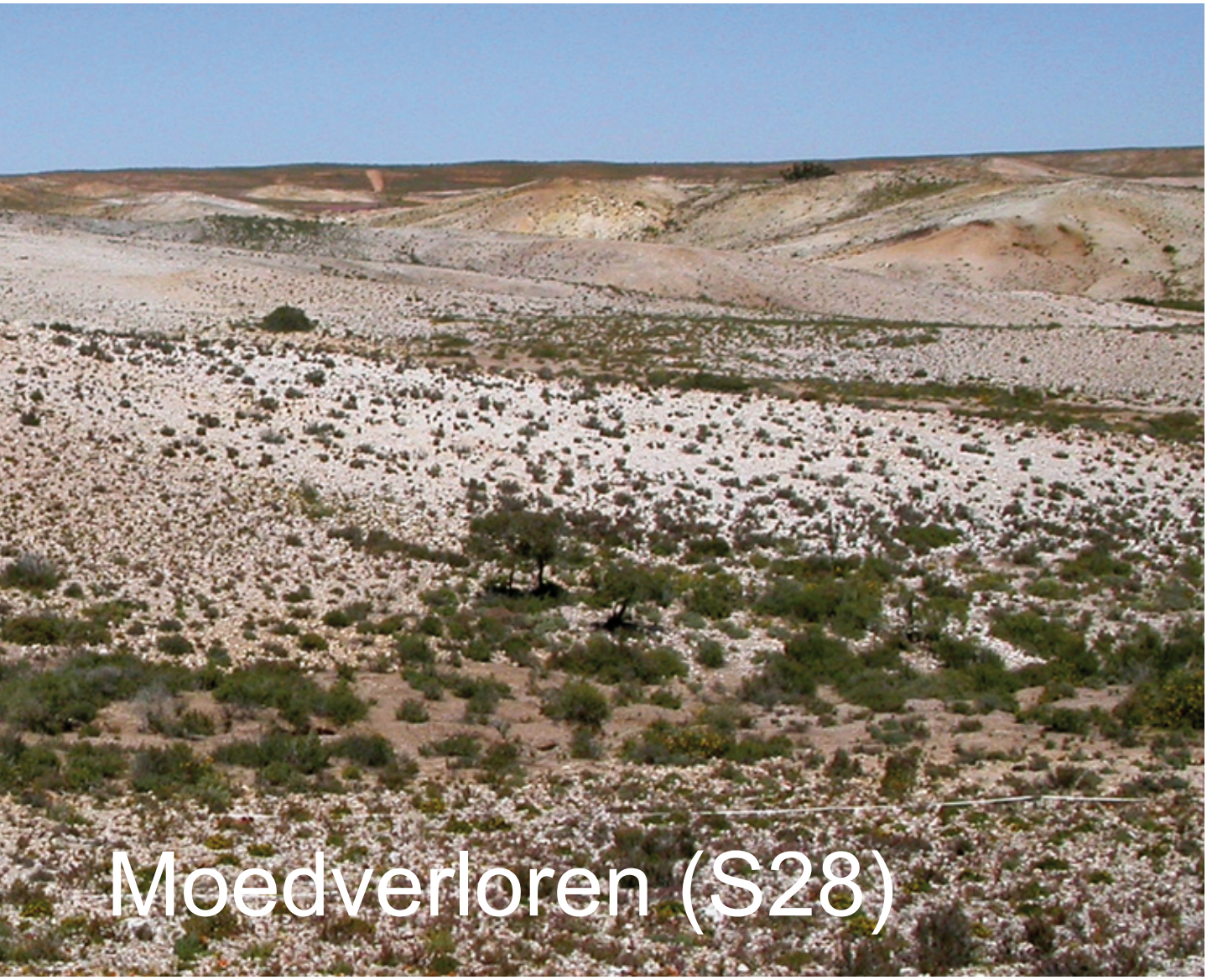
In order to assist the management of the Knersvlakte Conservation Area with future management decisions, the influence of different livestock grazing intensities and habitat types on small mammals in the Knersvlakte was investigated. The study was carried out on the Observatory farm Ratelgat and several other farms nearby. A total of 22 plots were selected according to two grazing intensities (moderate and intensive), and two major habitat types (quartz fields, loamy soils). On each of these plots, small mammal live trapping (90 traps during 4 nights) was carried out and the cover of different vegetation layers was estimated.

In total, 140 small mammal individuals from 10 species were caught during 7,920 trap nights. The small mammal species composition on intensively grazed fields was a subset of that on moderately grazed fields. The most abundant species on loam fields were *Macroscelides proboscideus* and *Rhabdomys pumilio* and on quartz fields *Macroscelides proboscideus* and *Gerbillurus paeba*. Generalised linear models (GLMs) revealed that habitat type had the strongest influence on abundance and diversity of small mammals. Vegetation cover only had an indirect influence on abundance, diversity and the body condition of small mammals via the habitat type. Overall, a high grazing intensity had a negative influence on the diversity and activity of small mammals. From a conservation point of view, it would thus be desirable to reduce the livestock grazing intensity in the future Conservation Area.

Bösing, B.M. (2009): Interactions between wildlife and vegetation under different grazing intensities and habitat types in the Knersvlakte, South Africa. – Diplom thesis in Biology. Hamburg: University of Hamburg.

General data

Number	Name	Alternative name(s)
S28	Moedverloren	n.a.
Implementation	**Country**	**Province/ region**
2001	South Africa	Western Cape
District/ constituency	**Locality**	**Farm name**
West Coast	Vredendal	Moedverloren 208
Latitude	**Longitude**	**Altitude**
31.460932 S	18.439058 E	140 m a.s.l.
Rainfall season	**Biome**	**WWF Ecoregion**
Winter	Succulent Karoo	AT1322 Succulent Karoo
Agro-Ecological Zone	**Relative intensity of land use**	**Tenure**
n.a.	Low	State
Type and history of landuse	**Land owner**	
Conservation area	CapeNature	



Moedverloren (S28)

Quartz fields at the Moedverloren. Photo: R. Christiaan.

The BIOTA Observatory Moedverloren (S28) is situated on the farm Moedverloren in the western part of the Knersvlakte about 25 km north of the small town of Vredendal and 30 km from the West Coast. The farm, which was used for commercial sheep farming until 1999, is now part of a conservation area managed by CapeNature, the nature conservation authority of the Western Cape Province.

The Knersvlakte is a low lying, gently undulating plain (approximately 140 m a.s.l. at Moedverloren), in the Succulent Karoo Biome of southern Namaqualand. The average annual rainfall in the area is very low but the plants benefit from the regular occurrence of fog and dew. The area is dominated by shale, phyllite, and limestone, and is intruded by numerous quartz veins from which the dense layer of quartz gravel which form the quartz fields originates. The quartz fields, which are prominent on large parts of Moedverloren, are a defining feature of the Knersvlakte. They accommodate a unique and special flora dominated by compact, leaf-succulent dwarf shrubs. Many species found on the quartz fields are obligate quartz field dwellers and often have a very restricted distribution range. The rich flora of the Knersvlakte thus contributes strongly to the generally high levels of diversity and endemism of the Knersvlakte. The quartz fields are the main reason for the recent implementation of a nature reserve.

The BIOTA Observatory was established, at the request of CapeNature, to

investigate the recovery of the vegetation after intensive small-stock farming, and to monitor the impacts of projected climate change on the diverse Succulent Karoo flora of the Knersvlakte under conservation management.

Responsible authors: U. Schmiedel & D.H. Haarmeyer

Remote sensing and landscape

Geomorphology	Geological units	Lithological units
Alluvial plains, hills, rivier	Nama System	Quartzite, arkose, limestone, shale, phyllite, tillite, lava, tuff
Mean EVI	**EVI absolute range**	**Mean leaf area index**
0.086 (0.070–0.108)	0.064 (2001)–0.136 (2008)	0.28

Grid map of Observatory

	0	1	2	3	4	5	6	7	8	9
0	87	34	13	79	82	88	12	14	93	77
1	28	85	72	32	81	35	60	19	86	71
2	29	64	56	4	58	76	16	2	23	45
3	6	51	52	18	47	46	20	22	75	10
4	53	94	98	27	8	70	5	99	73	9
5	59	57	49	50	74	91	30	95	31	1
6	17	90	40	36	41	25	62	42	69	24
7	44	54	89	43	11	38	15	78	7	96
8	63	68	48	3	61	100	55	66	92	33
9	80	97	21	83	84	67	26	39	65	37

1 Alluvial plain with shrubby vegetation
2 Quartz fields with compact dwarf succulents
3 Quartz field with intersection (rivier)
4 Transition zone between quartz fields and alluvial plain
5 River with dense woody vegetation

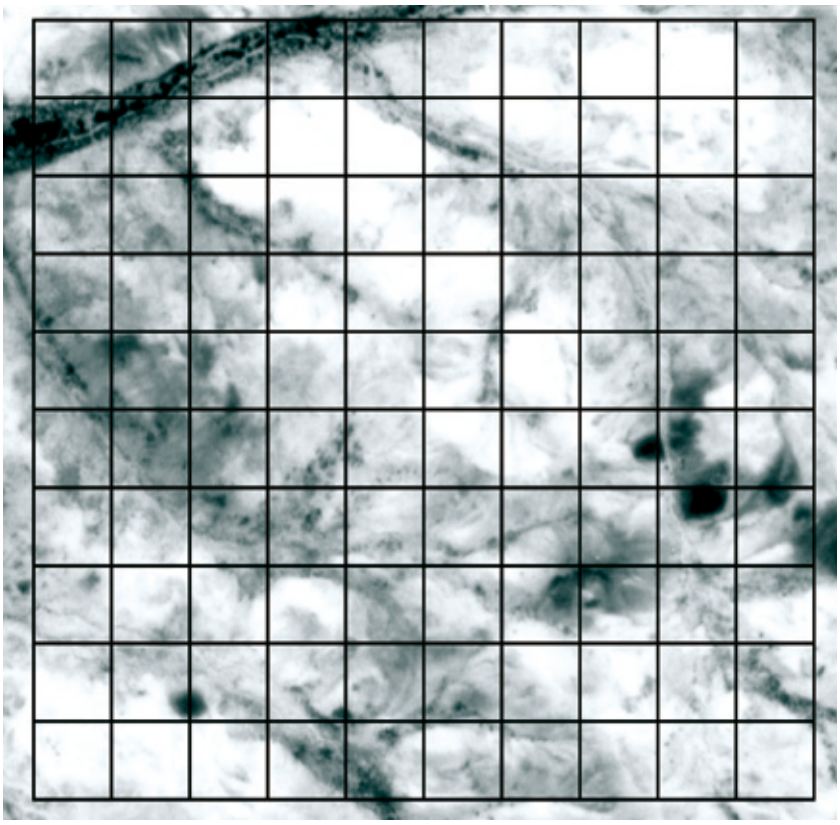
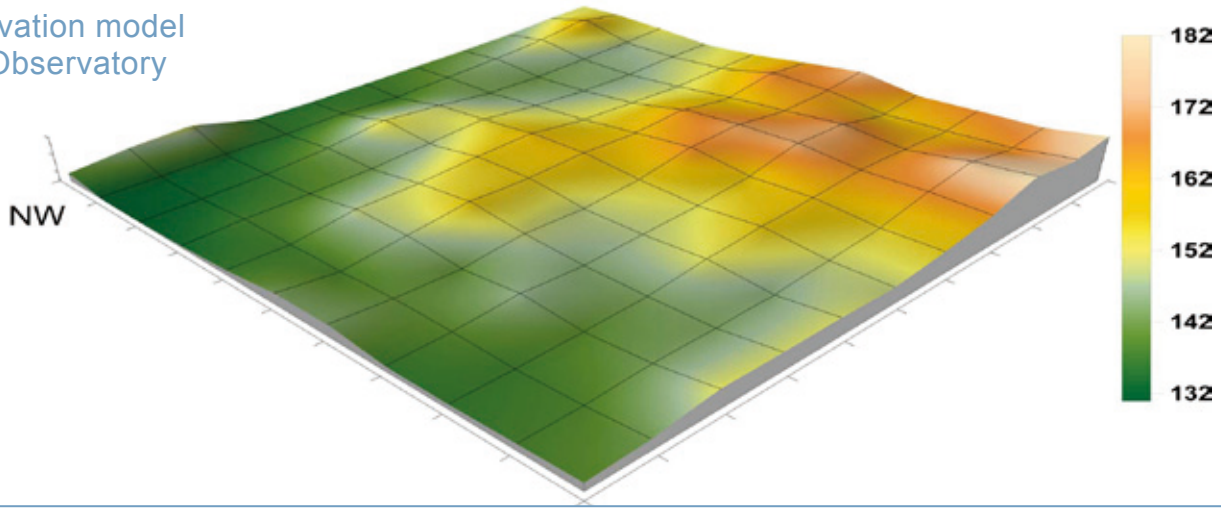


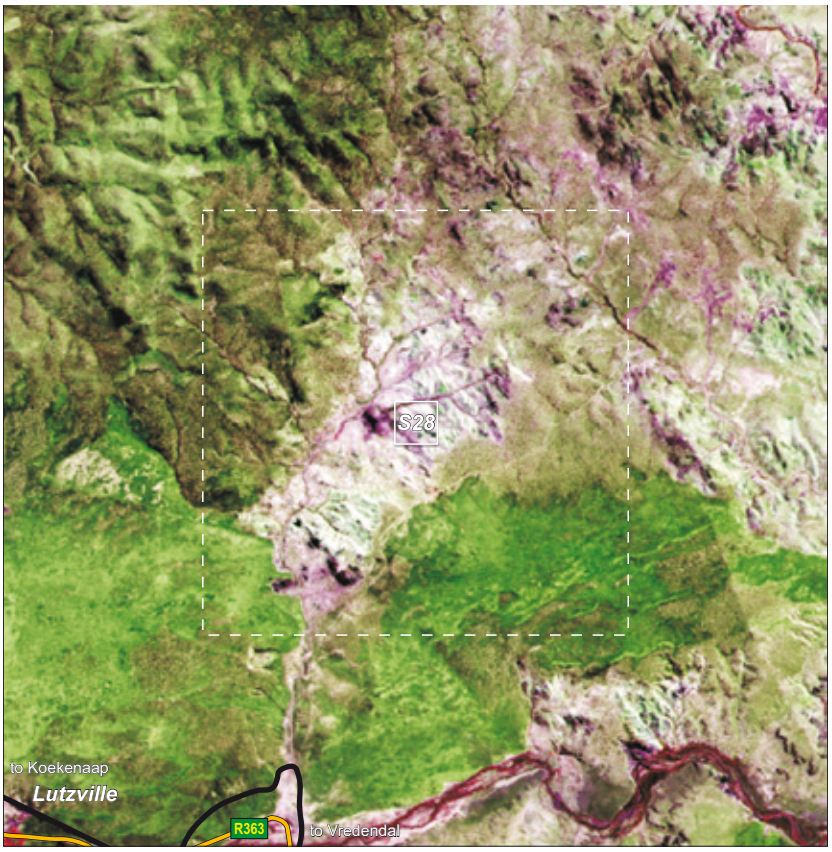
Image: aerial photograph

Elevation model of Observatory



Landsat image

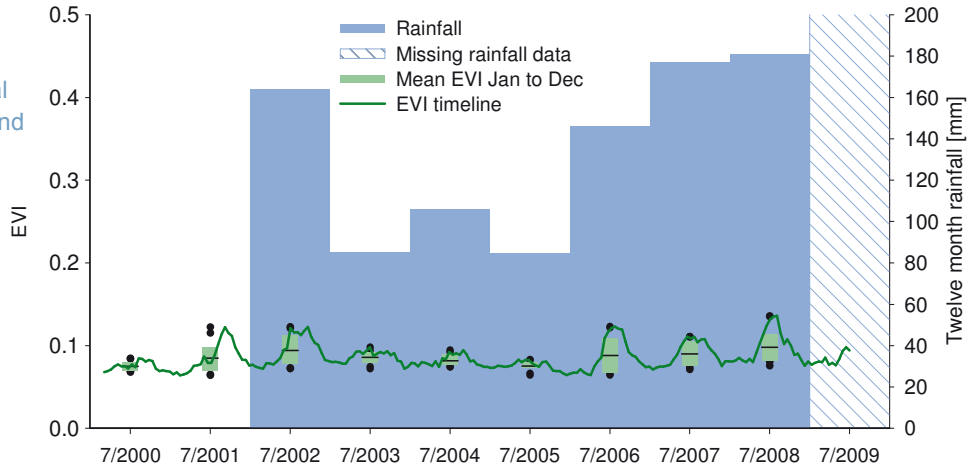
Defining features of the lithology in the Knersvlakte are the numerous intruded quartz veins and dens layers of quartz gravels, as well as shale, phyllite, and limestone rocks. The quartz fields in the Knersvlakte represent a unique flora and vegetation, dominated by leaf-succulent dwarf shrubs. They cover the central parts of the image, including the Observatory and surroundings. The western part of the Observatory and the surrounding areas to the west show nearly bare surfaces (violet to white colours), and the eastern and southern parts possess a higher vegetation coverage indicated by the light green tones. The grey-green parts in the west and east of the image can be attributed to other succulent shrub communities, which have much higher cover. The parts of the image in the south-west and south-east (in green tones) represent grass communities on sandy soils, also with high cover.



Scene 178/75, acquisition date: 24 April 2006

MODIS time series

Temporal patterns of annual rainfall, vegetation cover, and phenology



Responsible authors: M. Keil & T. Labitzky

Climate

Data from BIOTA weather station

Location	Recorded period	Mean temperature
Moedverloren (S28)	2001–2009	19.6 (2.4–46.0) °C
Mean solar radiation	**Mean wind speed**	**Mean annual precipitation**
566 (260–956) MJ·m^{-2}·month^{-1}	3.0 (12.0) m·s^{-1}	131 (85–181) mm
Mean annual potential evapotranspiration	**Interannual precipitation variability**	**Mean relative humidity**
1331 mm	112%	69% (48–96%)
Aridity index (UNEP)		
0.10 (arid)		

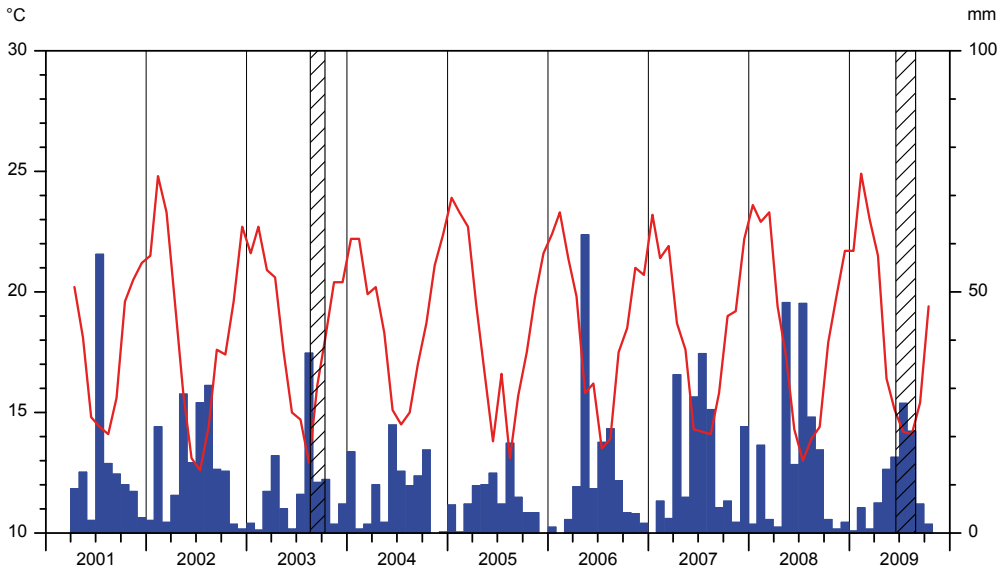
Modelled data

Mean temperature	Mean annual temperature range	Mean diurnal temperature range
18.7 (7.0–31.0) °C	9.5 °C	14.7 °C
Mean annual precipitation	**Precipitation seasonality**	**Percentage winter precipitation**
162 mm	67%	79% (winter)
Climate type	**Length of dry season**	**Aridity index (De Martonne)**
BWk	10 months	5.6 (dry)

The climate at the Observatory is characterised by arid to semi-arid conditions. Rainfall shows a moderate seasonality with more rain falling during the winter season, peaking in July. The mean annual rainfall over the observation period was 131 mm, which is fairly dry in comparison to the average rainfall recorded over the entire transect, but is in line with the average of the Observatories within the Succulent Karroo. However, substantial interannual variability is evident. The observed near-surface air temperatures show a moderate seasonal cycle. The mean annual temperature is 19.6°C, which approximates the average for this biome. Compared to the interpolated long-term data taken from the WorldClim dataset, a slightly warmer mean annual temperature is evident at the BIOTA weather station, and the maximum and minimum temperatures of the station records also deviate. For precipitation, mean annual rainfall observed at the station is markedly lower than that of the WorldClim dataset.

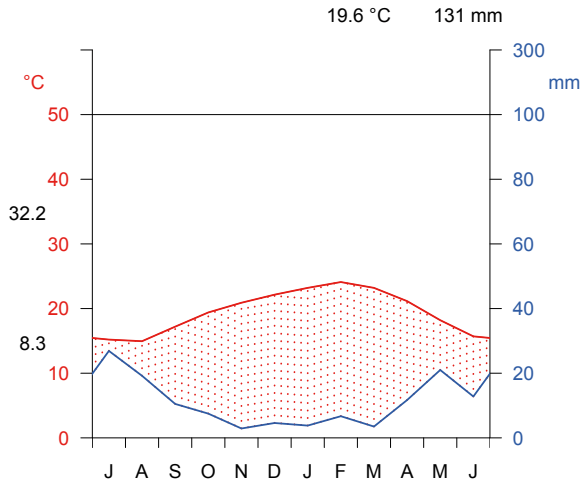
The observed near-surface winds at the Observatory are predominantly constituted of south-westerly flows, but a north-easterly component is also evident during autumn and winter. Mean wind speed shows a pronounced annual cycle in the early afternoon and evening, with slightly higher wind speeds in the afternoon. Winds in the mornings are noticeably weaker and are only moderately variable over the course of the year.

Time series: rainfall and temperature

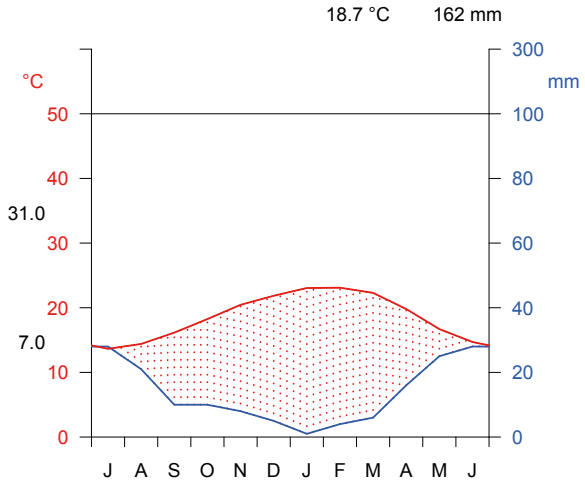


Climate diagrams

Recorded data (BIOTA)

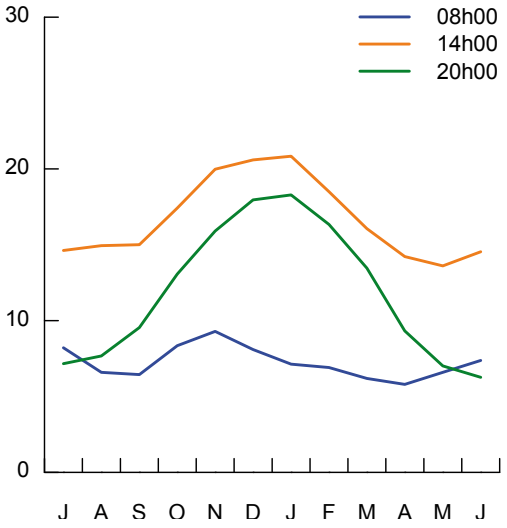


Modelled data (WorldClim)

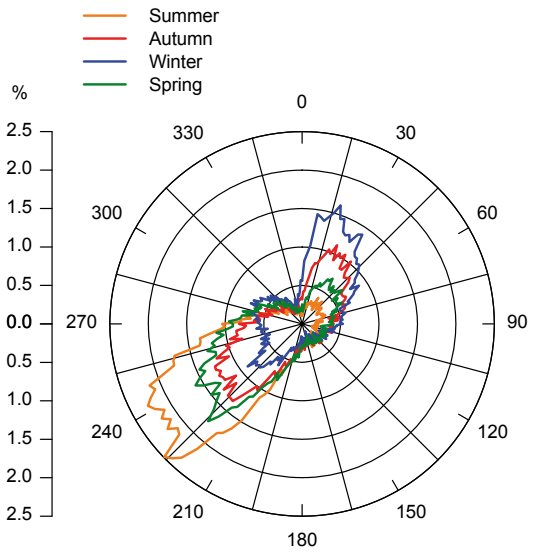


Wind diagrams

Speed



Directions

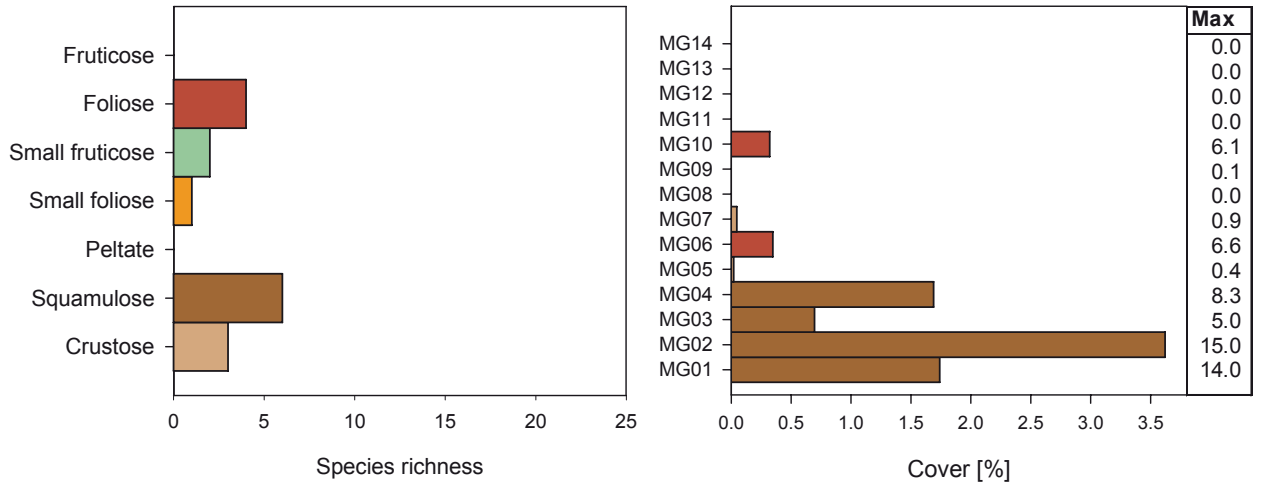


Responsible authors: K. Berger, A. Haensler & J. Luther-Mosebach

Lichens

Sampling period(s)	Hectare plots sampled	Cover
2001, 2002	12 (R1−R10, R53, R66)	7% (0−22%)
Total species richness	**Species richness on soil [1 km²]**	**Species richness on rock [1 km²]**
43	16 (38%)	17 (39%)
Species richness on plants [1 km²]	**Species richness on soil [1000 cm²]**	
10 (23%)	2 (0−6)	

Life forms



List of Taxa

Terricolous (on soil):

Buellia sp. 01 (M-0038988)
Buellia sp. 02 (M-0039075)
Caloplaca sp. 01 (M-0039083)
Collema coccophorum
Eremastrella crystallifera
Peccania arabica
Peccania font-queriana
Placidium squamulosum
Placidium tenellum
Psora crenata
Toninia australis
Toninia lutosa
Xanthoparmelia aff. imitatrix
Xanthoparmelia epigaea
Xanthoparmelia leonora
Xanthoparmelia simulans

Saxicolous (on rock):

Acarospora sp.
Acarospora strigata
Buellia sp. (2)
Caloplaca sp.
Caloplaca aff. rubelliana
Diploschistes aeneus
Diploschistes austroafricanus
Diploschistes henssenieae
Heppia sp.
Lecidea sp.
Rinodina sp.
Xanthomaculina hottentotta
Xanthoparmelia spp. (4)

Epiphytic (on plants):

Amandinea extenuata
Caloplaca aff. hungarica
Hyperphyscia pruinosa
Lecanora sp.
Opegrapha sp.
Rinodina sp.
Xanthoria dissectula
Xanthoria parietina
Xanthoria sp. 01 (M-0039089)
Xanthoria turbinata

Placidium tenellum. Photo: L. Zedda & G. Rambold.

Xanthoparmelia spp. Photo: L. Zedda & G. Rambold.

Xanthomaculina hottentotta. Photo: L. Zedda & G. Rambold.

This site is the poorest in lichen richness among the Observatories of the Knersvlakte, in spite of their similar climatic conditions. However, lichens occur on all major substrates, including soil. Grazing by small stock and marble mining on the Observatory before 2000 are likely to be the responsible factors for the relatively low species richness. Lichen cover on soil is lower, especially in comparison to the Observatory S26 (Goedehoop).

The occurrence and cover of the different lichen morphological groups are similar to the Observatory S27 (Ratelgat), although there is a slightly higher frequency of foliose lichens belonging to the genus *Xanthoparmelia* and representing the morphogroups MG06 and MG10 at this Observatory. Lichens are concentrated on the hectare plots H30, H39, H40 and H83, which are characterised by more alkaline soils and a lower cover of quartz pebbles.

Responsible authors:
L. Zedda & G. Rambold

Vascular plants

Sampling period(s)	Hectare plots sampled	Biome
2001–2009	20 (R1–R20)	Succulent Karoo
Vegetation unit (level 1)	**Vegetation unit (level 2)**	**Identification rate**
Knersvlakte Bioregion	SKk 3 Knersvlakte Quartz Vygieveld	72% – 88% – 90%
Cumulative family richness	**Dominant families (cover)**	**Dominant families (richness)**
47	Aizoaceae, Chenopodiaceae, Solanaceae	Asteraceae, Aizoaceae, Crassulaceae
Cumulative species richness (1 km²)	**Species richness (1000 m²)**	**Species richness (100 m²)**
429 – 291	59.9 (19–96)	28.7 (7–54)
***z*-value**	**Species richness change per year (1000 m²)**	**Evenness (1000 m²)**
0.320 (0.021–0.730)	0.95	0.663 (0.271–0.857)
Evenness (100 m²)	**Simpson (1000 m²)**	**Simpson (100 m²)**
0.608 (0.079–0.862)	0.848 (0.394–0.957)	0.759 (0.073–0.934)

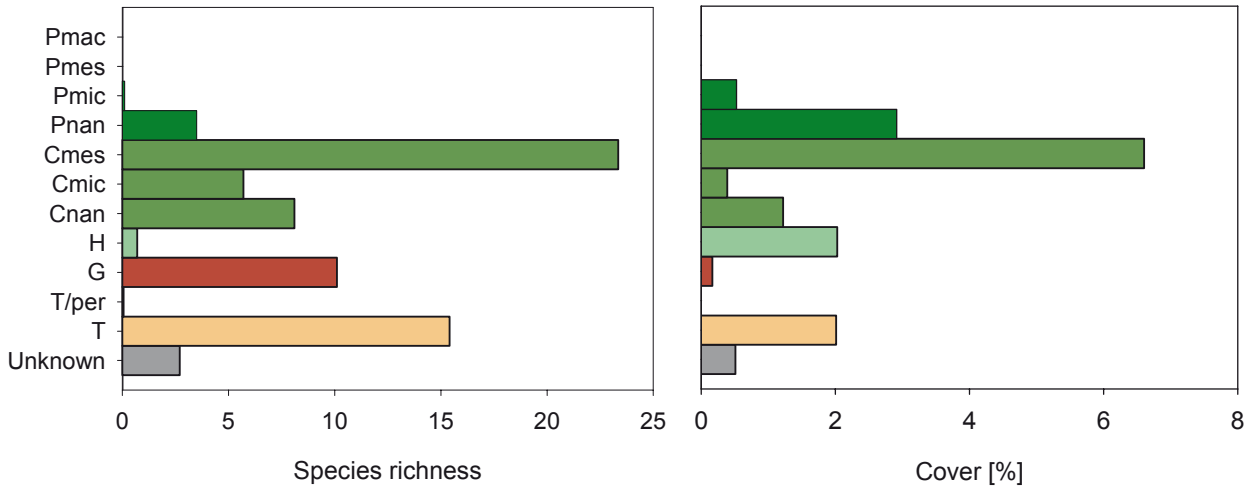
The vegetation, which falls under the Knersvlakte Quartz Vygieveld (SKk 3, Mucina et al. 2006), is characterised by a mosaic of different quartz field types on gentle hills, and sandy-loamy plains without quartz cover. The latter are dominated by dwarf shrub growth forms (C mes, P nan), mainly leaf-succulent Aizoaceae or Asteraceae, and may obtain a high cover (up to 10%) of annual Asteraceae (the Namaqua daisies) and geophytes. The quartz fields are sparsely covered by compact dwarf shrubs of the Aizoaceae and Crassulaceae (which possess few, thick, succulent leaves), many of which are endemic to the quartz fields of the Knersvlakte. Quartz field soils are either very saline with a pH around 7, or less saline with a very low pH (Schmiedel & Jürgens 1999). The vegetation on quartz fields is often dominated by a single species, which may reach high abundances, with other species only occurring with low cover and in low abundances. The average species richness at smaller spatial scales, with a mean of 28.7 species on 100 m²-plots (minimum: 7 species), is above the transect average but not exceptional. However, spatial species turnover (β-diversity), as expressed by high *z*-values between 100 m² and 1000 m², is very high. With a mean richness of 87.3 on 1 ha and 291 (in a single year) for 1 km², this Observatory is amongst the richest at these spatial scales along the entire BIOTA transect.

The *Stipagrostis namaquensis-Rhus undulata* community (unit 1) is restricted to riverbeds with favourable growing conditions for large, dense bushes and trees (P nan, P mic) such as *Rhus undulata* (Taaibos), *Euclea undulata* (Gewone Ghwarrie), *Lycium* spp. (Kriedoring), *Galenia africana* (Kraalbos), tall perennial grasses such as *Stipagrostis namaquensis* (Steekrietboesmangras), and the annual grass *Ehrharta longiflora* (Pêpê-gras). After good rainfall, the cover of the herbaceous layer may reach 100%, thus making the vegetation almost impenetrable. Saline quartz fields may occur on slopes adjacent to the riverbed, and are associated with obligate quartz field-dwelling dwarf succulents from the Knersvlakte-endemic Aizoaceae genera, e.g. *Dactylopsis digitata* (Duim-en-vinger), *Oophytum oviforme*, and *Argyroderma crateriforme*.

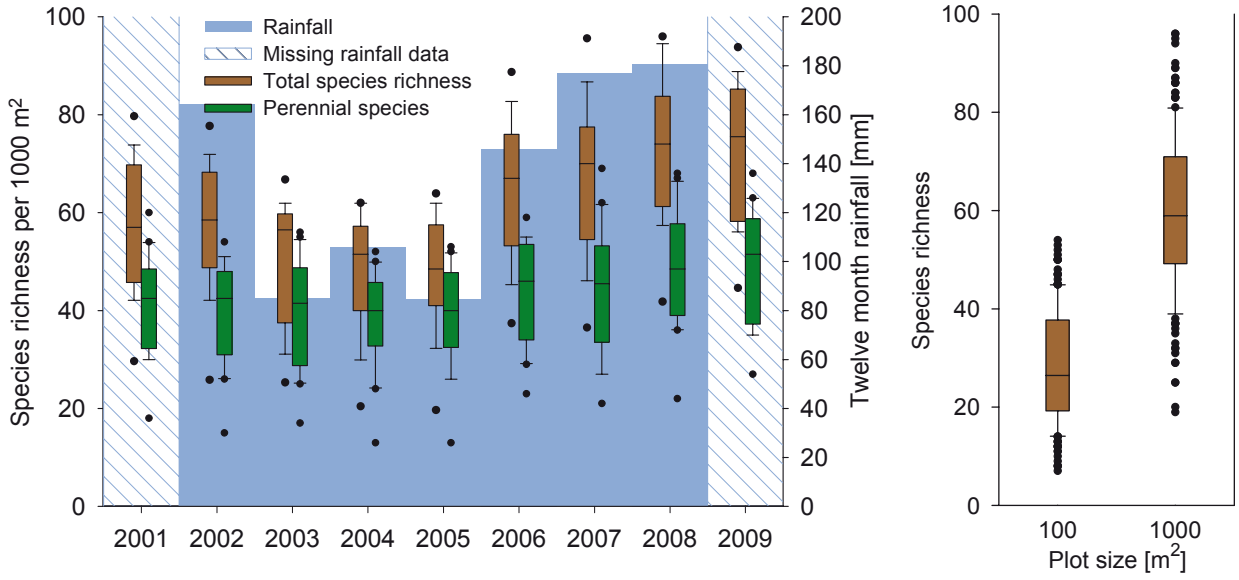
Homogeneous, low-lying areas of sandy-loamy soils without quartz cover occur between the quartz hills that dominate the landscape on Moedverloren. They often possess a high cover of biological soil crusts and are inhabited by the *Amphibolia saginata-Ruschia versicolor* community (unit 2). *Amphibolia saginata* (syn. *Ruschia stricta* subsp. *turgida*), a shrubby species with comparatively large succulent leaves and typically found on soils with high gypsum content in the western parts of the Knersvlakte. *Ruschia versicolor*, often found on sandy soils throughout lowland Namaqualand, is a mat-forming leaf-succulent shrub of the family Aizoaceae. The community is often accompanied by annual non-succulent Asteraceae (*Rhynchopsidium pumilum*, *Foveolina dichotoma*) and Scrophulariaceae (*Zaluzianskya affinis*), which can reach high cover values after strong rainfall.

The *Argyroderma framesii* ssp. *hallii-Ruschia burtoniae* community (unit 3) is characterised by obligate quartz dwelling dwarf shrubs such as the Knersvlakte-endemic species *Dicrocaulon humile*, *Argyroderma framesii* subsp. *hallii*, *Lampranthus hallii*, *Phyllobolus quartziticus*, and *Monilaria moniliformis* (Bobbejaansvinger). The community occurs on acid quartz fields, which are typically covered by quartz gravel with larger diameters (6–20 cm) than the saline quartz fields (see also Observatories S26 and S27). Characteristic features of these quartz fields are the leaf-succulent, dwarf "quartz" ecotypes (C mes) of *Berkheya fruticosa* and *Tripteris oppositifolia*, two Asteraceae species, which grow in zonal habitats as tall, non-succulent shrubs (P nan).

Life forms



Species richness



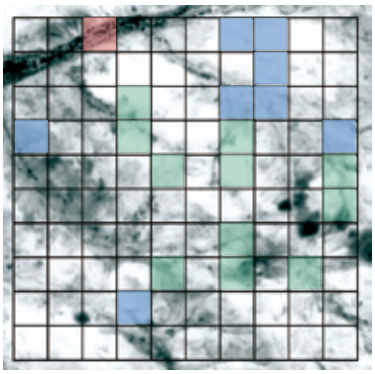
Unit 1, H02, dense shrub vegetation in the dry riverbed, 2006. Photo: R. Christiaan.

Unit 2, H39, 2002. Photo: U. Schmiedel.

Unit 2, H26, 2002. *Amphibolia saginata* (syn. *Ruschia stricta* subsp. *turgida*) and pink flowering *Psilocaulon dinteri*. Photo: U. Schmiedel.

Unit 3, H59, with *Monilaria moniliformis* and succulent ecotype of *Berkheya fruticosa* on quartz fields, 2002. Photo: U. Schmiedel

Map of vegetation units



Drosanthemum diversifolium an endemic species of the Knersvlakte. Photo: U. Schmiedel.

Triglochin bulbosa is an obligate quartz field dweller that is also endemic to the Knersvlakte. Photo: U. Schmiedel.

Classification table 2008

Column		Cover	All	*1*	2	3
Number of relevés			**20**	***1***	**8**	**11**
Mean cover [%]			16.8	*105*	12.6	11.9
Mean species richness (1000 m²)			73.4	*71.0*	65.1	79.6
Inclination [°]			7.0	*30.0*	3.9	7.1
Biotic crust [%]			32.0	*20.0*	45.6	23.2
Unit 1: Stipagrostis namaquensis-Rhus undulata community*						
Cmes	Viscum sp.	0.05	5	*100*	.	.
T/Hper	Malva parviflora var. parviflora	0.05	5	*100*	.	.
Cmes	Lycium oxycarpum	0.10	5	*100*	.	.
H	Stipagrostis namaquensis	0.02	5	*100*	.	.
Pnan	Didelta spinosa	0.65	5	*100*	.	.
n.a.	Zygophyllum leptopetalum	1.00	5	*100*	.	.
H	Fingerhuthia africana	0.02	5	*100*	.	.
Cmes	Afrolimon teretifolium	0.10	5	*100*	.	.
Cmes	Gnidia pedunculata	0.02	5	*100*	.	.
G	Bromus sp. 116588	40.00	5	*100*	.	.
T	Atriplex vestita	1.00	5	*100*	.	.
Cmes	Pteronia divaricata	0.50	5	*100*	.	.
Cmes	Ballota africana	0.02	5	*100*	.	.
Cmes	Tetragonia sp. 118947	1.00	5	*100*	.	.
Cmes	Psilocaulon leptarthron	0.50	5	*100*	.	.
Cmes	Galenia africana	1.00	5	*100*	.	.
Unit 2: Amphibolia saginata-Ruschia versicolor community						
Cmes	Ruschia versicolor	0.24	40	.	100	.
Cmes	Amphibolia saginata	2.70	45	.	100	9
Cmes	Drosanthemum ramosissimum	0.13	50	.	100	18
T	Zaluzianskya affinis	0.01	30	.	75	.
Cmes	Drosanthemum curtophyllum	0.41	25	.	63	.
Cmes	Drosanthemum sp. 116576	0.34	50	.	88	27
Cnan	Antimima solida	0.01	20	.	50	.
T	Heliophila variabilis	0.02	45	.	75	27
T	Bromus pectinatus	0.01	15	.	38	.
Unit 3: Argyroderma framesii ssp. Hallii-Ruschia burtoniae community						
Cmes	Tetragonia verrucosa	1.03	55	.	.	100
Cnan	Argyroderma framesii ssp. hallii	0.12	60	.	13	100
Cnan	Senecio aloides	0.01	45	.	.	82
Cmes	Ruschia burtoniae	0.68	45	.	.	82
H	Ehrharta barbinodis	0.04	45	.	.	82
Cmic	Dicrocaulon humile	0.11	40	.	.	73
Cmes	Lampranthus hallii	0.12	40	.	.	73
G	Ornithogalum pruinosum	0.01	50	.	13	82
Cnan	Conophytum calculus ssp. calculus	0.01	35	.	.	64
Cmes	Salsola sp. 116553	0.04	35	.	.	64
Cmes	Berkheya fruticosa	0.19	35	.	.	64
Pnan	Tripteris oppositifolia	0.14	45	.	13	73
Cnan	Spergularia media	0.16	65	.	38	91
G	Gladiolus orchidiflorus	0.01	30	.	.	55
T	Tribolium utriculosum	0.04	30	.	.	55
Cnan	Polygala mossii	0.05	30	.	.	55
Cmes	Phyllobolus quartziticus	0.11	70	.	50	91
Cnan	Crassula columnaris ssp. prolifera	0.01	70	.	50	91
Cmes	Asparagus capensis	0.13	40	.	13	64
Cmes	Monilaria moniliformis	0.53	60	.	38	82
Cmic	Antimima watermeyeri	0.06	60	.	38	82
G	Moraea deserticola	0.02	50	.	25	73
Cmes	Salsola sp. 118975	0.12	50	.	25	73
T	Arctotis campanulata	0.02	25	.	.	45
Cnan	Antimima dualis	0.06	25	.	.	45

** diagnostic species are not significant*

Continued on next page

Classification table (continued)

Column		Cover	All	*1*	2	3
Number of relevés			**20**	***1***	**8**	**11**
Par	Hyobanche sanguinea	0.01	25	.	.	45
Cnan	Euphorbia celata	0.01	25	.	.	45
Cmes	Mesembryanthemum longistylum	0.03	25	.	.	45
G	Gladiolus alatus	0.01	25	.	.	45
Cmes	Berkheya fruticosa	0.11	25	.	.	45
Most frequent companions						
Cmes	Psilocaulon dinteri	0.11	100	*100*	100	100
T	Didelta carnosa	0.21	95	*100*	100	91
T	Mesembryanthemum nodiflorum	0.13	95	.	100	100
Cmes	Tetragonia fruticosa	0.10	95	.	100	100
Cmes	Salsola zeyheri	0.61	90	*100*	88	91
Cnan	Cephalophyllum spissum	0.39	90	.	88	100
Hper	Gazania krebsiana ssp. krebsiana	0.22	90	.	100	91
Cmes	Drosanthemum diversifolium	0.20	90	*100*	100	82
Cmes	Galenia fruticosa	0.07	85	*100*	88	82
T	Osteospermum pinnatum var. pinnat	0.06	85	*100*	88	82
G	Oxalis pes-caprae	0.03	85	*100*	88	82
Pnan	Lycium cinereum	1.15	80	*100*	75	82
T	Foveolina dichotoma	0.97	80	.	100	73
Cmes	Sarcocornia xerophila	0.70	80	*100*	75	82
Cmes	Ruschia bolusiae	0.40	80	*100*	75	82
T	Atriplex lindleyi ssp. inflata	0.10	80	.	100	73
Cnan	Argyroderma crateriforme	0.05	80	*100*	75	82
T	Amellus microglossus	0.03	80	*100*	100	64
T	Senecio arenarius	0.01	80	*100*	100	64
Cmic	Zygophyllum cordifolium	0.07	75	*100*	88	64
Cmes	Drosanthemum pulverulentum	0.69	70	.	63	82
Cmes	Hermannia cuneifolia var. glabrescer	0.06	70	*100*	38	91
T	Oncosiphon suffruticosum	0.06	70	*100*	75	64
T	Helichrysum leontonyx	0.04	70	.	75	73
Cnan	Dactylopsis digitata	0.18	65	*100*	50	73
Cmic	Helichrysum dregeanum	0.09	65	.	75	64
T	Poaceae sp. 15036	0.06	65	.	50	82
G	Oxalis luteola	0.02	65	.	75	64
T	Cromidon sp. 15009	0.02	65	*100*	75	55
G	Oxalis sp. 116549.1	0.01	65	*100*	50	73
T	Tripteris clandestina	0.01	65	*100*	63	64
Cnan	Malephora purpureo-crocea	0.39	60	*100*	75	45
Cnan	Argyroderma fissum	0.19	60	.	75	55
Cmes	Asparagus recurvispinus	0.11	60	.	50	73
Cmic	Zygophyllum teretifolium	0.07	60	*100*	50	64
G	Othonna intermedia	0.01	60	*100*	88	36
Cnan	Cephalophyllum framesii	0.42	55	.	75	45
Cmes	Euphorbia decussata	0.12	55	.	38	73
Cmes	Pelargonium crithmifolium	0.07	55	.	38	73
T	Schismus barbatus	0.07	55	*100*	63	45
Cmes	Crassula subaphylla var. subaphylla	0.01	55	.	50	64
G	Lapeirousia pyramidalis	0.01	55	*100*	25	73
Cmes	Salsola sp. 116603	0.26	50	*100*	50	45
T	Mesembryanthemum fastigiatum	0.22	50	.	75	36
Cmes	Crassula subaphylla var. virgata	0.01	50	.	63	45
T	Ursinia nana ssp. nana	0.01	50	.	38	64
Cmes	Crassula muscosa var. muscosa	0.01	50	.	50	55
Pnan	Lycium ferocissimum	1.31	45	*100*	50	36
Cmes	Drosanthemum globosum	0.38	45	*100*	63	27
Cmes	Pteronia heterocarpa	0.16	45	.	38	55
T	Mesembryanthemum guerichianum	0.08	45	*100*	38	45
Cmes	Pteronia sp. 123431	0.04	45	.	25	64
Cmic	Drosanthemum schoenlandianum	0.01	45	*100*	38	45
G	Triglochin bulbosa	0.01	45	*100*	50	36
G	Bulbine dactylopsoides	0.01	45	*100*	50	36

Tylecodon pygmaeus produces very few leaves every year. Photo: S. Etzold.

Crassula columnaris ssp. *prolifera* is typically found on quartz fields. Photo: U. Schmiedel.

Responsible authors:
U. Schmiedel & J. Luther-Mosebach

Vertebrates

Total species richness	Reptile species richness	Bird species richness
13	n.a.	13
Large mammal species richness	Small mammal species richness	
n.a.	n.a.	

Birds

Passeriformes	**Perching birds**
Ploceus capensis	Cape Weaver
Serinus alario	Blackheaded Canary
Spreo bicolor	Pied Starling
Urocolius indicus	Redfaced Mousebird
Parus afer	Southern Grey Tit
Ptyonoprogne fuligula	Rock Martin
Prinia maculosa	Karoo Prinia
Serinus albogularis	White-throaded Canary
Cisticola subruficapillus	Grey-backed Cisticola
Passer melanurus	Cape Sparrow
Telophorus zeylonus	Bokmakierie
Cercomela schlegelii	Karoo Chat
Emberiza capensis	Cape Bunting

Responsible author: W. Mey

Impact of disturbance and restoration potential of quartz field vegetation

► *See* **S27.01**

Photo: J. Dengler

Fynbos

Boundaries

- International Boundary
- Provincial Border

Hydrography

- River
- Periodical River
- Salt Pan
- Lake
- Wetland

Contour Levels

- up to 300 m
- up to 600 m
- up to 900 m
- up to 1200 m
- up to 1500 m
- up to 1800 m
- more than 1800 m

Communications

- Motorway
- Road
- Railway

Populated Places

- City
- Provincial Capital
- Capital

- Transect
- S32 Elandsberg — BIOTA Observatory

0 250 500 km

Uwe Ulrich Jäschke & Karen Langner • HTW - University of Applied Sciences Dresden

Fynbos vegetation at the Cape of Good Hope Observatory. Photo: G. Miehlich.

Fynbos

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II.7.2 Riverlands (S31) 748
II.7.3 Elandsberg (S32)..... 762
II.7.4 Cape of Good Hope (S33)..... 776
II.7.5 Nieuwoudtville (S45) 790

The Fynbos Biome is characterised by dense vegetation dominated by hard-leaved shrubs, small trees, and grass-like growth forms. The biome is part of the Cape Floristic Region, a global biodiversity hotspot located in the south-western part of South Africa. The Fynbos Biome has a Mediterranean type climate, with comparatively high rainfall occurring during the winter months. A combination of topographic, edaphic, and climatic gradients and the frequent occurrence of fire have been suggested as the main driving forces of speciation in the Fynbos Biome, resulting in a great variety of vegetation types. The lowlands in particular have been extensively transformed due to agriculture, urbanisation, and invasion, and once continuous habitats have been reduced to small, fragmented islands surrounded by transformed land.

The four Observatories in the Fynbos Biome represent different major vegetation units. Rocherpan Observatory (S29) close to the west coast is situated in the Western Strandveld vegetation. The Riverlands Observatory (S31) represents the Sand Fynbos, the Elandsberg Observatory (S32) represents the Alluvium Fynbos bordering the Shale Renosterveld, and Nieuwoudtville Observatory (S45) is situated on Shale-, Granite- and Dolorite Renosterveld, while the Cape of Good Hope Observatory (S33) is part of the Sandstone Fynbos. All vegetation types are highly endangered by fragmentation, transformation, and invasive alien plant species. [U. Schmiedel]

General data

Number	Name	Alternative name(s)
S29	Rocherpan	Rocherpan Nature Reserve
Implementation	**Country**	**Province/ region**
2001	South Africa	Western Cape
District/ constituency	**Locality**	**Farm name**
West Coast	Piquetberg	Rocherpan
Latitude	**Longitude**	**Altitude**
32.600848 S	18.305600 E	35 m a.s.l.
Rainfall season	**Biome**	**WWF Ecoregion**
Winter	Fynbos	AT1202 Lowland fynbos and renosterveld
Agro-Ecological Zone	**Relative intensity of land use**	**Tenure**
n.a.	None	State
Type and history of landuse	**Land owner**	
Conservation area	CapeNature	

Rocherpan (S29)

Coastal wetland at Rocherpan Observatory. Photo: R. Kongor.

The Rocherpan BIOTA Observatory is situated within the Rocherpan Nature Reserve (named after Pierre Rocher who was in the area around 1839). The reserve is located approximately 180 km north of Cape Town and 35 km north of the Berg River near the Langebaan Peninsula, in the winter rainfall region of the west coast of South Africa. The reserve is bounded by farmlands to the north, east and south and the Atlantic Ocean in the west. The Observatory is situated on flat to gently undulating aeolian sands (deep tertiary to recent) and calcrete of marine origin (Mucina & Rutherford 2006). The vegetation on the observatory has been rested from livestock grazing to varying degrees, with certain areas having been rested for 40 years and others for 16 years (by 2010). The altitude at the Observatory is approximately 35 m a.s.l. Mean annual rainfall ranges between 230 mm and 355 mm (Rebelo et al. 2006) with the wettest months being June, July and August. Mean annual rainfall was between 173 and 357 mm during the BIOTA study period.

Prior to the establishment of the reserve in 1967, the area was used for light grazing of goats, sheep, and cattle since ca. 1840 (Cheney 2004, Kongor 2009). The first portion of the reserve (394 ha) was proclaimed in 1967 and a second portion (520 ha) was proclaimed in 1990, which marked the end of grazing and fire. Currently the Rocherpan Nature Reserve covers some 900 hectares and is a provincial nature reserve managed

by CapeNature. It consists of five main habitat types, namely Dunes, Seasonal Wetland, West Coast Strandveld, Sandy Beach, and the Marine Ecosystem. The reserve represents part of the 30% of the Langebaan Dune Strandveld vegetation type under statutory conservation. This vegetation type is classified as vulnerable, with about 35% recently transformed for cultivation and by urban sprawl. Alien *Acacia cyclops* and *A. saligna* have also invaded and degraded broad stretches of this vegetation type (Rebelo et al. 2006, Kongor 2009).

The objectives of the Rocherpan BIOTA Observatory are to monitor the impacts of land use change and human-induced habitat transformation (fragmentation and degradation) on both animal (birds, small mammals) and plant species, focusing on plant traits, which are predictors of ecosystem response to global changes.

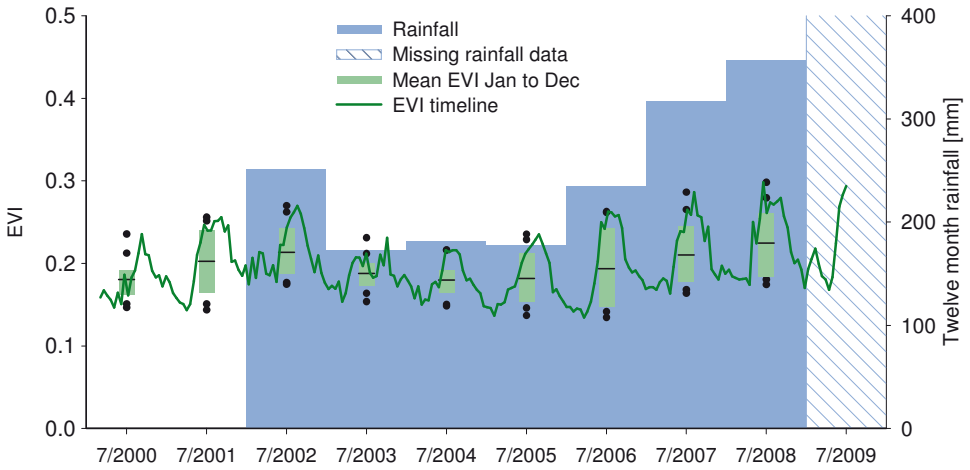
Responsible authors: R.Y. Kongor & D.H. Haarmeyer

Remote sensing and landscape

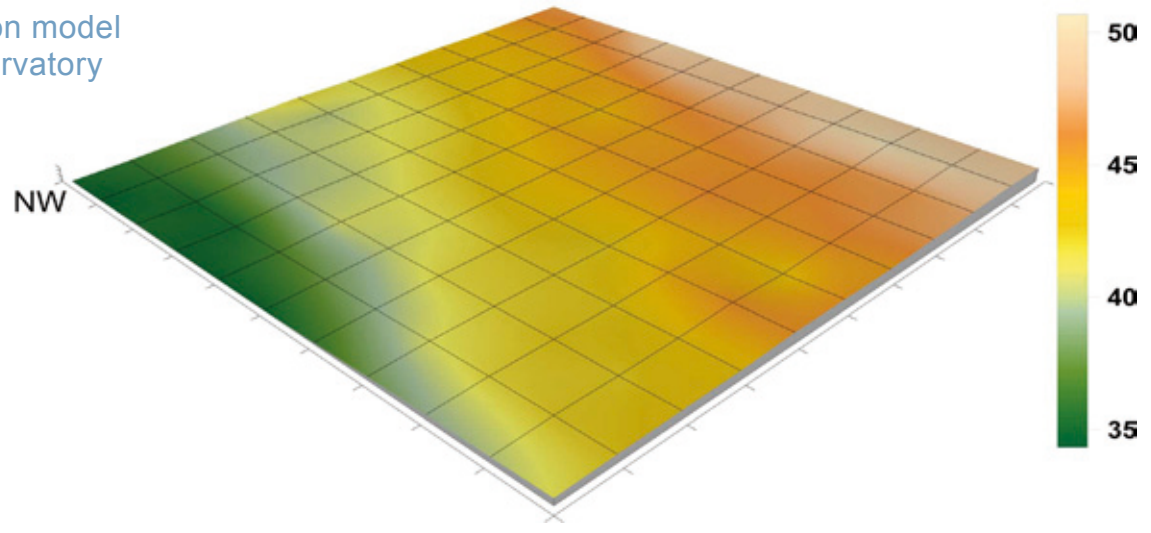
Geomorphology	Geological units	Lithological units
Wetland (seasonal), strandveld	Cenozoic Deposits	Unconsolidated superficial deposits, Conglomerate, Limestone, Sandstone, arl, high-level gravel
Mean EVI	**EVI absolute range**	**Mean leaf area index**
0.197 (0.153–0.254)	0.135 (2006)–0.298 (2009)	0.68

MODIS time series

Temporal patterns of annual rainfall, vegetation cover, and phenology



Elevation model of Observatory



Landsat image

Rocherpan is a coastal wetland about two kilometres in length (appearing in pink-red because of the low water level in February, with only a small area of standing water in blue at the southern edge) occurring behind a beach (white-blue) and a narrow coastal dune belt (dark grey). The pan and neighbouring Strandveld vegetation are part of a nature reserve managed by CapeNature. The fynbos vegetation of the Strandveld vegetation type shows as dark grey-green. The neighbouring agricultural fields show mainly in green, bare fields in white, and fallow lands (in the southern part) in grey. Round spots are fields with circular irrigation systems, and those with standing crops in the green vegetation phase appear red. Fields with a grey-green streaky pattern indicate fields with strips of remnant natural vegetation used to reduce wind erosion.

Scene: 175/83, acquisition date: 07 February 2007

Grid map of Observatory

	0	1	2	3	4	5	6	7	8	9
0	11	15	47	79	42	24	64	1	94	6
1	3	23	83	44	72	12	30	59	85	69
2	35	19	62	33	9	78	98	100	43	26
3	39	7	90	71	65	20	8	32	17	37
4	31	58	89	68	16	38	99	67	84	21
5	27	36	4	73	34	70	50	93	25	41
6	46	51	92	60	76	74	63	45	49	5
7	57	86	66	91	95	56	88	96	54	82
8	97	87	10	13	75	55	53	80	22	81
9	2	48	61	77	14	29	40	52	18	28

1	Seasonal wetland
2	Strandveld vegetation - restios and woody shrubs

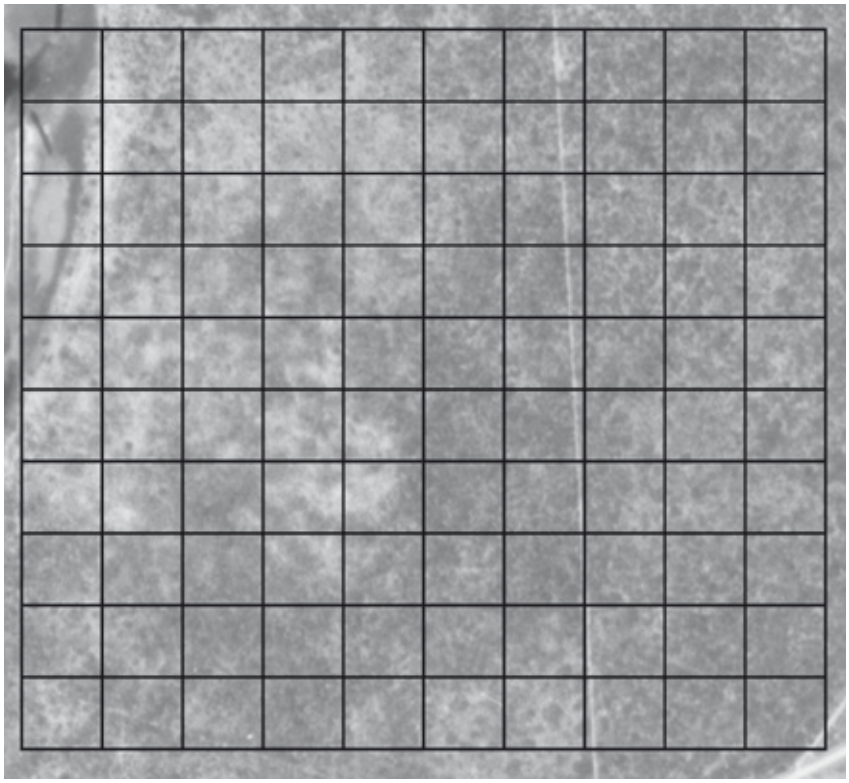


Image: aerial photograph

Responsible authors: M. Keil & T. Labitzky

Climate

Data from BIOTA weather station

Location	Recorded period	Mean temperature
Rocherpan (S29)	2001–2009	16.9 (-0.6–41.5) °C
Mean solar radiation	**Mean wind speed**	**Mean annual precipitation**
547 (232–908) MJ·m^{-2}·month^{-1}	2.2 (7.5) m·s^{-1}	250 (173–357) mm
Mean annual potential evapotranspiration	**Interannual precipitation variability**	**Mean relative humidity**
1280 mm	103%	63% (38–93%)
Aridity index (UNEP)		
0.20 (arid)		

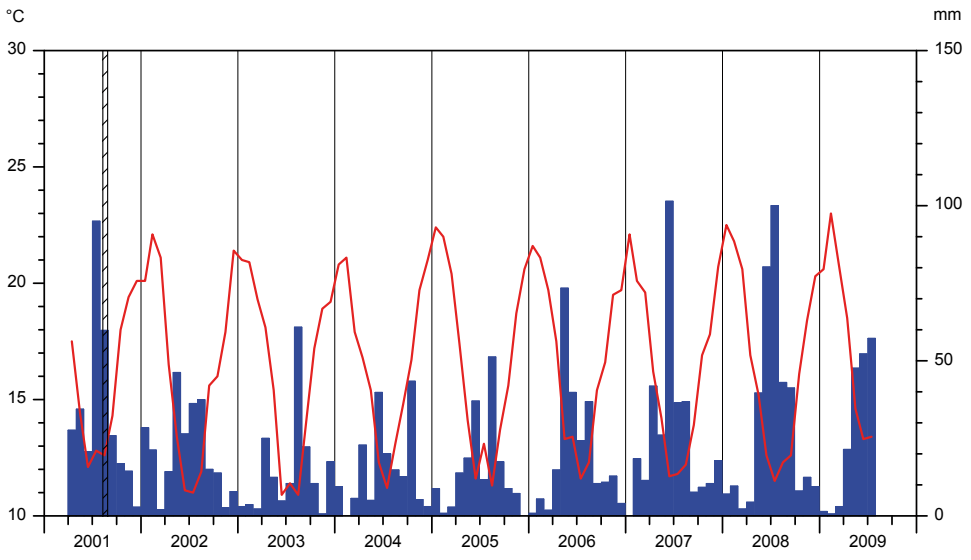
Modelled data

Mean temperature	Mean annual temperature range	Mean diurnal temperature range
17.5 (7.6–28.5) °C	8.8 °C	12.2 °C
Mean annual precipitation	**Precipitation seasonality**	**Percentage winter precipitation**
251 mm	67%	79% (winter)
Climate type	**Length of dry season**	**Aridity index (De Martonne)**
BSk	8 months	9.1 (dry)

The climate at the Observatory is characterised by semi-arid conditions. Rainfall shows a moderate seasonality with the major portion of rain falling during the winter season, peaking in June. The mean annual rainfall over the observation period was 250 mm, which is the approximate average rainfall recorded over the entire transect, but is fairly dry compared to the Observatories within the Fynbos Biome. However, substantial interannual variability is evident. The observed near-surface air temperatures show a moderate seasonal cycle. The mean annual temperature is 16.9°C and is therefore one of the coldest of all Observatories. The observed mean minimum temperature is above the freezing point, but there is still a possibility of the occurrence of frost in June. Compared to the interpolated long-term data taken from the WorldClim dataset, a slightly cooler mean annual temperature is observed at the station. Furthermore, station records of extreme temperatures deviate substantially from the interpolated data, showing warmer maximum and colder minimum temperatures. For precipitation, only minor differences compared to the WorldClim dataset are evident.

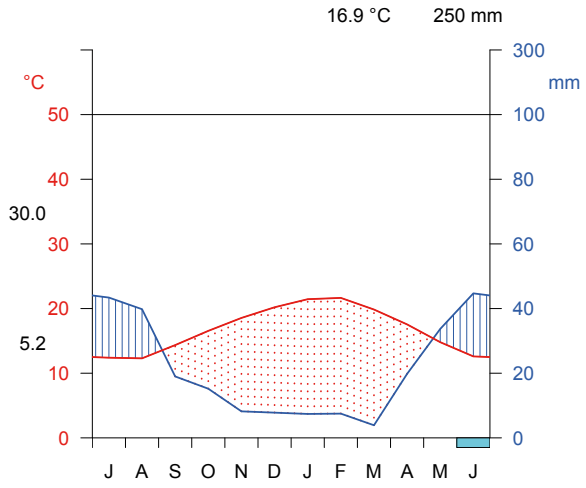
The observed near-surface winds at the Observatory are predominantly constituted of south-southeasterly flows throughout the year. Mean wind speed is highest during the early afternoons, reaching about 10 km/h. Winds during that time of the day stay fairly constant throughout the year, whereas a pronounced annual cycle is evident for the mean wind speeds during the mornings and evenings.

Time series: rainfall and temperature

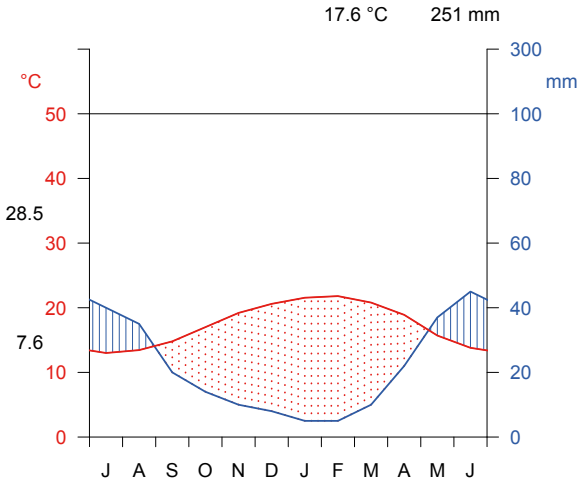


Climate diagrams

Recorded data (BIOTA)

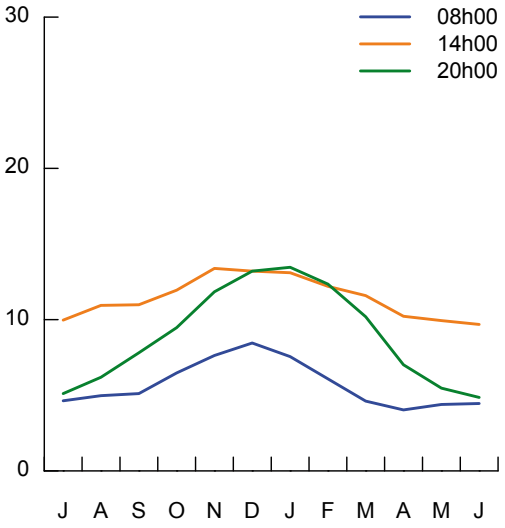


Modelled data (WorldClim)

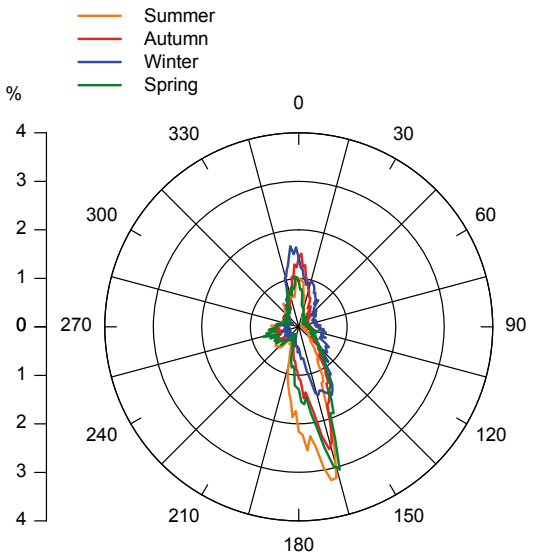


Wind diagrams

Speed



Directions



Responsible authors: K. Berger, A. Haensler & J. Luther-Mosebach

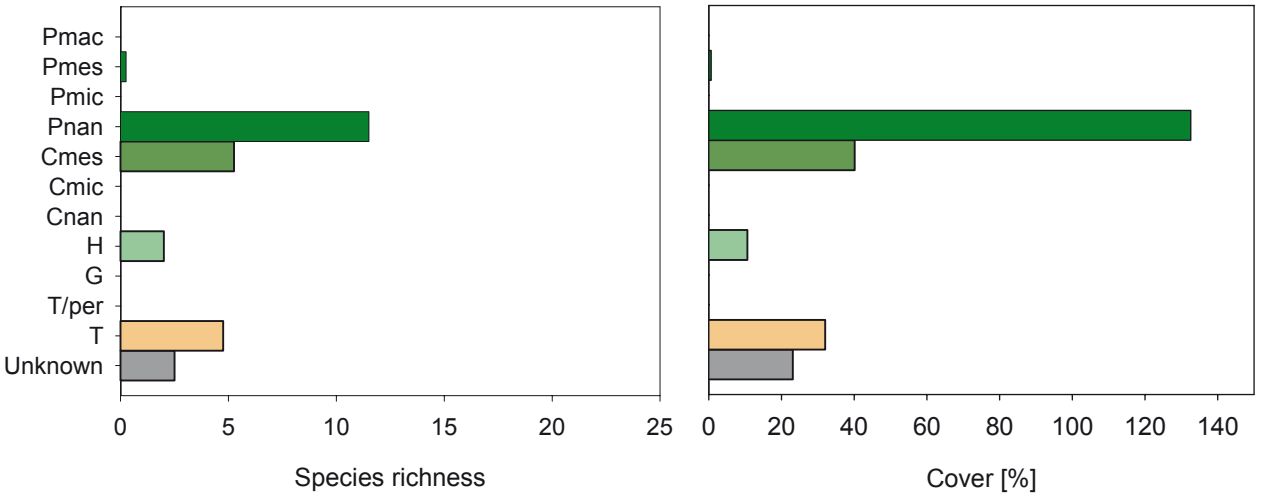
Vascular plants

Sampling period(s)	Hectare plots sampled	Biome
2005	20 (R1–R20)	Fynbos
Vegetation unit (level 1)	**Vegetation unit (level 2)**	**Identification rate**
Western Strandveld	FS 5 Langebaan Dune Strandveld	88% – n.a. – 85%
Cumulative family richness	**Dominant families (cover)**	**Dominant families (richness)**
22	Asteraceae, Restionaceae, Anacardiaceae	Asteraceae, Fabaceae, Poaceae
Cumulative species richness (1 km²)	**Species richness (1000 m²)**	**Species richness (100 m²)**
n.a.	n.a.	27.5 (24–31)
***z*-value**	**Species richness change per year (1000 m²)**	**Evenness (1000 m²)**
n.a.	n.a.	n.a.
Evenness (100 m²)	**Simpson (1000 m²)**	**Simpson (100 m²)**
0.861 (0.819–0.906)	n.a.	0.917 (0.895–0.931)

The vegetation of the Rocherpan BIOTA Observatory forms part of the Western Strandveld and is classified as Langebaan Dune Strandveld (FS 5, Mucina & Rutherford 2006). Two main habitat types can be identified within the BIOTA Observatory. A seasonal wetland to the south covers some 10% and supports mainly fleshy-leafed cushion plants. The drier duneveld to the north covers some 90% and supports mainly evergreen, low to medium (up to 2 m tall), sclerophyllous or succulent and fleshy fruited shrubs as well as geophytes, graminoids and annual herbaceous species, which occur mainly in gaps. Ornithochory is a very common feature in strandveld with the presence of many fleshy-fruited plant and frugivorous bird species (Knight 1988, Kongor 2009). This drier section of the Observatory was the area sampled by Kongor (2009).

As is generally the case in the Cape Floristic Region, plant diversity is particularly high. Species richness at 100 m² is above the mean and Simpson's Diversity Index at 100 m² is the highest along the entire transect. An average of 50 ± 10 species can be recorded per 1000 m² (Kongor 2009). However, the number of plant families is amongst the lowest of the BIOTA Southern Africa Observatories. Complementarity (C), which is a measure of local scale species turnover (β-diversity) or distinctness between species assemblages (Colwell

Life forms



Species list (2005)

Column		Cover	All
Number of relevés			**4**
Mean cover [%]			243.5
Mean species richness (1000 m²)			27.5
Pnan	Willdenowia incurvata	29.13	100
Pnan	Eriocephalus racemosus	22.00	100
Cmes	Othonna cylindrica	20.13	100
Pnan	Rhus glauca	20.13	100
Pnan	Tetragonia decumbens	17.63	100
Pnan	Salvia lanceolata	10.63	100
Cnan	Senecio aloides	8.75	100
Pnan	Zygophyllum morgsana	8.75	100
T	Helichrysum moeserianum	7.50	100
T	Phyllopodium cephalophorum	6.88	100
n.a.	Ruschia sp. 9957	6.88	100
H	Ehrharta calycina	6.25	100
Pnan	Anisodontea cf. scabrosa	5.00	100
Cmes	Hermannia trifurca	3.13	100
T	Hebenstretia sp. 9958	16.83	75
n.a.	Ruschia sp. 9956	16.67	75
Pnan	Lebeckia multiflora	10.83	75
Cmes	Pteronia divaricata	5.00	75
Pmic	Rhus laevigata var. laevigata	5.00	75
n.a.	Trachyandra divaricata	5.00	75
L	Cissampelos capensis	4.17	75
H	Ehrharta villosa	4.17	75
Pnan	Melianthus elongatus	2.50	75
Cmes	Leysera gnaphalodes	3.75	50
T	Apatesia pillansii	2.50	50
L	Asparagus aethiopicus	2.50	50
T	Isolepis cf. marginata	2.50	50
Pnan	Lycium cinereum	2.50	50
T	Nestlera biennis	2.50	50
Pnan	Putterlickia pyracantha	2.50	50
T	Ursinia anthemoides	2.50	50
H	Chaetobromus involucratus	5.00	25
Cmes	Argyrolobium velutinum	2.50	25
Pnan	Chrysanthemoides monilifera	2.50	25
Cmes	Cotyledon orbiculata	2.50	25
Pmes	Euclea racemosa	2.50	25
Pnan	Euphorbia arceuthobioides	2.50	25
Pnan	Euphorbia caput-medusae	2.50	25
Cmes	Microloma sagittatum	2.50	25
Cmes	Pteronia onobromoides	2.50	25
Cmes	Tylecodon wallichii	2.50	25
Pnan	Wiborgia cf. fusca	2.50	25

**list from plot size 100 m²*

& Coddington 1994), ranged between 45%–66% with an average of 57% ± 8% (Kongor 2009). This relatively low complementarity is due to the high proportion of common species to unique species recorded between any two communities and reflects the relatively uniform habitat within the sampled dry section of the Rocherpan Observatory. The most common species included: *Hermannia trifurca*, *Othonna cylindrical*, *Pteronia divaricata* and *Leysera gnaphalodes* (C mes); *Senecio aloides* (C nan); *Trachyandra divaricata* (G); *Ehrharta calycina* and *E. villosa* (H); *Cissampelos capensis* and *Asparagus aethiopicus* (L); *Euclea racemosa* (P mes); *Rhus laevigata* var. *laevigata* (P mic); *Anisodontea scabrosa*, *Chrysanthemoides monilifera*, *Eriocephalus racemosus*, *Euphorbia arceuthobioides*, *E. caput-medusae*, *Lebeckia multiflora*, *Lycium cinereum*, *Melianthus elongates*, *Putterlickia pyracantha*, *Rhus glauca*, *Ruschia* spp., *Salvia lanceolata*, *Tetragonia decumbens*, *Willdenowia incurvata*, *Wiborgia fusca*, *Zygophyllum morgsana* (for P nan); *Apatesia pillansii*, *Hebenstretia* sp., *Helichrysum moeserianum*, *Nestlera biennis*, *Phyllopodium cephalophorum* and *Ursinia anthemoides* (T).

Leysera gnaphaloides (Asteraceae). Photo: R. Kongor.

Dense Strandveld vegetation. Photo: R. Kongor.

Dense Strandveld vegetation. Photo: R. Kongor.

Ruschia sp. (Aizoaceae). Photo. R. Kongor.

Willdenowia incurvata (*Restionaceae*). Photo: R. Kongor.

Responsible authors: R.Y. Kongor & J. Luther-Mosebach

Plant response to habitat fragmentation in the Cape lowlands (S29.01)

[R.Y. Kongor]

The conservation worthiness of Cape Floristic Region lowland habitat fragments was determined using plant functional traits, which are better than species for predicting ecosystem response to global change. Four patches of decreasing sizes: one "mainland" (i.e. Riverlands/S31, Rocherpan/S29, Tygerberg) Nature Reserves and three fragments were selected in representative fynbos, renosterveld, and strandveld vegetation types. There species were sampled at four scales within modified Whittaker plots, in spring/summer of 2004/2005, and assigned traits selected based on their relevance to species' and plant-functional types' responses to fragmentation.

Reduced patch size effect on species richness was evident in fynbos where fragments below 600 ha had fewer species than the "mainland", but was not unequivocal in renosterveld and strandveld where the grazed fragments were richer in species than the ungrazed ones. Two independent techniques to categorise trait syndromes (expert approach vs. CART) yielded parsimonious results and highlighted sensitive traits (dispersal, pollination, and breeding modes) and trait syndromes (short distance dispersed, specialist-pollinated annual seeders and dioecious perennial seeders). The fragment-size effect was higher on trait syndrome diversity than richness, with strandveld being the least affected. Some degree of functional redundancy as well as significant trait-convergence/divergence assembly patterns linked to habitat fragmentation was also revealed. The fragment size effects were weak and confounded by sampling scale, site history and matrix type.

Kongor, R.Y. (2009): Plant response to habitat fragmentation: clues from species and functional diversity in three Cape lowland vegetation types of South Africa. – PhD thesis in Conservation Ecology. Stellenbosch: Stellenbosch University.

Photo SSS29.1: Raphael Kongor measuring plants in the field. Photo: T.F. Athanasius.

Trait convergence and divergence assembly patterns (S29.02)

[R.Y. Kongor]

Trait-convergence (TCAP) and trait-divergence (TDAP) have been identified as the two main assembly patterns that govern plant communities. TCAP is expressed when external factors governing species' adaptation select for species with similar traits, while TDAP is revealed when plant communities contain species with less-similar traits or if the coexistence of species is constrained by their trait similarity. The question asked is whether these patterns exist in the fragmented Cape lowland vegetation.

Four patches of decreasing sizes were selected in and around Riverlands (S31; fynbos), Rocherpan (S29; strandveld), and Tygerberg (renosterveld) Nature Reserves. In each patch, species were sampled from nine 10 m × 10 m plots during spring/summer of 2004/2005, and assigned traits selected based on their relevance to species' and plant-functional types' responses to fragmentation. A three-matrix approach was adopted in the data analysis. The matrices respectively described each species by traits and cover-abundance and sites by variables. Optimal trait subsets that maximised the expression of TCAP (*Long and Short-distance dispersal, Perennial, Seeders, Dioecious* and *Generalist-pollinated*) and TDAP (*Annual*) were searched by an iterative algorithm. The composition of annuals in the three vegetation types varied considerably due to variations in soil fertility and disturbance regime, which might explain why TDAP was only expressed by the trait *Annual*. The results revealed significant TCAP and TDAP ($p = 0.001$) and redundancy among traits for TCAP. Habitat fragmentation does play a role in plant community composition and ecological functions in the Cape lowlands.

Kongor, R.Y., Esler, K.J., Mucina, L., Krug, C.B., Sosinski, E.E. (subm.): Evidence of trait-convergence and trait-divergence assembly patterns in fragmented South African Cape vegetation. – Journal of Vegetation Science.

Floristic and functional approach to plant diversity conservation (S29.03)

[R.Y. Kongor]

Habitat transformation in South Africa's Cape lowlands has led to habitat loss, habitat fragmentation and changes in natural disturbance regimes. To provide information on minimum viable fragment size, the floristic and plant functional type (PFT) richness, and diversity in four fragments (ranging from large to small) of three representative Cape lowland fynbos (S31), renosterveld, and strandveld (S29) was assessed (Photo SSS29.03). Plant traits which are better predictors of ecosystem response to global changes than individual species were selected based on relevance to species' and PFTs responses to fragmentation.

The expert and CART approaches used to categorise trait syndromes yielded similar results, highlighting sensitive traits (dispersal, pollination and breeding modes) and trait syndromes (short distance dispersed, specialist-pollinated annual seeders and dioecious perennial seeders). The effect of reduced patch size was higher on PFT diversity than on PFT richness. Strandveld where habitat fragmentation is more recent was least affected. Fragments from 600, 100 and 20 ha in fynbos, renosterveld, and strandveld respectively were most likely to retain their full functional diversity. Fragment size effects were weak and confounded by site history (notably disturbance regime), matrix type and the time lag since fragmentation. To prevent the potential extinction debt, measures that allow pollinator/disperser movement between fragments such as provision of stepping stones should be implemented, fragments restored to at least the minimum viable size and their should mimic the typical disturbance regimes prevalent in the respective vegetation types to render them functional.

Kongor, R.Y. (2009): Plant response to habitat fragmentation: clues from species and functional diversity in three Cape lowland vegetation types of South Africa. – PhD thesis in Conservation Ecology. Stellenbosch: Stellenbosch University.

General data

Number	Name	Alternative name(s)
S31	Riverlands	n.a.
Implementation	Country	Province/ region
2001	South Africa	Western Cape
District/ constituency	Locality	Farm name
West Coast	Malmesbury	Riverlands
Latitude	Longitude	Altitude
33.489343 S	18.580119 E	140 m a.s.l.
Rainfall season	Biome	WWF Ecoregion
Winter	Fynbos	AT1202 Lowland fynbos and renosterveld
Agro-Ecological Zone	Relative intensity of land use	Tenure
n.a.	None	State
Type and history of landuse	Land owner	
Conservation area	CapeNature	

Riverlands (S31)

Riverlands landscape with the Dassenberg hills in the background. Photo: L.W. Powrie.

The BIOTA Observatory Riverlands (S31) is situated within the highly species diverse Cape Floristic Kingdom in the provincial nature reserve Riverlands, managed by CapeNature, approximately 13 km southwest of Malmesbury in the Western Cape Province of South Africa. The Observatory is situated on a gently undulating sand sheet about 23 km from the southern Atlantic Ocean. The altitude at the Observatory is approximately 140 m a.s.l. Mean annual precipitation is 453 mm.

The area around Malmesbury was first explored in 1655, and the town of Malmesbury was established in 1745. Riverlands was bought in 1900 by South African Railways (now Transnet) to establish a water point for passing trains, and to build a school and church for the informal residents. In 1985, the area was purchased by CapeNature (then Western Cape Nature Conservation Board) and proclaimed as a provincial nature reserve because of a high density of rare and locally endemic plant species (Holmes 2008). The reserve also protects one of the last remaining remnants of Atlantis Sand Fynbos. The reserve itself covers a number of environmental gradients (dry → wet, deep sands → shallow sands → clay) and associated vegetation types, and there are also fallow, previously cultivated fields (mainly wheat), and areas recently cleared of invasive alien vegetation (Holmes 2008). Today, the reserve is part of the Cape West Coast Biosphere Reserve.

The objectives of this BIOTA Observatory are to monitor land use change, especially the effects of habitat transformation and fragmentation, and the impacts of invasive alien plant species on biodiversity.

Responsible authors: M.C. Rutherford, L.W. Powrie, L.B. Husted, C. Krug & D.H. Haarmeyer

Remote sensing and landscape

Geomorphology	Geological units	Lithological units
n.a.	Cenozoic Deposits, Nama System	Unconsolidated superficial deposits, Conglomerate, Limestone, Sandstone, arl, high-level gravel, Quartzite, arkose, limestone, shale, phyllite, tillite, lava, tuff
Mean EVI	**EVI absolute range**	**Mean leaf area index**
0.183 (0.155–0.228)	0.130 (2004)–0.200 (2008)	0.85

Grid map of Observatory

	0	1	2	3	4	5	6	7	8	9
0	4	97	78	20	71	89	98	8	88	46
1	72	100	23	3	36	73	9	47	18	28
2	22	54	65	25	76	96	60	50	17	40
3	32	16	34	77	29	52	64	31	94	95
4	59	49	26	74	43	11	7	82	42	91
5	44	10	87	66	68	56	51	69	75	45
6	55	39	86	12	99	21	85	61	57	70
7	38	33	84	1	90	63	81	30	14	80
8	48	27	41	24	92	15	93	67	83	79
9	19	6	13	35	53	2	62	58	5	37

1 *Leucadendron* dominated proteoid fynbos
2 Proteoid fynbos shrub vegetation
3 Vlei
4 Invasive Acacia thicket

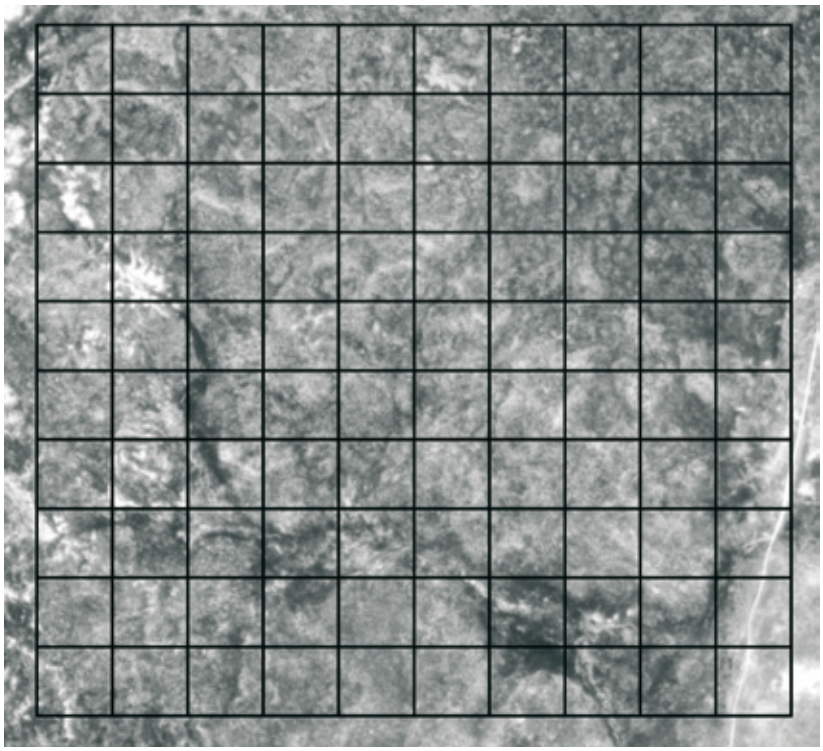
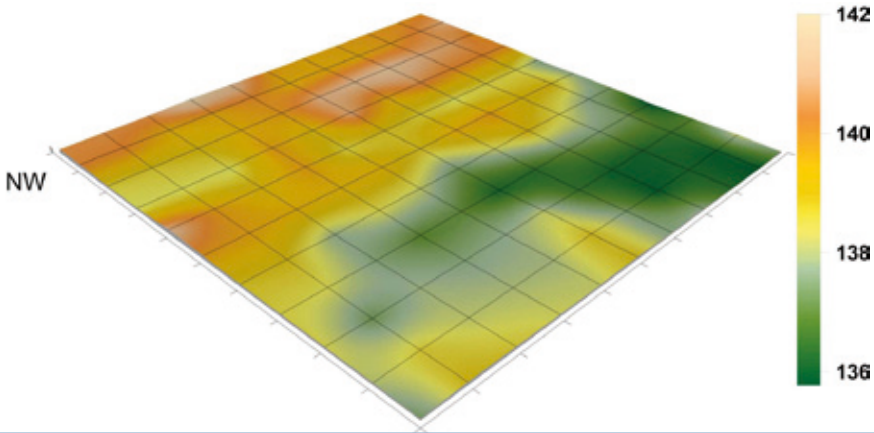


Image: aerial photograph

Elevation model of Observatory



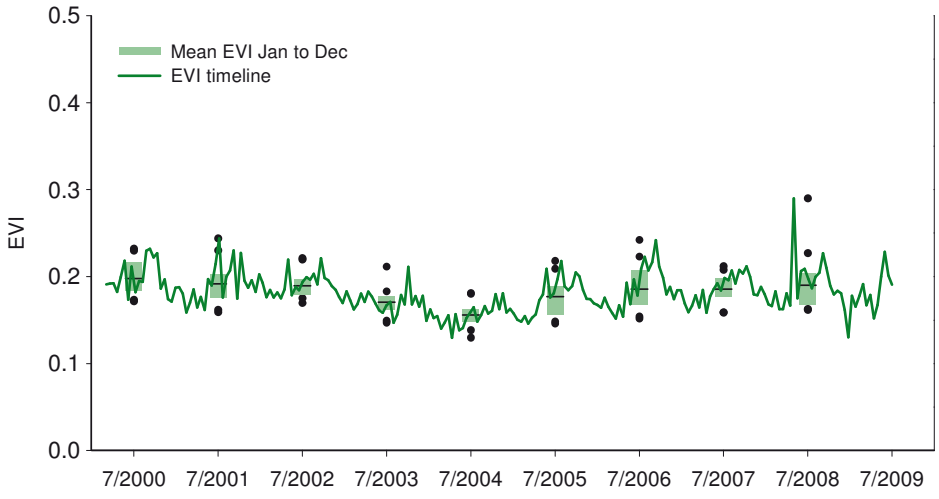
Landsat image

The Observatory is located on a remnant of Sand Fynbos vegetation (dark green to mid-green) within an intensively utilised agricultural landscape. Fields with standing crops appear in red, bare fields in bright grey and white, and fields with remnant dry vegetation and fallow lands in light green tones. Extensive fires in the reserve, which burnt parts of the Observatory, occurred in February 2005 and March 2006. Settlements (in the central eastern part of the image) can be identified as blue-red mosaics, and woody vegetation and tree clusters (in the southern part of the image) show up in red-brown.

Scene: 175/83, acquisition date: 07 February 2007

MODIS time series

Temporal patterns of vegetation cover, and phenology



Responsible authors: M. Keil & T. Labitzky

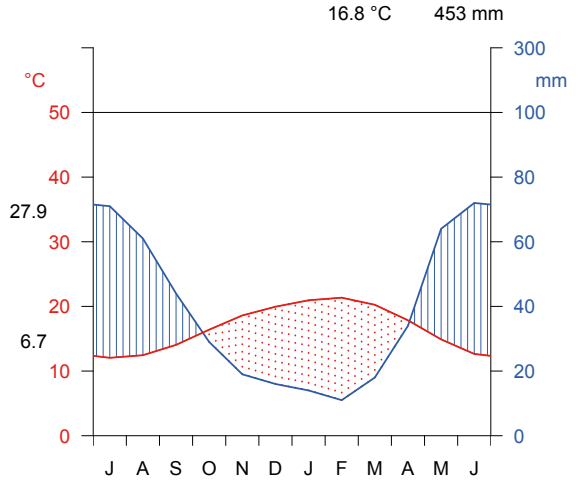
Climate

Modelled data		
Mean temperature	Mean annual temperature range	Mean diurnal temperature range
16.8 (6.7–27.9) °C	9.3 °C	11.9 °C
Mean annual precipitation	Precipitation seasonality	Percentage winter precipitation
453 mm	59%	76% (winter)
Climate type	Length of dry season	Aridity index (De Martonne)
Csa	6 months	16.9 (semi-dry)

Only interpolated data from the WorldClim dataset is available for this Observatory. The climate at the Observatory is characterised by temperate conditions. Rainfall shows a pronounced seasonality with the major portion of rain falling during the winter season, peaking in June. The mean annual rainfall is 453 mm, which is fairly wet in comparison to the average rainfall recorded over the entire transect, but is intermediate for the Observatories within the Fynbos Biome. Near-surface air temperatures show a moderate seasonal cycle. The mean annual temperature is 16.8°C and is therefore close to the average for the Fynbos Biome.

Climate diagrams

Modelled data (WorldClim)



Responsible authors: K. Berger, A. Haensler & J. Luther-Mosebach

Lichens

Sampling period(s)	Hectare plots sampled	Cover
2005	11 (R1–R11)	0% (0–0.2%)
Total species richness	Species richness on soil [1 km²]	Species richness on rock [1 km²]
33	4 (14%)	1 (3%)
Species richness on plants [1 km²]	Species richness on soil [1000 cm²]	
28 (83%)	0.2 (0–2)	

This Observatory is very rich in epiphytic lichens, with a high percentage of fruticose and foliose species, due to the high air humidity and rainfall and the presence of suitable plant substrates at this site. All recorded lichens are green algal taxa. In contrast, lichen diversity on soil is low, due to the sandy texture and acidity of the soils and shading caused by vegetation which usually has a cover of 80% or higher. Rocks and stones are infrequent and therefore only a few saxicolous lichens occur. Two major burning events occurred on parts of the Observatory in 2005 and 2006, which may have temporarily decreased lichen cover and diversity. Mean lichen cover is very low for the investigated hectare plots, and only very small individuals of *Cladonia* and *Placidium* spp. occur at one plot (H07), where soil acidity (pH 6.4) and vascular plant cover (60%) are lower.

List of taxa

Terricolous (on soil):

Cladonia cervicornis
Cladonia sp.
Placidium squamulosum
Toninia sp.

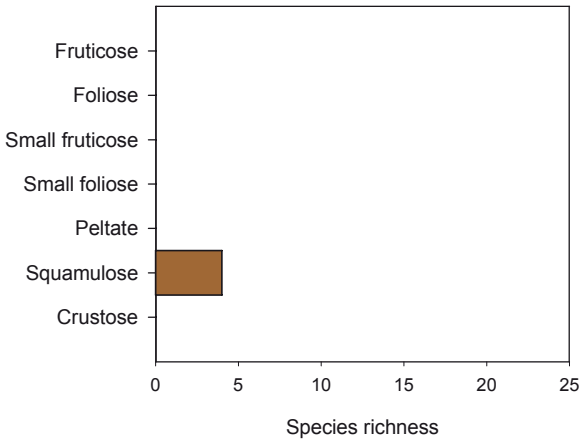
Saxicolous (on rock):

Xanthoparmelia sp.

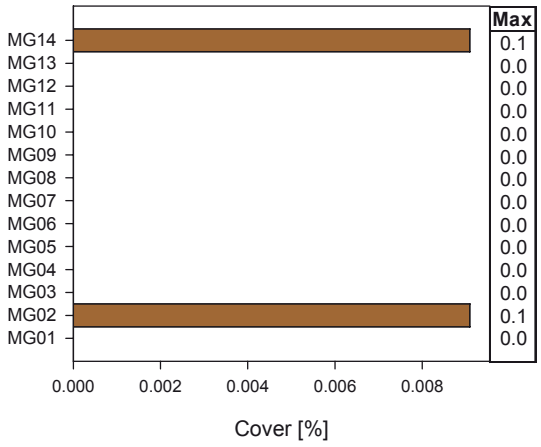
Epiphytic (on plants):

Amandinea extenuata
Amandinea punctata
Arthonia punctiformis
Arthonia radiata
Arthopyrenia sp.
Buellia parastata
Buellia pulverea
Caloplaca holocarpa s.l.
Caloplaca obscurella
Candelaria concolor
Candelariella antennaria
Canoparmelia cf. crozalsiana
Flavoparmelia soredians
Lecanora chlarotera
Lecanora expallens
Lecanora symmicta
Lepraria sp.
Opegrapha sp.
Parmelia cf. sulcata
Parmotrema austrosinense
Ramalina aff. implectens
Ramalina celastri
Ramalina cf. fraxinea
Ramalina sp.
Teloschistes chrysophthalmus
Usnea sp.
Xanthoria dissectula
Xanthoria parietina

Growth forms



Morpho groups



Teloschistes chrysophthalmus. Photo: L. Zedda & G. Rambold.

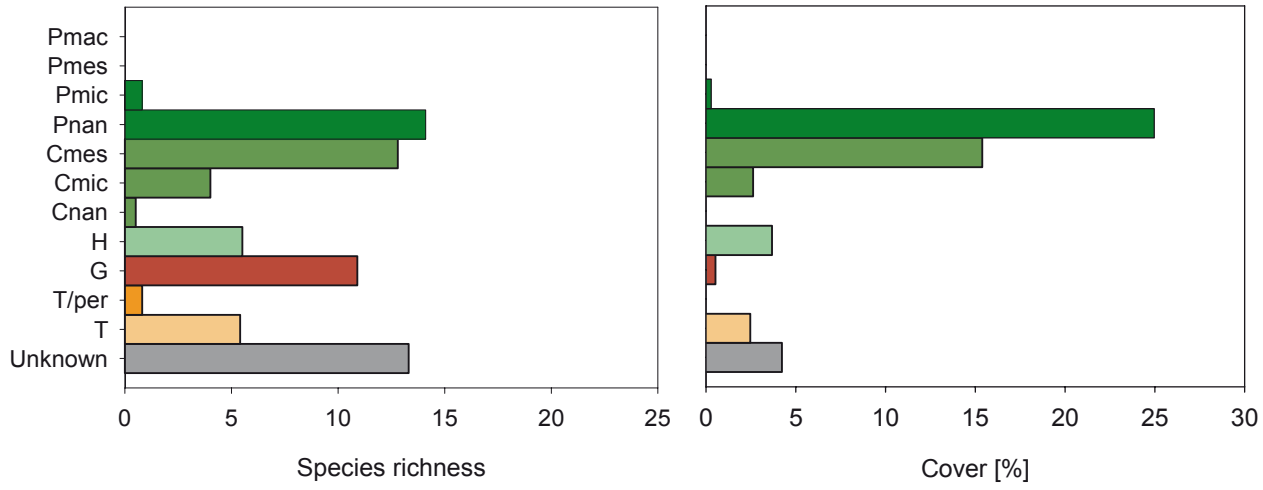
Ramalina celastri. Photo: L. Zedda & G. Rambold.

Responsible authors: L. Zedda & G. Rambold

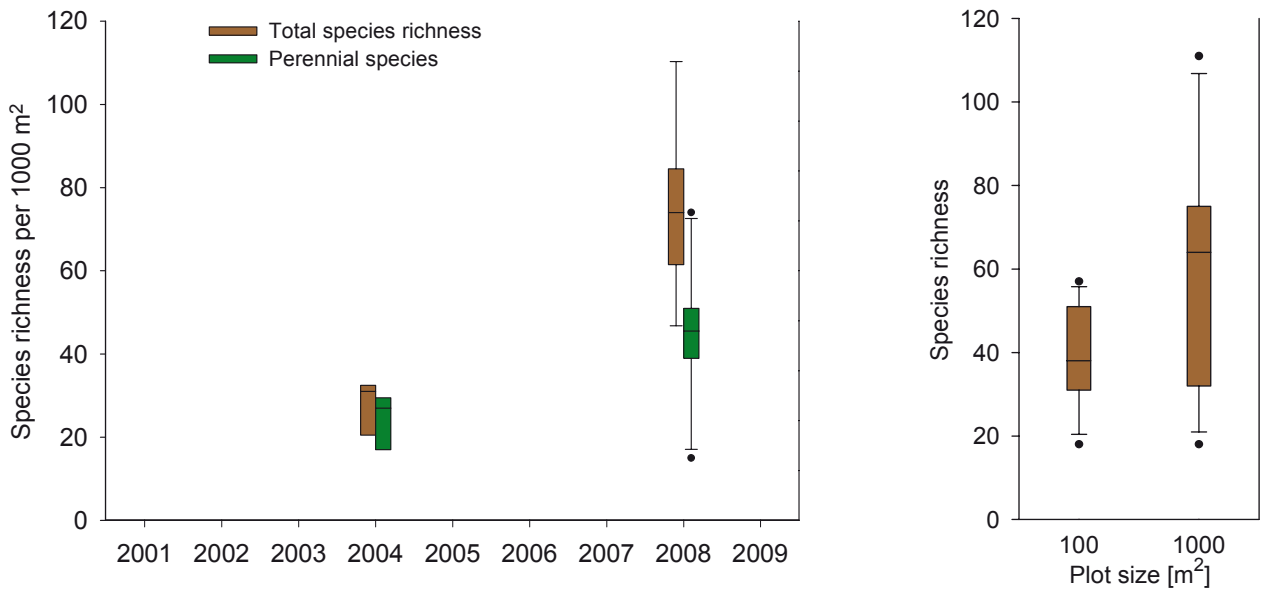
Vascular plants

Sampling period(s)	Hectare plots sampled	Biome
2004, 2008, 2009	20 (R1–R20)	Fynbos
Vegetation unit (level 1)	**Vegetation unit (level 2)**	**Identification rate**
Sand Fynbos	FFd 4 Atlantis Sand Fynbos	79% – 90% – 90%
Cumulative family richness	**Dominant families (cover)**	**Dominant families (richness)**
62	Restionaceae, Proteaceae, Rhamnaceae	Asteraceae, Iridaceae, Restionaceae
Cumulative species richness (1 km²)	**Species richness (1000 m²)**	**Species richness (100 m²)**
439 – 288	91.6 (45–143)	58.0 (21–93)
***z*-value**	**Species richness change per year (1000 m²)**	**Evenness (1000 m²)**
0.199 (0.104–0.331)	2.60	0.608 (0.279–0.716)
Evenness (100 m²)	**Simpson (1000 m²)**	**Simpson (100 m²)**
0.610 (0.271–0.784)	0.866 (0.428–0.931)	0.829 (0.362–0.927)

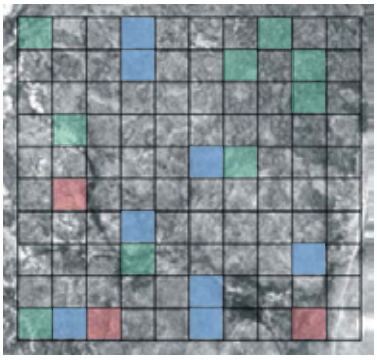
Life forms



Species richness



Map of vegetation units



The vegetation forms part of the Atlantis Sand Fynbos (FFd4, Mucina & Rutherford 2006) and is dominated by evergreen sclerophyllous shrubs (P nan), mainly Proteaceae, and graminoids (H), mainly wiry Restionaceae. The landscape is a gently sloping sandy plain with eroded protruding mounds in some places often covered by the shrub *Rhus* cf. *glauca* (P nan). Water accumulates in some localised areas during the winter months. Soils are generally deep sands often with intense mole-rat activity. Plant diversity is particularly high. Species richness at all scales, and number of families are among the highest of the BIOTA Southern Africa Observatories. Local scale species turnover (β-diversity as expressed in z-values) is amongst the lowest of the other Observatories, possibly reflecting relatively uniform habitat at the Riverlands Observatory. Mean richness change (1000 m²) per year is the highest value observed amongst all Observatories.

The *Berzelia abrotanoides-Chondropetalum nudum* community (unit 1) is found in seasonally inundated depressions on the sandy plain during winter. The vegetation is dense and dominated by graminoids (H) *Staberoha distachyos*, *Chondropetalum nudum*, and *Willdenowia arescens,* which all belong to Restionaceae. *Berzelia abrotanoides* tends to be the dominant shrub (P nan).

The *Phylica cephalantha-Protea scolymocephala* community (unit 2) occurs on sandy soils often with intense mole-rat activity. Vegetation varies from closed to open patches. The dominant

Classification table (2009)

Column		Cover	All	1	2	3
Number of relevés			**22**	**3**	**8**	**9**
Mean cover [%]			79.6	84.0	83.6	74.6
Mean species richness (1000 m²)			100.3	84.0	89.9	114.9
Unit 1: Berzelia abrotanoides-Chondropetalum nudum community						
Pnan	Stilbe ericoides	0.62	15	100	.	.
Pnan	Berzelia abrotanoides	1.78	15	100	.	.
Cmes	Lachnaea uniflora	0.14	25	100	.	22
G	Hessea cinnamomea	0.02	10	67	.	.
G	Trachyandra revoluta	0.04	40	100	25	33
n.a.	Restio multiflorus	0.67	15	67	.	11
Cmes	Erica bruniades	0.02	15	67	13	.
n.a.	Pelargonium oenothera	0.02	15	67	13	.
n.a.	Thamnochortus sp.	2.03	15	67	13	.
Unit 2: Phylica cephalantha-Protea scolymocephala community						
n.a.	Cannomois arenicola	6.65	40	.	100	.
n.a.	Polycarena gilioides	0.02	45	.	88	22
Cmes	Erica plumosa	3.55	50	33	100	11
n.a.	Calopsis impolita	0.71	25	.	63	.
Cmes	Lachnospermum fasciculatum	0.15	25	.	63	.
Cmes	Lachnaea capitata	0.33	25	.	63	.
n.a.	Roepera flexuosa	0.16	50	.	88	33
T	Heliophila digitata	0.02	40	.	75	22
G	Drimia elata	0.07	20	.	50	.
Pnan	Microdon dubius	0.45	20	.	50	.
Hper	Ficinia bulbosa	0.03	55	.	88	44
H	Pentaschistis barbata	0.16	45	33	88	11
n.a.	Leucospermum hypophyllocarpodendror	2.44	55	67	100	11
Pnan	Serruria linearis	0.58	55	67	100	11
Hper	Rumex lativalvis	0.01	50	33	88	22
Pnan	Phylica cephalantha	11.52	60	67	100	22
Pnan	Diosma oppositifolia	3.05	60	67	100	22
n.a.	Relhania recurved	0.21	15	.	38	.
Cmes	Asparagus rubicundus	2.07	15	.	38	.
Pnan	Metalasia densa	0.49	15	.	38	.
Pnan	Lobostemon glaucophyllus	0.60	15	.	38	.
G	Moraea cf. viscaria	0.01	15	.	38	.
n.a.	Stoebe leucocephala	0.04	15	.	38	.
G	Asclepias crispa	0.00	15	.	38	.
Unit 3: Leucadendron corymbosum-Leucadendron lanigerum community						
Cmes	Berkheya armata	0.76	40	.	.	89
G	Micranthus junceus	0.42	40	.	.	89
G	Oxalis cf. purpurea	0.12	50	.	13	100
G	Disa bracteata	0.01	35	.	.	78
Cmes	Lampranthus reptans	0.26	35	.	.	78
n.a.	Senecio pubigerus	0.13	45	.	13	89
n.a.	Lichtensteinia obscura	0.04	30	.	.	67
G	Micranthus tubulosus	0.72	30	.	.	67
G	Bulbinella triquetra	0.11	30	.	.	67
T	Briza minor	0.02	30	.	.	67
G	Ornithogalum hispidum ssp. hispidum	0.00	40	.	13	78
Cmic	Hypodiscus rugosus	1.76	45	33	.	89
Pnan	Diosma dichotoma	0.40	45	33	.	89
Pnan	Leucadendron corymbosum	4.74	45	33	.	89
Hper	Itasina filifolia	0.03	25	.	.	56
H	Cynodon dactylon	0.59	25	.	.	56
Cmic	Oedera capensis	0.04	25	.	.	56
G	Triglochin bulbosa	0.04	25	.	.	56
Cmes	Osteospermum polygaloides	0.08	25	.	.	56
n.a.	Arctopus echinatus	0.03	55	.	38	89

Continued on next page

The *Phylica cephalantha-Protea scolymocephala* community (Unit 2) showing *Phylica cephalantha* in the foreground and some scattered *Protea scolymocephala*. Photo: L.W. Powrie.

The *Leucadendron corymbosum-Leucadendron lanigerum* community (unit 3) showing tall *Leucadendron corymbosum* and lower *Leucadendron lanigerum* with diverse restioid layer. Photo: L.W. Powrie.

The *Berzelia abrotanoides-Chondropetalum nudum* community (unit 1) showing the shrub *Berzelia abrotanoides* and locally abundant tall *Restio bifurcus*. Photo: L.W. Powrie.

shrub layer (P nan) is diverse including *Phylica cephalantha*, *Erica plumosa*, *Protea scolymocephala*, *Staavia radiata*, *Diosma oppositifolia*, *Trichocephalus stipularis*, and *Erica mammosa*, and the prostrate shrub (C mic) *Leucospermum hypophyllocarpodendron*. Dominant graminoids (H) are the restionaceous *Cannomois arenicola*, *Staberoha distachyos*, and *Willdenowia arescens*.

The *Leucadendron corymbosum-Leucadendron lanigerum* community (unit 3) is common on the sandy plain. The vegetation cover is relatively continuous with *Leucadendron corymbosum* clearly emergent above the other vegetation. The dominant shrubs (P nan) are *Leucadendron corymbosum*, *Leucadendron lanigerum*, and *Athanasia rugulosa*. The most abundant graminoids (H) are the restionaceous *Chondropetalum nudum*, *Hypodiscus rugosus*, and *Elegia filacea.*

Classification table (continued)

Column		Cover	All	1	2	3
Number of relevés			**22**	**3**	**8**	**9**
H	Merxmuellera stricta	1.29	35	.	13	67
Cmes	Lampranthus spiniformis	0.18	35	.	13	67
T/Cmes	Orphium frutescens	0.25	50	33	13	89
n.a.	Nenax hirta	2.05	50	33	13	89
Cmes	Lachnaea grandiflora	0.33	40	33	.	78
n.a.	Cyphia phyteuma	0.02	40	33	.	78
Cmac	Afrolimon purpuratum	0.21	40	33	.	78
Cmes	Thamnochortus fruticosus	1.76	40	33	.	78
G	Wurmbea inusta	0.02	20	.	.	44
n.a.	Relhania rotundifolia	0.45	20	.	.	44
T	Arctotis acaulis	0.03	20	.	.	44
T	Sebaea aurea	0.01	20	.	.	44
Cmes	Serruria brownii	0.25	20	.	.	44
G	Ornithogalum dregeanum	0.01	20	.	.	44
n.a.	Centella capensis	0.10	20	.	.	44
G	Geissorhiza imbricata	0.02	20	.	.	44
G	Moraea angulata	0.06	20	.	.	44
G	Hesperantha radiata	0.18	20	.	.	44
Hper	Vellereophyton dealbatum	0.17	50	.	38	78
Pnan	Phylica cuspidata	0.14	55	33	25	89
G	Satyrium bicorne	0.03	30	.	13	56
n.a.	Nenax acerosa	0.18	30	.	13	56
T	Adenogramma glomerata	0.07	40	.	25	67
n.a.	Juncus rupestris	0.31	65	67	25	100
n.a.	Isolepis leucoloma	0.08	65	67	25	100
Cmes	Galenia ecklonis	0.02	45	33	13	78
G	Tulbaghia cf. alliacea	0.01	45	33	13	78
n.a.	Tetraria cuspidata	0.28	45	33	13	78
Hper	Ficinia indica	0.16	45	33	13	78
T	Isolepis hystrix	0.04	45	33	13	78
n.a.	Heliophila pusilla	0.15	35	33	.	67
Most frequent companions						
Cmes	Staberoha distachyos	1.68	100	100	100	100
n.a.	Hypochaeris glabra	0.05	100	100	100	100
Cmes	Muraltia ericoides	0.37	95	100	100	89
H	Tribolium uniolae	0.22	95	100	100	89
G	Wachendorfia paniculata	0.04	95	100	100	89
Pnan	Protea scolymocephala	3.03	90	100	100	78
H	Ehrharta erecta	0.45	90	67	100	89
T	Felicia tenella	0.15	90	67	100	89
Cmes	Pelargonium triste	0.14	90	100	100	78
T	Helichrysum indicum	0.73	85	100	100	67
Pnan	Ischyrolepis monanthos	2.22	80	67	100	67
T	Wahlenbergia capensis	0.03	80	100	100	56
n.a.	Isolepis marginata	0.06	75	67	50	100
G	Trachyandra muricata	0.05	75	67	88	67
G	Cyanella hyacinthoides	0.04	75	100	50	89
G	Eriospermum cf. nanum	0.01	75	33	75	89
Cmes	Chondropetalum nudum	9.21	70	100	25	100
Pnan	Athanasia rugulosa	5.26	70	67	50	89
Pnan	Leucadendron lanigerum var. lanigerum	4.38	70	67	63	78
Pnan	Willdenowia arescens	3.29	70	100	100	33
n.a.	Pentaschistis triseta	0.22	70	33	75	78
n.a.	Crassula glomerata	0.21	70	100	25	100
G	Watsonia coccinea	0.04	70	100	38	89
n.a.	Dischisma capitatum	0.01	70	100	88	44
Pnan	Trichocephalus stipularis	1.90	65	100	100	22
Cmes	Ischyrolepis macer	1.29	65	100	38	78
H	Pentaschistis curvifolia	1.06	65	100	38	78
Cmic	Macrostylis villosa	0.76	65	67	100	33
Cmes	Agathosma imbricata	0.73	65	67	75	56

Serruria fasciflora. Photo: L.B. Husted.

Leucospermum hypophyllocarpodendron subsp. *hypophyllocarpodendron.* Photo: L.B. Husted.

Responsible authors: M.C. Rutherford, L.W. Powrie, L.B. Husted & J. Luther-Mosebach

Erica mammosa. Photo: L.B. Husted.

Berzelia abrotanoides. Photo: L.B. Husted.

Diastella proteoides. Photo: L.B. Husted.

Wachendorfia paniculata. Photo: L.B. Husted.

Protea scolymocephala. Photo: L.B. Husted.

Relation of microbial diversity to plant diversity (S31.01)

[K.J. Esler]

The Fynbos Biome in South Africa is well known for its high plant diversity, and the conservation of this area is particularly important for the region. This is especially true in the case of endangered vegetation types of the lowlands such as Sand Fynbos, of which only small fragments remain. The question is whether the diversity of the above-ground flora is mirrored in the below-ground microbial communities.

To determine the relationship of the above- and below-ground communities, we characterised the soil community composition of both fungal and bacterial groups in Sand Fynbos over space and time. A molecular approach was used, based on the isolation of total soil genomic DNA and automated ribosomal intergenic spacer analysis of bacterial and fungal communities. Soil from four different sites was compared to resolve the microbial diversity of eubacterial and fungal groups on a local (alpha diversity) scale as well as a landscape scale (beta diversity). The below-ground community structures from different sites were compared and found to exhibit strong spatial patterns which remained stable over time. The plant community data were compared with the fungal and the bacterial communities. We concluded that the microbial communities in Sand Fynbos are highly diverse and closely linked to the above-ground floral communities.

Slabbert, E., Kongor, R.Y., Esler, K.J., Jacobs, K. (2010): Microbial diversity and community structure in Fynbos soil. – Molecular Ecology **19**: 1031–1041.

Plant response to habitat fragmentation in the Cape lowlands

► *See* **S29.01**

Trait convergence and divergence assembly patterns

► *See* **S29.02**

Floristic and functional approach to plant diversity conservation

► *See* **S29.03**

General data

Number	Name	Alternative name(s)
S32	Elandsberg	n.a.
Implementation	**Country**	**Province/ region**
2001	South Africa	Western Cape
District/ constituency	**Locality**	**Farm name**
Cape Winelands	Wellington	Elandsberg
Latitude	**Longitude**	**Altitude**
33.414160 S	19.031110 E	95 m a.s.l.
Rainfall season	**Biome**	**WWF Ecoregion**
Winter	Fynbos	AT1202 Lowland fynbos and renosterveld
Agro-Ecological Zone	**Relative intensity of land use**	**Tenure**
n.a.	None	Private
Type and history of landuse	**Land owner**	
Conservation area	Private	

Elandsberg (S32)

Elandsberg landscape with Elandskloofberge massif in the background. Photo: L.B. Husted.

The BIOTA Observatory Elandsberg (S32) is located in the species-rich Cape Floristic Region. The Observatory was established at a private nature reserve on the farm Bartholomeus Klip, 13 km east of Riebeek-Kasteel and 2 km north of Hermon, in the Western Cape of South Africa. The Elandskloof mountain range forms the eastern boundary of the 3600 ha reserve, and to the west, the reserve is bordered by land where a mix of wheat, canola, and sheep are farmed. The nature reserve is known for its high plant species diversity (more than 800 species have been identified to date) and accommodates a number of species endemic to the area, for example the Elandsberg Candelabra Lily, *Brunsvigia elandsmontana*. Originally, the reserve was established to protect the last remaining large population of the endangered geometric tortoise (*Psammobates geometricus*).

The Observatory, which lies approximately 95 m a.s.l., receives an average rainfall of about 560 mm per year, with the majority falling during the winter months.

The farm Bartholomeus Klip was established in 1966, and before that it was used for sheep and cattle grazing as well as game hunting (Memiaghe 2008). In addition to this, oats were grown on fields in the reserve during the 1960s and 1970s (Newton 2008). In 1973, a private nature reserve of 2600 ha was established on the farm to protect the geometric tortoise. However, grazing by sheep and game continued in the reserve until 1983.

The reserve is also currently part of the Quagga (*Equus quagga quagga*) breeding programme (Makady 2009). From the establishment of the reserve in 1973 until 1997, additional abandoned agricultural fields have been incorporated into the reserve, increasing the reserve area to 3600 ha (Memiaghe 2008). The reserve was recently granted provincial nature reserve status under a stewardship agreement with the provincial nature conservation authority CapeNature.

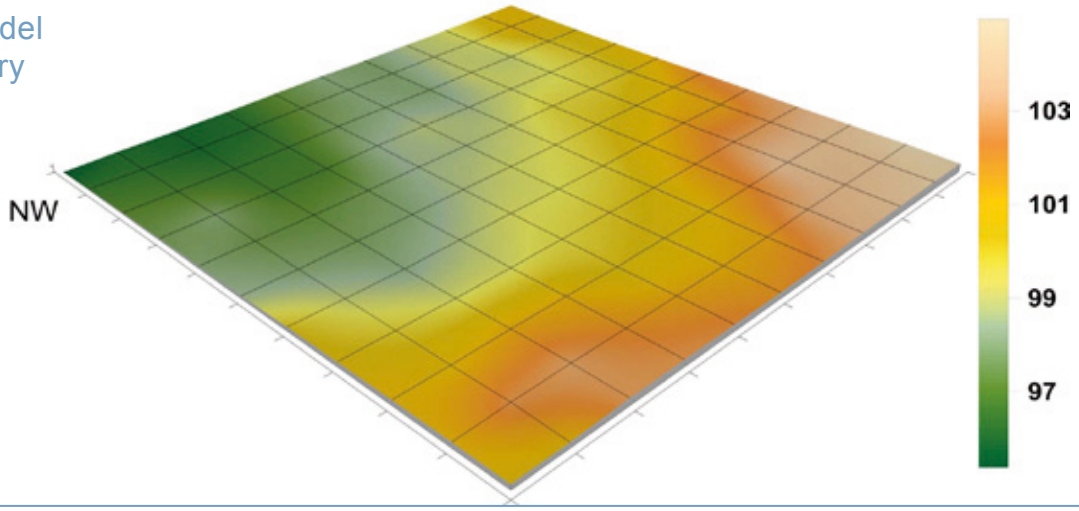
The objectives of this BIOTA Observatory are to monitor landuse change, especially the effects of habitat transformation and fragmentation, and the impacts of grazing on biodiversity.

Responsible authors: C.B. Krug, M.C. Rutherford, L.W. Powrie, L.B. Husted & D.H. Haarmeyer

Remote sensing and landscape

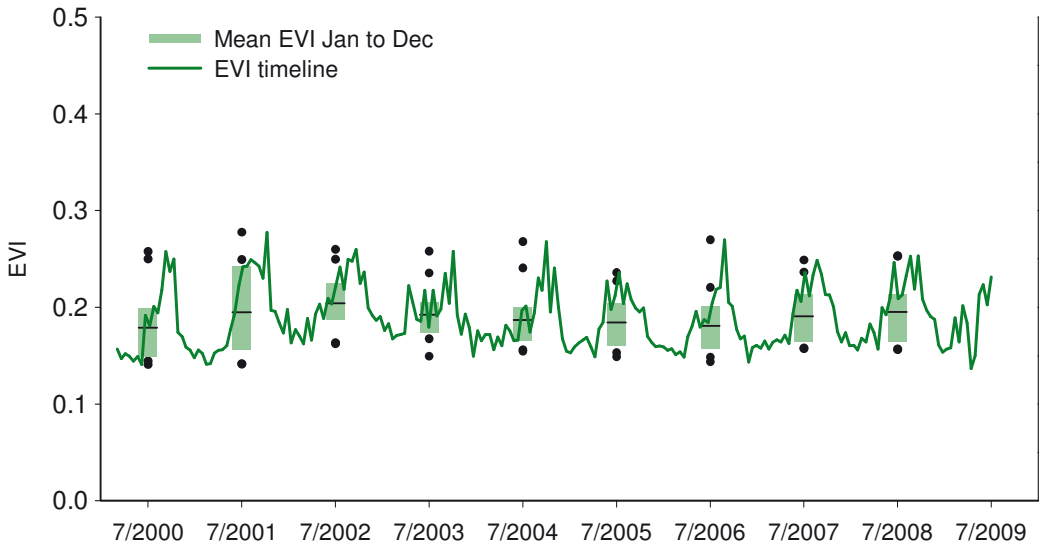
Geomorphology	Geological units	Lithological units
Undulating plains	Nama System, Table mountain system of Cape series	Quartzite, arkose, limestone, shale, phyllite, tillite, lava, tuff, Quartzite, shale, tillite
Mean EVI	**EVI absolute range**	**Mean leaf area index**
0.190 (0.150–0.258)	0.140 (2009)–0.278 (2001)	0.79

Elevation model of Observatory



MODIS time series

Temporal patterns of vegetation cover, and phenology



Grid map of Observatory

	0	1	2	3	4	5	6	7	8	9
0	48	83	75	86	99	43	45	27	96	4
1	28	49	65	87	89	35	1	66	54	29
2	13	92	69	6	85	26	46	42	73	8
3	33	60	77	63	68	95	18	82	70	20
4	12	58	61	47	79	59	15	80	24	14
5	88	53	91	32	84	52	36	5	38	11
6	9	98	7	100	40	51	50	93	19	56
7	23	62	55	10	2	39	34	41	57	71
8	64	97	67	78	22	44	76	94	81	72
9	16	37	25	31	21	90	74	3	30	17

1 Low vegetation

2 Renosterveld

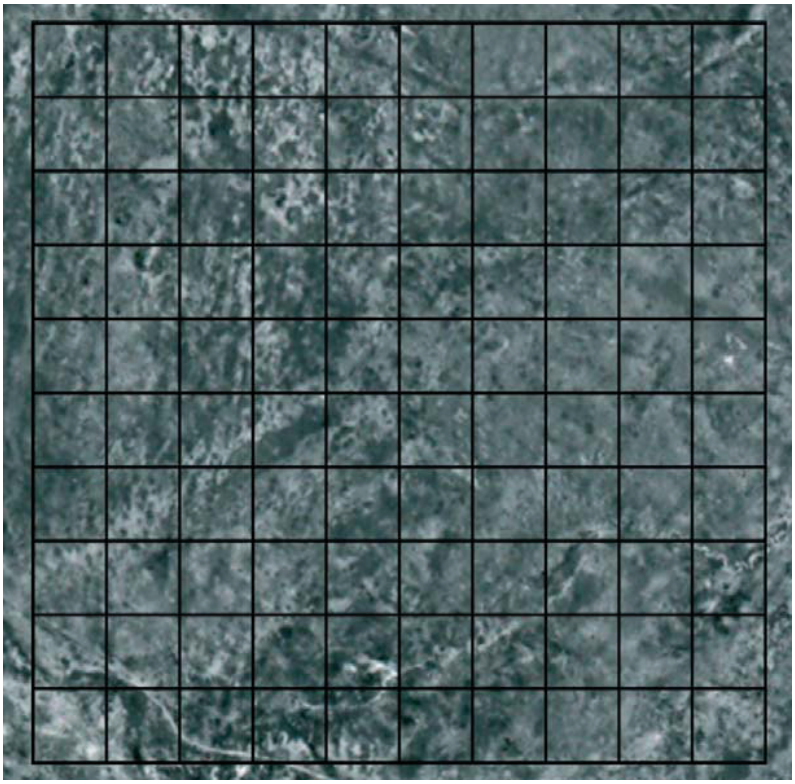


Image: aerial photograph

Landsat image

The Observatory is located at the edge of an intensively utilised agricultural area in the Shale Renosterveld/Alluvium Fynbos vegetation unit. Shale Renosterveld is mainly restricted to abandoned agricultural fields on the western fringe of the reserve, as well as the central northern portion (mid-green parts of the image). The main vegetation unit in the reserve is Alluvium Fynbos, and there is also a transition zone to Sandstone Fynbos of the neighbouring Elandskloof mountain range (eastern part, dark green). The Shale Renosterveld/Alluvium Fynbos vegetation of the Observatory and its surroundings appear dark green to brown green. The agricultural fields show up as light grey to white (probably ploughed in February) and light green tones. Clusters of trees and woody vegetation show up in red-brown. A few small irrigated fields can be detected (e.g. in the NW corner) by their bright red colour. Part of a large dam is visible (in blue) in the north.

Scene: 175/83, acquisition date: 07 February 2007

Responsible authors: M. Keil & T. Labitzky

Climate

Data from BIOTA weather station

Location	Recorded period	Mean temperature
Elandsberg (S32)	2004–2006	17.2 (1.7–43.2) °C
Mean solar radiation	**Mean wind speed**	**Mean annual precipitation**
528 (217–1134) MJ·m^{-2}·month^{-1}	2.7 (13.2) m·s^{-1}	666 (477–856) mm
Mean annual potential evapotranspiration	**Interannual precipitation variability**	**Mean relative humidity**
n.a.	68%	95% (50–100%)
Aridity index (UNEP)		

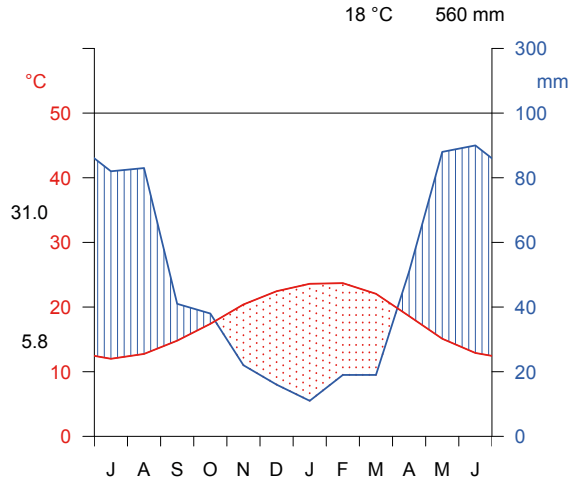
Modelled data

Mean temperature	Mean annual temperature range	Mean diurnal temperature range
18.0 (5.8–31.0) °C	11.7 °C	13.4 °C
Mean annual precipitation	**Precipitation seasonality**	**Percentage winter precipitation**
560 mm	63%	78% (winter)
Climate type	**Length of dry season**	**Aridity index (De Martonne)**
Csb	5 months	20.0 (mediterranean)

The climate at the Observatory is characterised by temperate conditions. Rainfall shows a pronounced seasonality with the major portion of rain falling during the winter season, peaking in June. The mean annual rainfall is 560 mm, making it one of the wettest Observatories over the entire transect and within the Fynbos Biome. Near-surface air temperatures show a moderate seasonal cycle. The mean annual temperature is 18.0°C and is therefore the warmest within this biome.

Climate diagrams

Modelled data (WorldClim)



Responsible authors: K. Berger, A. Haensler & J. Luther-Mosebach

Soils

Year of sampling	Hectare plots sampled	SOTER unit
2005	25 (R1–25)	ZA2947
Soilscape	**Dominant soil group(s)**	**Reference group richness**
Regosols	Regosol	1
Soil unit richness	**Soil unit evenness**	**Soil ecotype richness**
4	0.321	9
Parametric space	**pH**	**Electrical conductivity**
3.75	5.6 (5.1–6.5)	24 (14–83) $\mu S \cdot cm^{-1}$
Organic carbon		
0.66% (0.32–1.35%)		

The only soil reference group found on this Observatory are Regosols. A more detailed classification is possible by using the qualifier 'Stagnic', which indicates water-logged conditions over a period of time. Such conditions are evident for a number of profiles. By including the texture, the content of rock fragments and the base status of the soils were further specified. Except for a dominance of Stagnic Regosols in the north and northwest, no clear spatial pattern of soil units on the Observatory is detectable. Differences in microtopography and soil properties over short distances lead to a scattered distribution of the several soil units. Regosols with a sandy texture in the upper section of the profile are the most common soil unit, which typically cover a denser and more clayey horizon derived from shale.

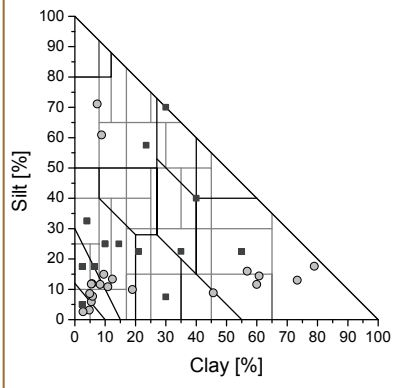
Electrical conductivity and pH values show low variability and low median values in the topsoil characterising the sandy and nutrient-poor, acid environment. When the thickness of this acid cover stratum exceeded 10 cm, increased ranges in the next lower soil stratum (10–30 cm) were found. The rooting space shows high variations caused by infrequently underlying bedrock and profiles with high contents of coarse rock fragments. However, the median of above 60% indicates a relatively deep rooting space.

A wide range of sand-, clay- or silt-dominated textures occur between substrates. With regard to the sand fractions, the samples cover a range from coarse sands as a component of the shale influenced strata to medium sand as the dominant fraction of the sandy alluvial cover substrate.

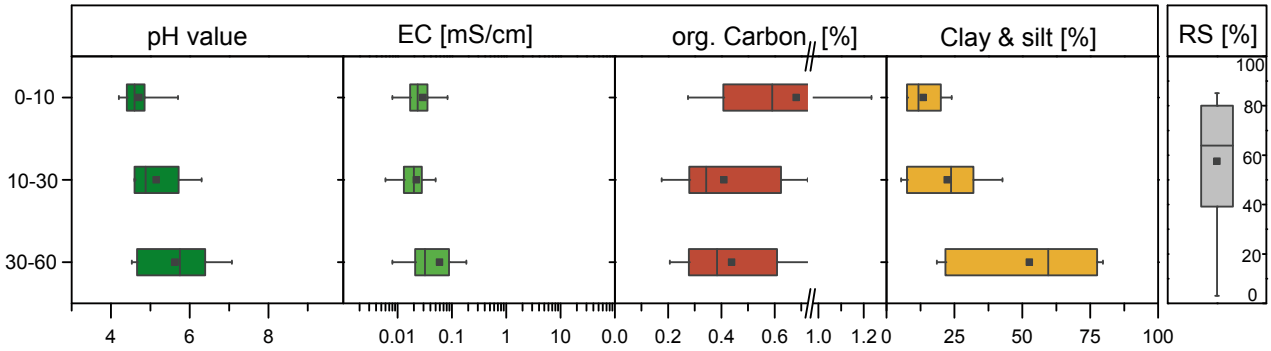
Map of soil profiles

Haplic Regosol
Stagnic Regosol

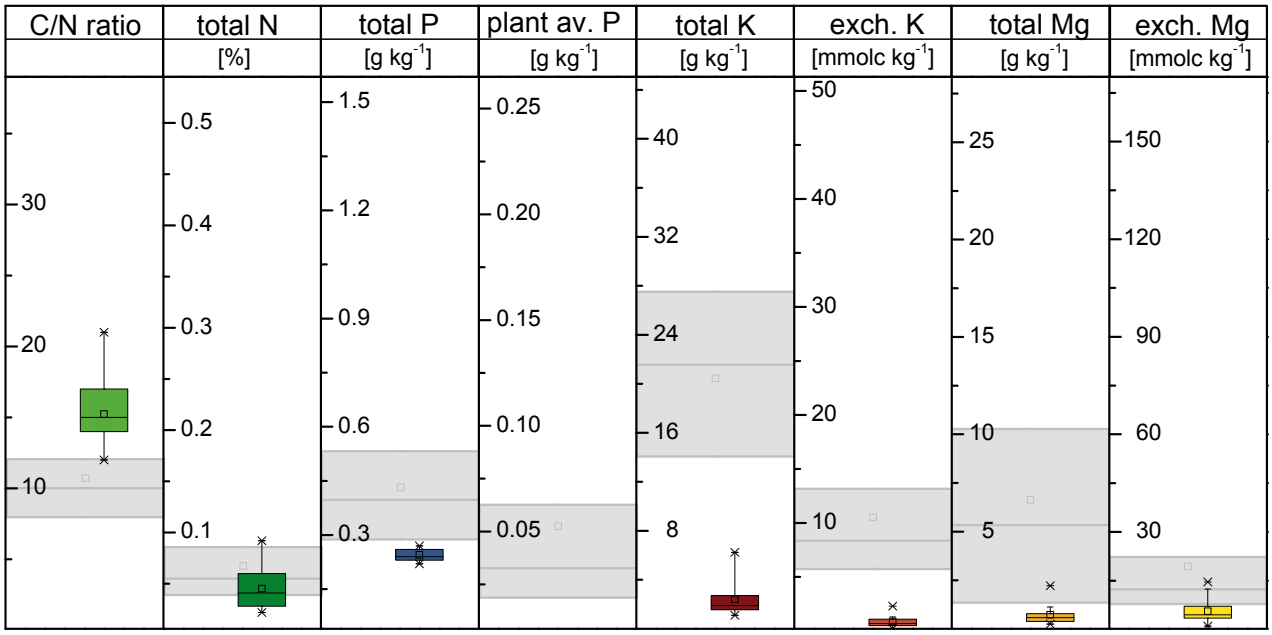
Soil texture triangle



Soil characteristics



Soil nutrients

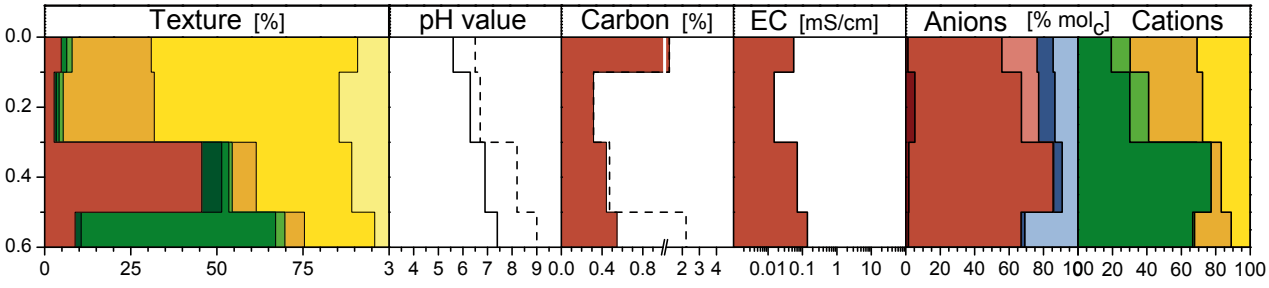


Reference profile (H09)

The **Stagnic Regosol (Eutric, Clayic)** is a typical example of soils that consist of two strata. The sandy top layer up to a depth of 30 cm contains around 30% coarse gravel with signs of fluvial transport. The horizon exhibits single grain structure and low excavation difficulty. Below, with a sharp border, follows a slightly calcareous, dense, sandy-clayey layer with fewer rock fragments. Iron and manganese concretions and the bleached character of the topsoil indicate hydromorphic dynamics in form of water logging in this profile.

The topsoil is densely rooted with over 50 roots dm^{-2} decreasing to 5 roots dm^{-2} at 60 cm. The electrical conductivity of 15 µS cm^{-1} in the second horizon indicates the extremely low nutrient status. The slightly acid soil reaction changes to neutral in the subsoil horizon, which contains > 2% inorganic carbon. Organic carbon decreases strongly with depth. The C/N ratio of 20 in the topsoil indicates a typical acid environment with reduced biological activity and litter with high C/N ratios.

The change in substrate is also reflected by a strong increase of total elements, iron for example increases from 10 to about 50 g kg^{-1} and the total base reserve from 10 in the quartz rich sand up to 100–400 $cmol_c$ kg^{-1} in the calcareous shale derived layer. The content of water-soluble ions is extremely low with 1–5 $mmol_c$ kg^{-1} from top to subsoil, while the amount of exchangeable bases increases from approximately 50 $mmol_c$ kg^{-1} in the topsoil to about 500 $mmol_c$ kg^{-1} in the subsoil as a result of carbonate dissolution.



Texture

- Fine silt
- Medium silt
- Coarse silt
- Clay
- Fine sand
- Medium sand
- Coarse sand

- pH ($CaCl_2$)
- pH (H_2O)
- Organic carbon
- Inorganic carbon
- Electrical conductivity

Water soluble ions

- Cloride
- Sulfate
- Nitrate
- Hydrocarbonate
- Fluoride, Bromide, Nitrite
- Calcium
- Magnesium
- Potassium
- Sodium

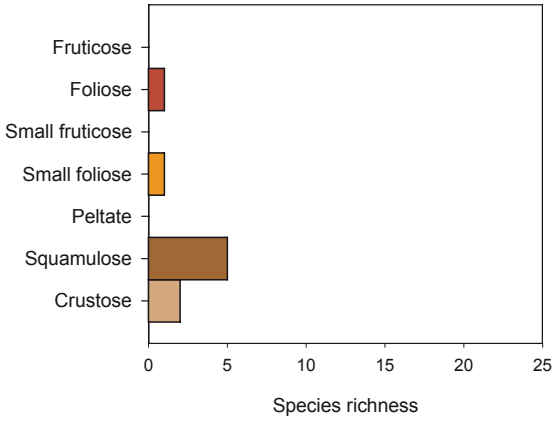
Responsible authors: U. Wisch, A. Petersen, A. Gröngröft & D. Mager

Lichens

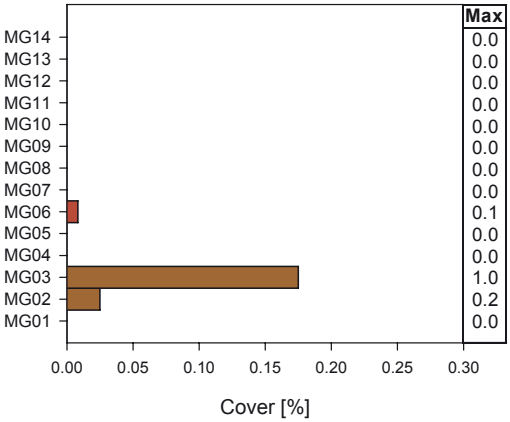
Sampling period(s)	Hectare plots sampled	Cover
2005	12 (R1–R12)	0.2% (0–1%)
Total species richness	**Species richness on soil [1 km²]**	**Species richness on rock [1 km²]**
39	9 (23%)	11 (28%)
Species richness on plants [1 km²]	**Species richness on soil [1000 cm²]**	
19 (49%)	1.3 (0–7)	

This site is the most species rich with regard to the lichen mycota among the Observatories of the Fynbos Biome. Epiphytic lichens are diverse and include broadly foliose, fruticose and leprose species, all indicators of high air humidity. Soil lichens are also more numerous, because of favourable soil properties at some of the investigated hectare plots, which are characterised by lower acidity and/or a greater component of silt and clay (20–25%, see chapter on soil characteristics). Furthermore, the more open and low vegetation of this Observatory favours lichen growth due to better exposure to sunlight. One as yet undescribed *Buellia* species grows exclusively on termite mounds. The majority of soil-inhabiting lichens are squamulose and have green algal photobionts. Despite the generally high species richness of lichens at the Observatory, the mean lichen cover on the investigated hectare plots is very low although lichens are very abundant in other plots of lower ranks, and outside the Observatory. The only investigated hectare plots possessing lichens are H16, H40 and H97.

Growth forms



Morpho groups



List of Taxa

Terricolous (on soil):

Buellia sp.
Cladonia symphycarpa
Collema coccophorum
Diploschistes henssenianae
Eremastrella crystallifera
Placidium squamulosum
Placidium tenellum
Toninia aff. lutosa
Xanthoparmelia terricola

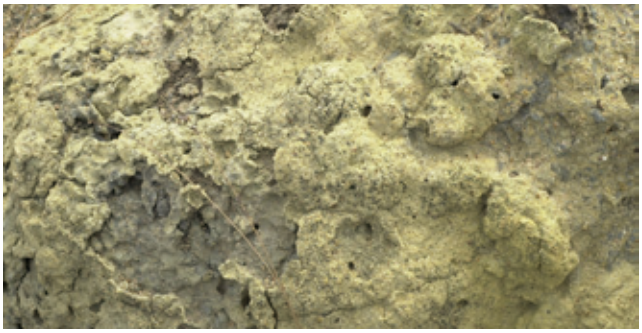
Saxicolous (on rock):

Acarospora sp.
Diploschistes aeneus
Buellia spp. (3)
Caloplaca cf. cinnabarina
Xanthoparmelia spp. (4)
Rinodina sp.

Epiphytic (on plants):

Amandinea extenuata
Caloplaca citrina
Caloplaca holocarpa s.l.
Caloplaca spp. (2)
Candelaria concolor
Candelariella cf. antennaria
Flavoparmelia soredians
Hypotrachyna sp.
Lecanora sp.
Lepraria sp.
Parmelia s.l.
Parmotrema austrosinense
Physcia adscendens
Ramalina celastri
Ramalina sp.
Teloschistes sp.
Unsea spp. (2)

Eremastrella crystallifera. Photo: L. Zedda & G. Rambold.



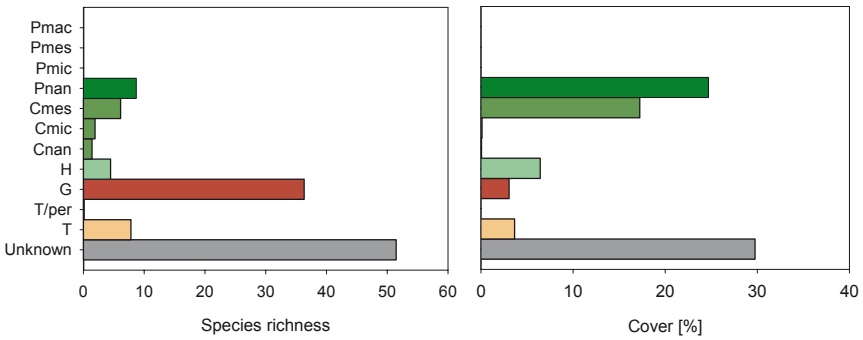
Buellia sp. nov., on termite hills. Photo: L. Zedda & G. Rambold.

Responsible authors: L. Zedda & G. Rambold

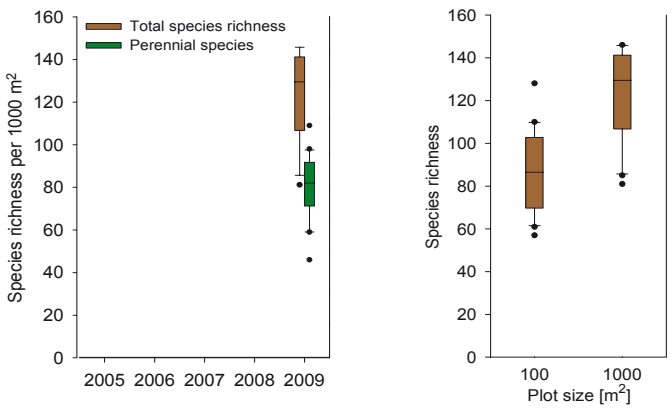
Vascular plants

Sampling period(s)	Hectare plots sampled	Biome
2009	20 (R1–R20)	Fynbos
Vegetation unit (level 1)	**Vegetation unit (level 2)**	**Identification rate**
Alluvium Fynbos	FFa 3 Swartland Alluvium Fynbos	83% – 86% – 85%
Cumulative family richness	**Dominant families (cover)**	**Dominant families (richness)**
62	Restionaceae, Poaceae, Proteaceae	Asteraceae, Iridaceae, Poaceae
Cumulative species richness (1 km²)	**Species richness (1000 m²)**	**Species richness (100 m²)**
385 – 385	123.7 (81–169)	87.3 (57–128)
***z*-value**	**Species richness change per year (1000 m²)**	**Evenness (1000 m²)**
0.151 (0.051–0.314)	n.a.	0.517 (0.296–0.656)
Evenness (100 m²)	**Simpson (1000 m²)**	**Simpson (100 m²)**
0.592 (0.369–0.698)	0.808 (0.488–0.940)	0.840 (0.634–0.945)

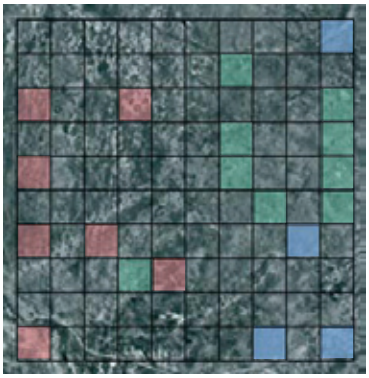
Life forms



Species richness



Map of vegetation units



Most of the vegetation at Elandsberg Observatory forms part of the Swartland Alluvium Fynbos (FFa3, Mucina & Rutherford 2006), but the observatory also borders the Swartland Shale Renosterveld (FRs9). The dominant growth forms are evergreen sclerophyllous shrubs (P nan, mainly Proteaceae) and graminoids (H, mainly Poaceae and Restionaceae). Plant diversity is particularly high. Species richness at the 100m², 1000m², 1 ha, and 1 km² scales is the highest of all BIOTA Southern Africa Observatories. The number of plant families are also amongst the highest along the transect. As with the other Fynbos-dominated Observatories, local scale species turnover (β-diversity expressed in z-values) is amongst the lowest of the BIOTA Observatories. Species evenness is one of the lowest, which results in a moderate Simpson diversity index.

The *Leucadendron stellare-Relhania fruticosa* community (unit 1) is found on loamy areas with a mean pH of 4.9. The vegetation composition is possibly influenced to some extent by the nearby Swartland Shale Renosterveld (FRs9, Mucina & Rutherford 2006), as evidenced by the near constant presence of *Dicerothamnus rhinocerotis*. Vegetation density varies from open to closed. Dominant shrubs (P nan) are *Leucadendron corymbosum*, *Leucadendron stellare*, and *Relhania fruticosa*. Dominant graminoids (H) are the restioid *Elegia filacea* and *Calopsis viminea*, as well as the invasive grass species *Briza maxima*.

The *Cynodon dactylon-Ehrharta calycina* community (unit 2) occurs on softer

Classification table (2009)

Column		Cover	All	1	2	3
Number of relevés			**20**	**7**	**4**	**9**
Mean cover [%]			83.6	78.7	84.5	87.0
Mean species richness (1000 m²)			122.4	125.1	96.0	132.0
Mean soil pH			4.74	4.92	4.63	4.65
Mean electrical conductivity [µS·cm^{-1}]			31	33	38	27
Organic carbon [%]			0.74	0.76	0.81	0.68
Nitrogen [%]			0.05	0.05	0.05	0.05
Unit 1: Leucadendron stellare-Relhania fruticosa community						
n.a.	Marasmodes oligocephala	0.20	40	100	.	11
n.a.	Leucadendron stellare	3.46	25	71	.	.
T	Aira cupaniana	0.07	55	100	.	44
n.a.	Selaginella pygmaea	0.05	40	86	.	22
n.a.	Aspalathus cf. atennuata	0.79	50	100	25	22
n.a.	Isolepis levynsiana	0.03	30	71	.	11
G	Ornithogalum dubium	0.03	60	100	.	56
n.a.	Juncus rupestris	0.09	65	100	.	67
Hper	Itasina filifolia	0.07	25	57	.	11
G	Moraea fugax	0.03	15	43	.	.
G	Pelargonium chelidonium	0.01	15	43	.	.
G	Drimia convallarioides	n.a.	15	43	.	.
Hper	Aizoon sarmentosum	0.01	15	43	.	.
Cmes	Agathosma serpyllacea	0.12	15	43	.	.
n.a.	Inuloides tomentosa	0.11	15	43	.	.
G	Wurmbea inusta	0.01	15	43	.	.
n.a.	Wahlenbergia ramulosa	0.01	15	43	.	.
G	Ferraria uncinata	n.a.	15	43	.	.
n.a.	Muraltia heisteria	0.19	50	86	25	33
T	Briza minor	0.05	70	100	25	67
Pnan	Dicerothamnus rhinocerotis	9.46	45	86	50	11
Unit 2: Cynodon dactylon-Ehrharta calycina community						
G	Babiana ambigua	0.17	25	.	75	22
G	Asplenium gemmiferum	0.03	10	.	50	.
T	Hebenstretia sp.	n.a.	10	.	50	.
Cmic	Diospyros glabra	0.25	10	.	50	.
H	Cynodon dactylon	1.24	25	14	75	11
n.a.	Arctopus monacanthus	0.04	25	28.6	75	.
Unit 3: Satyrium erectum-Leucadendron lanigerum community						
Cmic	Muraltia filiformis	0.03	60	43	.	100
G	Albuca suaveolens	0.01	40	14	.	78
G	Satyrium erectum	0.01	40	.	25	78
G	Asclepias crispa	0.01	35	14	.	67
n.a.	Lebeckia plukenetiana	0.04	45	29	.	78
n.a.	Anthospermum sp. 9642	0.22	50	.	50	89
T	Crassula umbellata	n.a.	20	.	.	44
n.a.	Thamnochortus insignis	0.16	20	.	.	44
G	Tulbaghia alliacea	0.04	55	29	25	89
n.a.	Silene cf. gallica	0.01	60	57	.	89
G	Trachyandra revoluta	0.02	45	14	25	78
G	Disperis villosa	0.01	50	43	.	78
G	Oxalis polyphylla	0.10	40	29	.	67
Most frequent companions						
Pnan	Calopsis viminea	5.83	100	100	100	100
T	Briza maxima	2.73	100	100	100	100
n.a.	Heliophila pusilla var. pusilla	1.34	100	100	100	100
T	Adenogramma glomerata	0.37	100	100	100	100
n.a.	Cotula turbinata	0.32	100	100	100	100
G	Oxalis versicolor	0.26	100	100	100	100
n.a.	Themeda triandra	2.14	95	86	100	100

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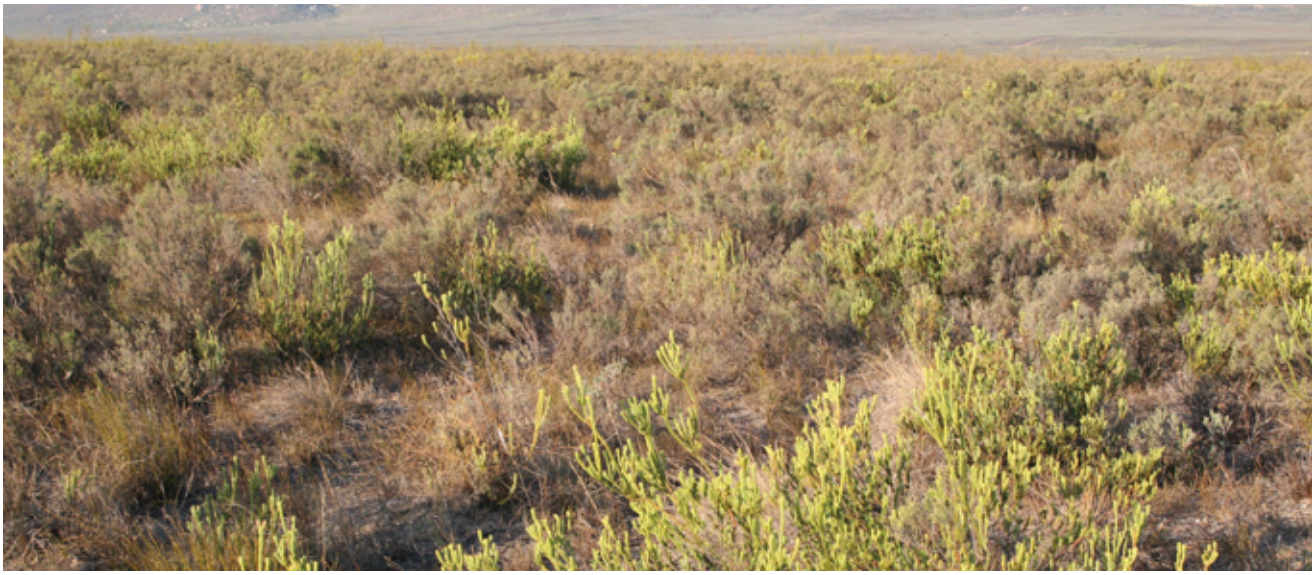


The *Leucadendron stellare-Relhania fruticosa* community (unit 1) showing the bright green *Leucadendron stellare* and the grey *Dicerothamnus rhinocerotis*. Photo: L.W. Powrie.

The *Cynodon dactylon-Ehrharta calycina* community (unit 2) showing dominant herbaceous layer Poaceae and Restionaceae. Photo: L.W. Powrie.

The *Satyrium erectum-Leucadendron lanigerum* community showing the shorter *Leucadendron lanigerum* var. *lanigerum* and taller *Leucadendron corymbosum*. The extensive herbaceous layer (unit 3) is dominated by Restionaceae and Poaceae. Photo: L.W. Powrie.

soils with a mean pH of 4.6. The vegetation is relatively dense and is predominantly herbaceous with species of both Poaceae and Restionaceae. Dominant graminoids (H) are the grasses *Cynodon dactylon*, *Ehrharta calycina*, and *Themeda triandra*, as well as the restioids *Calopsis viminea* and *Ischyrolepis capensis*. The dominant shrub (P nan) is *Leucadendron corymbosum*.

The *Satyrium erectum-Leucadendron lanigerum* community (unit 3) is found on pebbly, gritty sandy soils with a mean pH of 4.7. The vegetation is relatively open with varying ratios of woody to herbaceous elements. Dominant shrubs (P nan) are *Leucadendron lanigerum* var. *lanigerum* and *Leucadendron corymbosum*. The dominant graminoid species (H) are the restioids *Elegia filacea*, *Calopsis viminea*, and *Ischyrolepis capensis*, and the grasses *Aristida junciformis*, *Themeda triandra*, and *Ehrharta calycina*. There are approximately equal proportions of Restionaceae and Poaceae species of the more than 30 graminoids present.

Classification table (continued)

Column		Cover	All	1	2	3
Number of relevés			**20**	**7**	**4**	**9**
H	Ehrharta calycina	1.73	95	86	100	100
Hper	Ficinia indica	1.26	95	86	100	100
G	Micranthus tubulosus	0.86	95	100	75	100
n.a.	Cyphia volubilis	0.04	95	86	100	100
Cmes	Elegia filacea	14.10	90	100	50	100
Pnan	Ischyrolepis capensis	2.06	90	71	100	100
Cmes	Stoebe fusca	1.43	90	86	75	100
Hper	Corymbium africanum	0.85	90	100	100	78
T	Isolepis incomtula	0.52	90	86	75	100
G	Spiloxene schlechteri	0.12	90	86	100	89
G	Lachenalia pustulata	0.10	90	86	75	100
n.a.	Nenax sp.	0.09	90	86	75	100
G	Spiloxene capensis	0.09	90	71	100	100
n.a.	Hermannia scabra	0.09	90	86	100	89
n.a.	Babiana no flws	0.07	90	100	75	89
G	Oxalis purpurea	0.07	90	100	100	78
G	Oxalis sp.	0.05	90	86	75	100
n.a.	Dischisma capitatum	0.01	90	71	100	100
Cmes	Berkheya armata	0.11	85	86	75	89
G	Romulea hirsuta	0.10	85	71	75	100
G	Aristea africana	0.07	85	71	100	89
T	Ursinia cakilefolia	0.06	85	100	25	100
Cnan	Euphorbia tuberosa	0.05	85	86	75	89
Hper	Vellereophyton dealbatum	0.03	85	71	100	89
G	Ornithogalum hispidum ssp. hispidum	0.01	85	100	50	89
Pnan	Leucadendron lanigerum var. lanigerum	3.15	80	71	50	100
n.a.	Metalasia cf. densa	2.00	80	86	50	89
n.a.	Drosera cistiflora	0.16	80	71	100	78
G	Bulbinella triquetra	0.05	80	100	25	89
G	Eriospermum capense	0.02	80	57	100	89
n.a.	Aristida junciformis	5.33	75	57	75	89
H	Tribolium uniolae	0.57	75	86	75	67
n.a.	Centella capensis	0.57	75	86	25	89
n.a.	Erepsia cf. ramosa	0.14	75	86	50	78
n.a.	Cyphia bulbosa	0.04	75	57	75	89
n.a.	Hypochaeris glabra	0.04	75	57	50	100
G	Chlorophytum undulatum	0.02	75	71	75	78
n.a.	Drosera pauciflora	0.02	75	57	75	89
Pnan	Leucadendron corymbosum	11.78	70	71	75	67
n.a.	Pentaschistis triseta	1.08	70	86	.	89
Pnan	Cassytha ciliolata	0.30	70	86	50	67
G	Geissorhiza aspera	0.07	70	86	.	89
G	Geophyte LBH 653	0.06	70	71	100	56
n.a.	Phylica rogersii	0.05	70	57	75	78
n.a.	Pelargonium chamaedryfolium	0.02	70	57	50	89
G	Disa bracteata	0.01	70	86	.	89
n.a.	Relhania fruticosa	3.72	65	86	75	44
n.a.	Steirodiscus gamolepis	0.26	65	86	50	56
n.a.	Aspalathus parviflora	0.15	65	57	75	67
G	Oxalis livida	0.08	65	86	.	78
G	Trachyandra flexifolia	0.04	65	71	.	89
G	Isoetes capensis	0.02	65	86	.	78
G	Moraea lugubris	0.02	65	43	75	78
n.a.	Nemesia barbata	0.01	65	57	75	67
n.a.	Chlorophytum cf. undulatum	0.01	65	86	.	78
Cmes	Ischyrolepis macer	3.75	60	57	25	78
H	Stipagrostis zeyheri	1.99	60	57	50	67
n.a.	Aspalathus spinosa	1.81	60	29	75	78
H	Tribolium hispidum	0.30	60	71	50	56
n.a.	Tetraria cuspidata	0.27	60	57	75	56
Cmic	Zygophyllum sessilifolium	0.13	60	71	50	56
Hper	Drosera trinervia	0.11	60	71	25	67

Satyrium erectum. Photo: R. Cozien.

Disperis capensis var. *capensis*. Photo: R. Cozien.

Gladiolus alatus. Photo: L.B. Husted.

Disa flexuosa. Photo: R. Cozien.

Responsible authors: M.C. Rutherford, L.W. Powrie, L.B. Husted & J. Luther-Mosebach

General data

Number	Name	Alternative name(s)
S33	Cape of Good Hope	Olifantsbos, Cape Peninsula
Implementation	**Country**	**Province/ region**
2001	South Africa	Western Cape
District/ constituency	**Locality**	**Farm name**
City of Cape Town	Table Mountain National Park	Olifantsbos
Latitude	**Longitude**	**Altitude**
34.260204 S	18.392285 E	83 m a.s.l.
Rainfall season	**Biome**	**WWF Ecoregion**
Winter	Fynbos	AT1203 Montane fynbos and renosterveld
Agro-Ecological Zone	**Relative intensity of land use**	**Tenure**
n.a.	None	State
Type and history of landuse	**Land owner**	
Conservation area	SANParks	

Cape of Good Hope (S33)

Fynbos vegetation with flowering *Leucospermum conocarpodendron* in the foreground. Photo: A. Petersen.

The BIOTA Observatory Cape of Good Hope (S33) is situated within the highly diverse Cape Floristic Kingdom at the south-western tip of Africa. The Observatory is on the original farm Olifantsbos in the Cape of Good Hope Nature Reserve portion of the Table Mountain National Park, about 38 km south-southwest of the city of Cape Town. It is less than 1 km from the Atlantic Ocean in the west and lies at 60 to 80 m a.s.l. This part of the coastal Fynbos area occurs on light-grey quartzite Table Mountain Sandstone. The terrain is flat to moderately sloping and has varying degrees of rockiness. The vegetation is a mid-dense to dense shrubland with a tall proteoid layer and a lower ericoid-leaved layer, which includes proteoid, ericoid, and asteraceous elements. This Mediterranean type vegetation relies on winter rainfall and tolerates hot, dry summers. The average annual rainfall is 573 mm.

The Cape of Good Hope Nature Reserve has been protected since 1939, and became part of the Table Mountain National Park in 1998.

The objectives of this BIOTA Observatory are to monitor climate change, and the effects of fire on Fynbos.

Responsible authors:
M.C. Rutherford, L.W. Powrie, L.B. Husted & D.H. Haarmeyer

Remote sensing and landscape

Geomorphology	Geological units	Lithological units
n.a.	Table mountain system of Cape series	Quartzite, shale, tillite
Mean EVI	**EVI absolute range**	**Mean leaf area index**
0.221 (0.189–0.279)	0.113 (2007)–0.341 (2002)	1.29

Grid map of Observatory

	0	1	2	3	4	5	6	7	8	9
0	84	60	1	7	62	20	75	71	43	66
1	55	25	77	30	83	22	56	88	79	81
2	19	44	57	26	47	35	33	94	64	3
3	27	76	85	54	73	99	67	11	32	49
4	63	2	93	82	45	39	37	16	100	95
5	89	14	70	51	21	24	52	5	96	15
6	9	80	68	17	87	38	92	18	97	90
7	12	31	74	6	59	46	29	86	58	28
8	53	48	72	34	36	78	10	13	41	98
9	40	4	91	65	61	42	8	69	50	23

1 Unburnt (13-14 years) proteoid and ericoid fynbos (in 2004)
2 Recently burnt (2 years) proteoid and ericoid fynbos (in 2004)

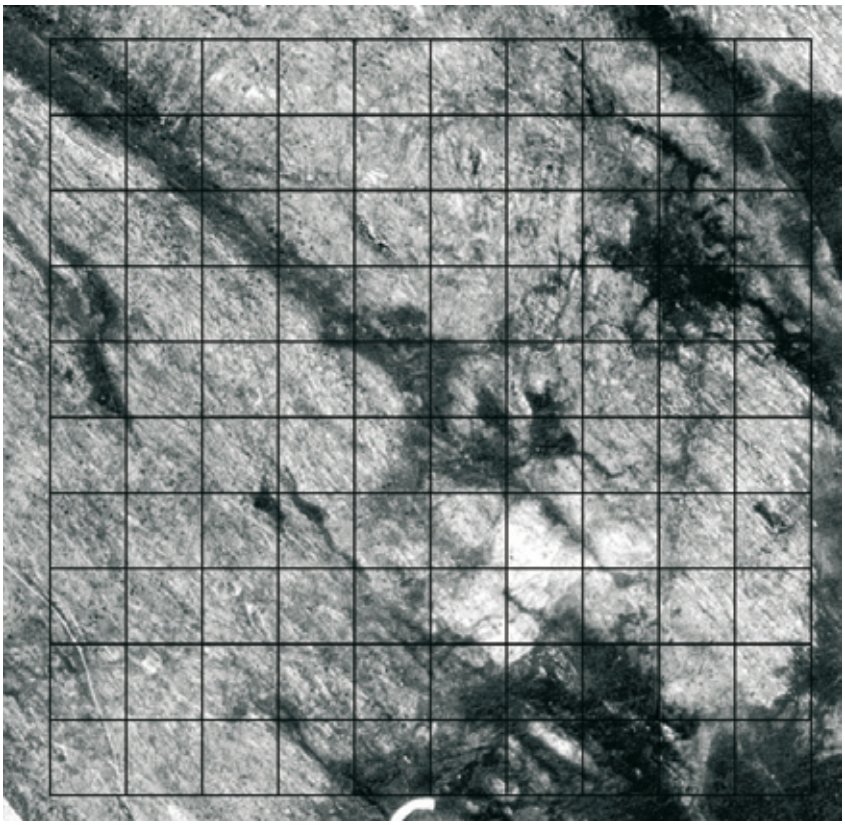
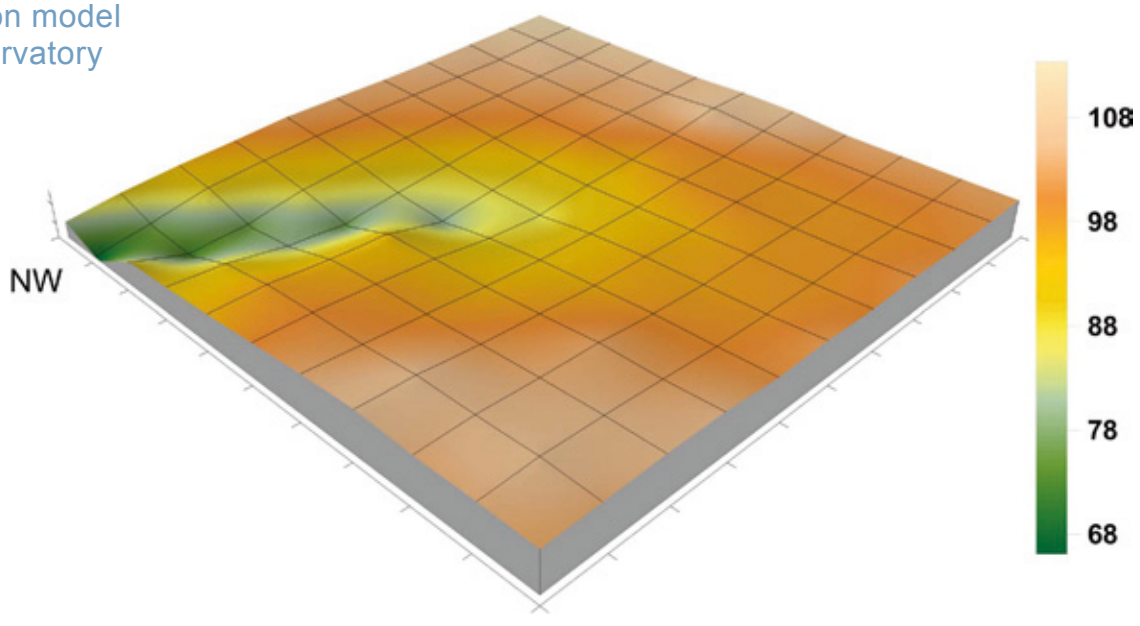


Image: aerial photograph

Elevation model of Observatory



Landsat image

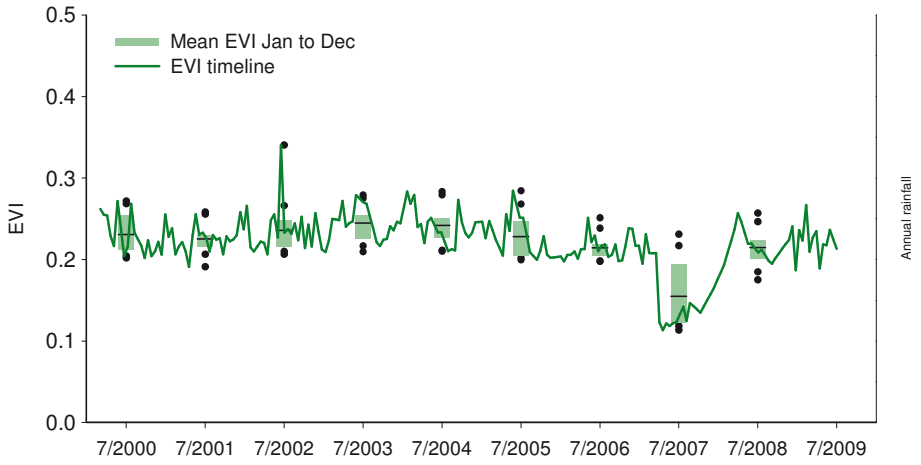
Small sandy beaches are visible (whitish tones) running parallel to the coastline between the ocean and the rocky slopes, which pass to a slightly undulated plateau, mainly based on sandstones. Several drainage valleys dissect the plateau, with one small drainage valley visible in the north-western part of the Observatory.

The typical fynbos vegetation covers most parts of the subscene, with different cover densities, and showing in dark green (higher cover) or green-grey (lower cover). The blue-grey strip in the south-western part of the image is due to an area burnt in a wildfire during 2002. Brown to red spots depict denser woody vegetation on slopes and in some valleys, e.g. in the valley in the north-eastern part of the image which drains in a north-westerly direction.

Scene: 175/84, acquisition date: 07 February 2007

MODIS time series

Temporal patterns of vegetation cover, and phenology



Responsible authors: M. Keil & T. Labitzky

Climate

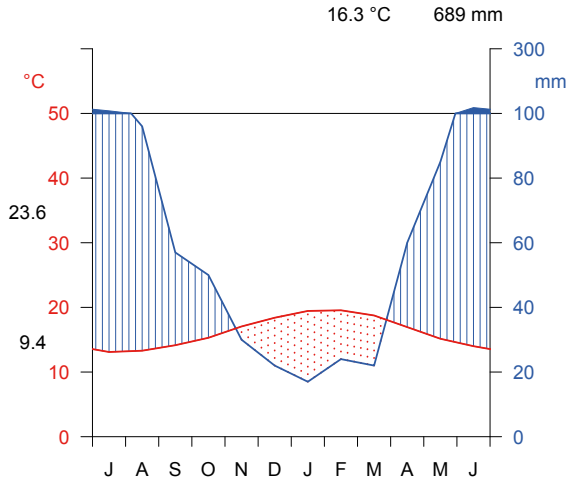
Modelled data

Mean temperature	Mean annual temperature range	Mean diurnal temperature range
16.2 (9.4–23.6) °C	6.4 °C	7.7 °C
Mean annual precipitation	**Precipitation seasonality**	**Percentage winter precipitation**
689 mm	60%	76% (winter)
Climate type	**Length of dry season**	**Aridity index (De Martonne)**
Csb	5 months	26.3 (semi-humid)

Only interpolated data from the WorldClim dataset is available for this Observatory. The climate at the Observatory is characterised by temperate conditions. Rainfall shows a pronounced seasonality with the major portion of rain falling during the winter season, peaking in June. The mean annual rainfall is 689 mm, making it to the wettest Observatory of the entire transect. However, the mean annual rainfall recorded over 27 years at Klaasjagerberg, 3 km from the Observatory, was 573 mm. Near-surface air temperatures show a moderate seasonal cycle. The mean annual temperature is 16.2°C and is therefore the lowest within the Fynbos Biome.

Climate diagrams

Modelled data (WorldClim)



Responsible authors: K. Berger, A. Haensler & J. Luther-Mosebach

Soils

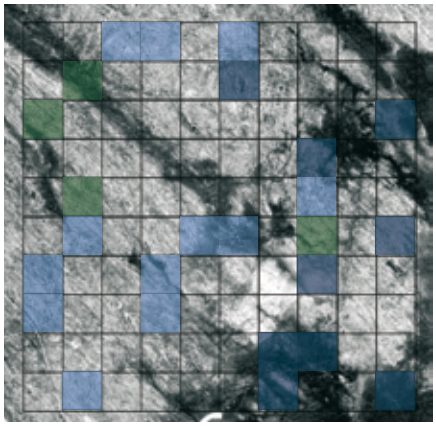
Year of sampling	Hectare plots sampled	SOTER unit
2005	25 (R1–25)	ZA3256
Soilscape	**Dominant soil group(s)**	**Reference group richness**
Podzols	Podzol	2
Soil unit richness	**Soil unit evenness**	**Soil ecotype richness**
7	0.530	9
Parametric space	**pH**	**Electrical conductivity**
3.49	5.4 (4.4–5.7)	23 (9–105) $\mu S \cdot cm^{-1}$
Organic carbon		
2.63% (1.20–16.00%)		

On this Observatory, all soils are classified as Podzols or Leptosols. The latter are restricted to the shallow outcrop regions of the arenite sandstone. The most frequent soil unit is the Episkeletic Podzol, mainly found in the central and south-western part of the Observatory, followed by the Gleyic Podzol in the eastern part. Here, the basin-like structure of underlying sandstone impedes drainage and deeper percolation of the water. As a result, seasonal 'Gleyic' conditions occur during the winter months. These conditions are found on wider areas in the eastern part of the Observatory, but are also infrequently found in other parts where similar microtopographic features are evident on a smaller scale.

The pH values and the electrical conductivity show very low median values and low ranges characterising the overall acid and nutrient-poor conditions of the Observatory. Fine earth texture is characterised by sand, predominantly medium sand, except for one profile with loamy sand. Organic carbon and the rooting space show very high variability. Organic carbon presents a with a range from 1% up to 10%, thus showing the highest values of any Observatory of BIOTA Southern Africa, and rooting space ranges from 5% to 100%. Also the C/N ratio is extraordinarily high with a median above 30, while other nutrients are so low that they are often near detection limits.

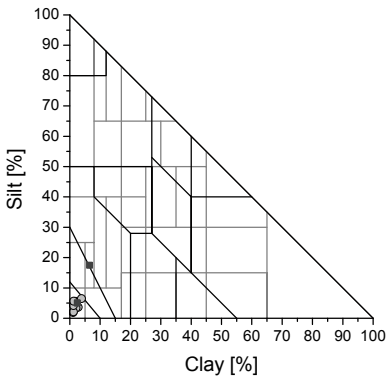
The analyses confirmed that especially the waterlogged profiles have slightly higher electrical conductivity values compared to the dry habitats. This may be a result of a soluble salt input with drainage water, which predominantly flows laterally in the soil originating from the surrounding areas.

Map of soil profiles

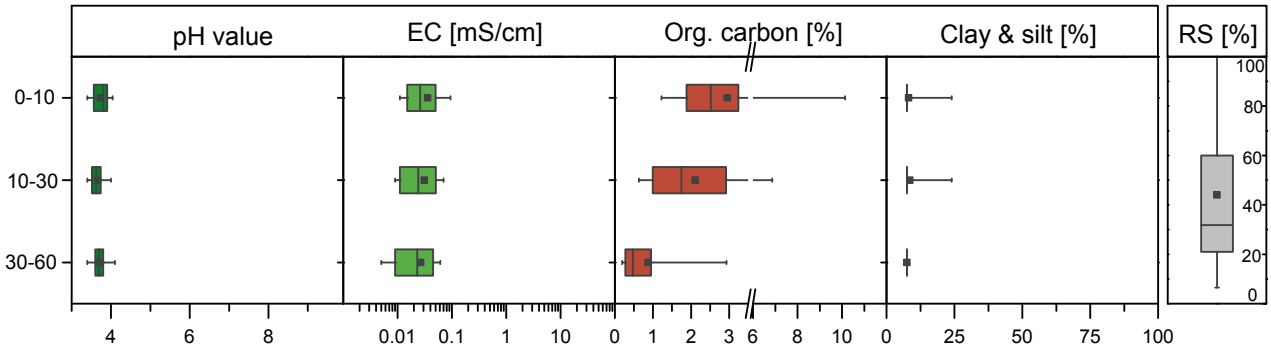


Haplic Podzol
Gleyic Podzol
Haplic Leptosol

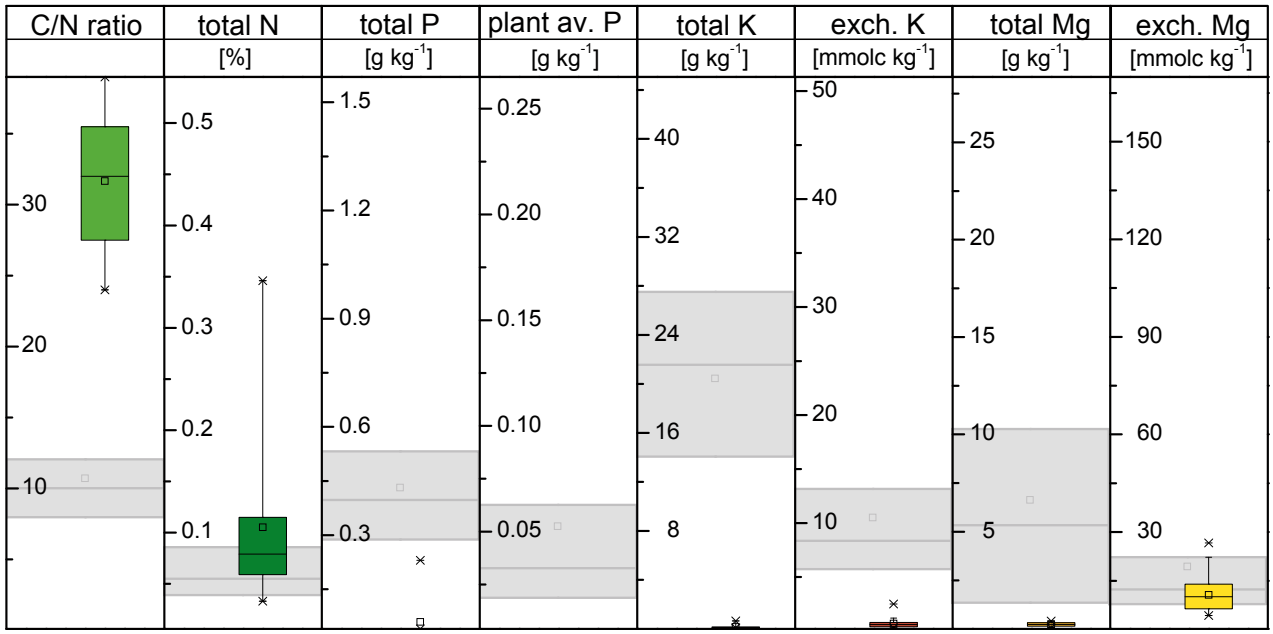
Soil texture triangle



Soil characteristics



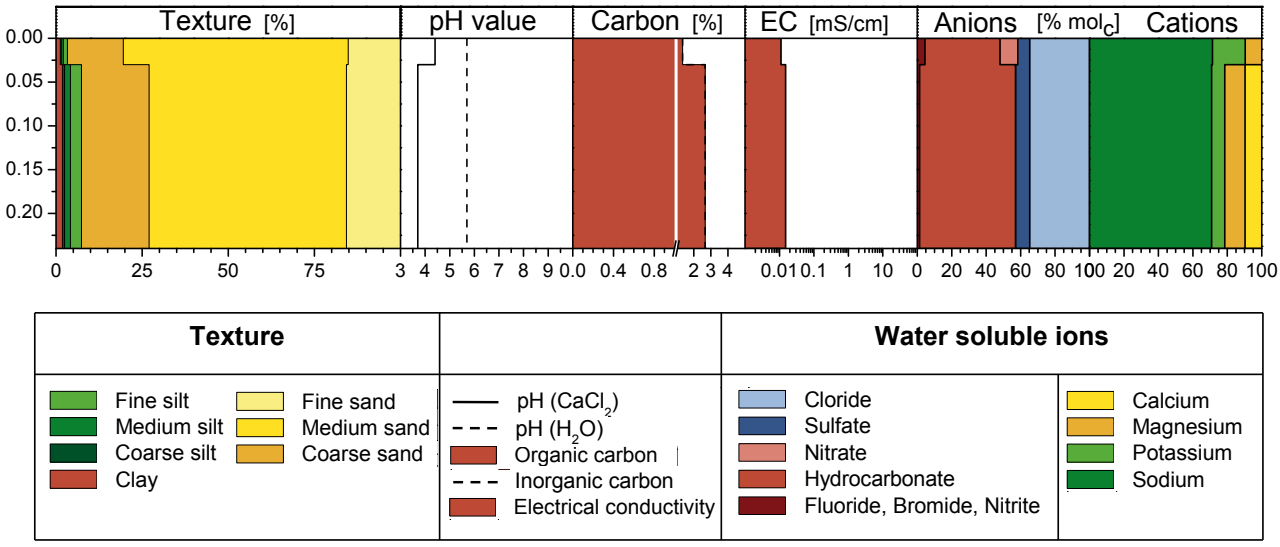
Soil nutrients



Reference profile (H70)

The **Episkeletic Podzol** is a typical example of the drier Podzol profiles in the western part of the Observatory. Except for the water logging, the profile morphology with a sandy layer of 20 cm thickness, overlying a fragment-rich transition zone to the arenite layer, is comparable to the Gleyic Podzols. However, drainage is favoured by stronger fragmented bedrock or the lack of bedrock barriers. A prominent feature of these drier Podzols is a thin topsoil horizon, which is more strongly bleached than the underlying horizons. Additionally, the content of silt, clay, and organic carbon are reduced. The thin horizon is probably of aeolian origin, i.e. translocated bleached sand of burned, open areas. Although fulfilling the requirement for an 'Albic' horizon, it should be noted that this leached horizon is too thin to be the single source of organic components in the subsoil.

The moderately low pH value and the electrical conductivity of around 12 µS cm^{-1} are nearly constant with depth. Organic carbon reaches high values of 2.6% in the second horizon. Both horizons again show wide C/N ratios of 27. The analyses of total element contents revealed the nutrient poor character of the sandstone-derived materials: almost all of the elements were not detectable except titanium and calcium with values below 1 g kg^{-1}. The same is true for the extremely low contents of water-soluble ions (about 2 $mmol_c$ kg^{-1}) and exchangeable cations (25 $mmol_c$ kg^{-1}).



Responsible authors: U. Wisch, A. Petersen, A. Gröngröft & D. Mager

Lichens

Sampling period(s)	Hectare plots sampled	Cover
2001, 2005	5 (R1−R5)	0%
Total species richness	Species richness on soil [1 km²]	Species richness on rock [1 km²]
10	1 (10%)	9 (90%)
Species richness on plants [1 km²]	Species richness on soil [1000 cm²]	
n.a.	0.4 (0−1)	

Despite the highly favourable climatic conditions, this Observatory possesses predominantly saxicolous crustose lichens with green algal photobionts. Only a few lichen crusts are present on bark or wood (although epiphytic lichens have not been studied in detail), but most woody plants in the burned part of the Observatory lack lichens due to the impact of a fire in 2002. The limited richness of lichens on soil is due to the high cover of Fynbos vegetation and to the presence of sandy soils. The influence of fire also appears to be important, since lichens are very slow growing organisms and need several years for soil re-colonisation. The only soil-inhabiting species recorded is the ubiquitous *Cladonia symphycarpa*, which typically occurs in relatively dry and warm habitats, especially on sandy soils, and is often accompanied by mosses. The mean cover of lichens is very low in the investigated hectare plots with only very small individuals of *Cladonia* occurring in two plots (H02, H41), which are situated in the most well-preserved and unburned vegetation on the Observatory.

List of Taxa

Terricolous (on soil):

Cladonia symphycarpa

Saxicolous (on rock):

Buellia distrata
Buellia sp.
Caloplaca cinnabarina
Caloplaca sp.
Lecanora cf. conferta
Ochrolechia sp.
Pertusaria sp.
Rinodina cf. microlepida
Xanthoparmelia sp.

Epiphytic (on plants):

No records

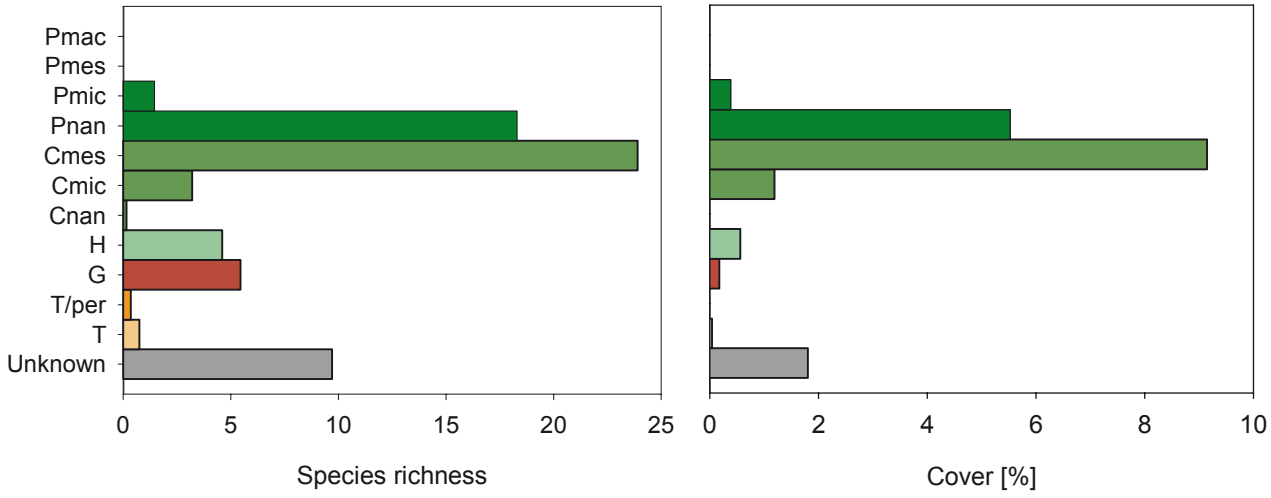
Saxicolous lichens.
Photo: L. Zedda & G. Rambold.

Responsible authors: L. Zedda & G. Rambold

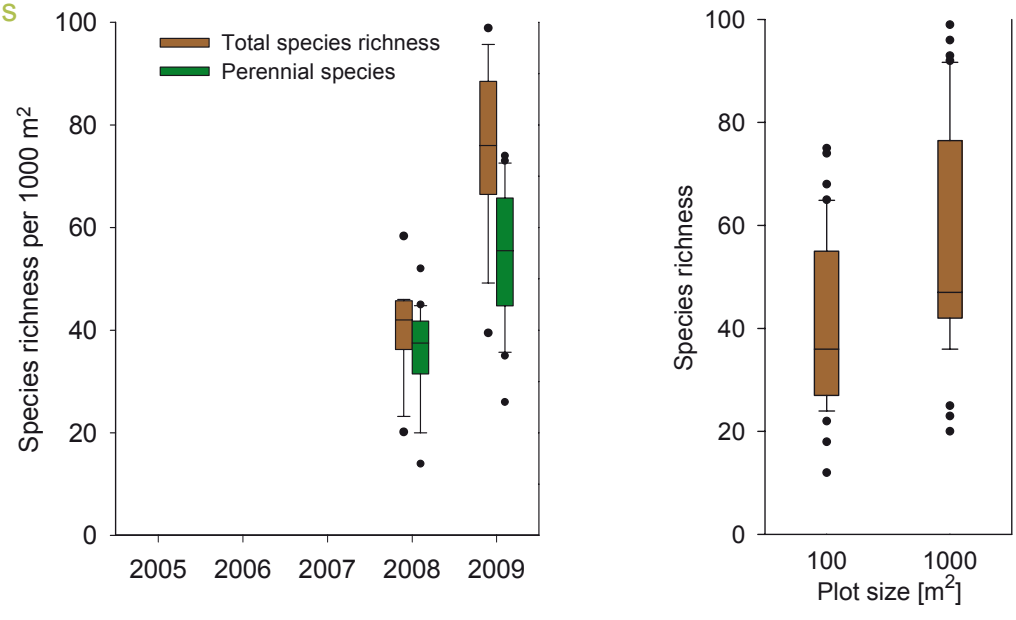
Vascular plants

Sampling period(s)	Hectare plots sampled	Biome
2008, 2009	20 (R1–R20)	Fynbos
Vegetation unit (level 1)	**Vegetation unit (level 2)**	**Identification rate**
Sandstone Fynbos	FFs 9 Peninsula Sandstone Fynbos	80% – 87% – 83%
Cumulative family richness	**Dominant families (cover)**	**Dominant families (richness)**
47	Restionaceae, Campanulaceae, Asteraceae	Ericaceae, Asteraceae, Restionaceae
Cumulative species richness (1 km²)	**Species richness (1000 m²)**	**Species richness (100 m²)**
287 – 218	67.2 (19–114)	49.0 (12–86)
***z*-value**	**Species richness change per year (1000 m²)**	**Evenness (1000 m²)**
0.137 (0.000–0.291)	n.a.	0.674 (0.260–0.911)
Evenness (100 m²)	**Simpson (1000 m²)**	**Simpson (100 m²)**
0.712 (0.341–0.881)	0.843 (0.475–0.970)	0.849 (0.340–0.959)

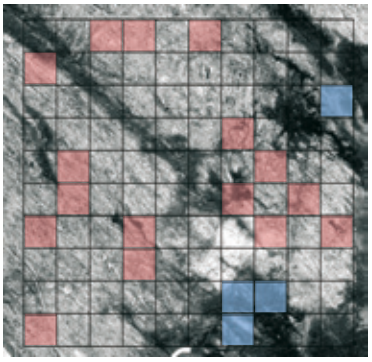
Life forms



Species richness



Map of vegetation units



The vegetation forms part of the Peninsula Sandstone Fynbos (FFs9, Mucina & Rutherford 2006) and is dominated by evergreen sclerophyllous shrubs (P nan, C mac, C mes) that include a relatively wide range of genera of Proteaceae and many species of *Erica*. The wiry Restionaceae are very well represented and abundant and there are relatively few Poaceae. Landscape varies from flat to moderate slope with very little to extensive rock cover that can include large boulders. There are also seep areas that are saturated during the rainy season in winter. Soils are nutrient poor sands with very low pH (< 4). Soil depth varies from extremely shallow to more than 60 cm deep. Species richness at both 100 m² and 1000 m² scales and Simpson's Diversity Index at 100 m² scale are among the highest of the BIOTA Southern Africa Observatories. Local scale species turnover (β-diversity as expressed in z-values) is lower than any other of the BIOTA Southern Africa Observatories, with less than a 40% increase in number of species from 100 m² to 1000 m² scales.

The *Elegia cuspidata-Restio dodii* community (unit 1) occurs in the seeps that are saturated in the rainy season but dry, at least on the surface, in summer. Rock cover is rare. Soil organic carbon is higher than that of community 2 and pH is 3.5. Graminoids (H) are overwhelmingly dominant and comprise mainly the restionaceous *Elegia cuspidata* and *Restio dodii*. Ericoid-leaved shrubs (C mic to C mac) as a group are consistently present although far less abundant and

Classification table (2009)

Column		Cover	All	1	2
Number of relevés			**20**	**4**	**16**
Mean cover [%]			45.2	73.1	38.2
Mean species richness (1000 m²)			84.5	40.5	95.5
Mean soil pH			3.73	3.48	3.79
Mean electrical conductivity [µS·cm^{-1}]			36	71	27
Organic carbon [%]			2.85	3.97	2.57
Nitrogen [%]			0.09	0.12	0.08
Unit 1: Elegia cuspidata-Restio dodii community					
Cmic	Muraltia filiformis	0.29	20	100	.
Pnan	Restio dodii	4.45	20	100	.
Cmes	Erica capensis	3.84	25	100	6
Cmes	Lachnaea densiflora	0.08	30	100	13
Cmes	Erica bruniades	0.20	30	100	13
Cmes	Elegia cuspidata	19.54	30	100	13
n.a.	Tetraria ustulata	2.64	35	100	19
Pnan	Serruria glomerata	0.64	35	100	19
Hper	Bobartia filiformis	0.01	15	75	.
Hper	Bobartia indica	0.67	40	100	25
Cmes	Elegia filacea	13.13	45	100	31
G	Drimia cf. elata	0.01	15	75	.
Cmes	Restio quinquefarius	0.23	45	100	31
Pnan	Restio bifurcus	1.51	25	100	6
Pnan	Berzelia abrotanoides	0.95	25	100	6
Hper	Linum thunbergii	0.17	20	75	6
n.a.	Rafnia crassifolia	0.38	10	50	.
Cmes	Erica obliqua	0.01	10	50	.
Unit 2: Hypodiscus aristatus-Mimetes fimbriifolius community					
Pnan	Metalasia densa	0.43	80	.	100
Cmes	Erica exleeana	0.83	75	.	94
G	Trachyandra ciliata	0.02	75	.	94
n.a.	Metalasia sp. 9873	0.45	75	.	94
n.a.	Thamnochortus cf. fruticosus	0.25	75	.	94
Cmes	Roella ciliata	0.37	70	.	88
Pnan	Aspalathus ciliaris	0.06	65	.	81
Cmes	Cullumia squarrosa	0.17	70	.	88
n.a.	Crassula fascicularis	0.01	65	25	81
Cmes	Syncarpha speciosissima	0.23	65	.	81
n.a.	Ficinia rigida	0.05	65	.	81
Cmac	Anaxeton laeve	0.02	65	.	81
n.a.	Thesium sp. 9888	0.28	85	25	100
Pnan	Thesium strictum	0.20	85	25	100
H	Merxmuellera decora	0.07	85	25	100
Pnan	Gnidia tomentosa	0.06	85	25	100
Pnan	Aspalathus capensis	0.73	85	25	100
Cmes	Ursinia paleacea	0.05	85	25	100
Pmic	Mimetes fimbriifolius	0.85	60	.	75
Hper	Corymbium africanum	0.22	85	100	100
Pnan	Phylica imberbis	0.17	60	.	75
Pnan	Microdon dubius	0.09	85	25	100
Pnan	Amphithalea ericifolia	0.12	55	.	69
H	Pentaschistis papillosa	0.03	55	.	69
Cmes	Liparia parva	0.07	55	.	69
n.a.	Tetraria compar	0.20	55	.	69
Pnan	Ischyrolepis capensis	0.38	85	25	100
Pnan	Asparagus lignosus	0.10	55	.	69
G	Pelargonium longifolium	0.01	50	.	63
Pnan	Saltera sarcocolla	0.13	50	.	63
Cmes	Erica cf. subcapitata	0.61	50	.	63
Cnan	Euphorbia tuberosa	0.01	50	.	63
Cmes	Serruria villosa	0.20	50	.	63

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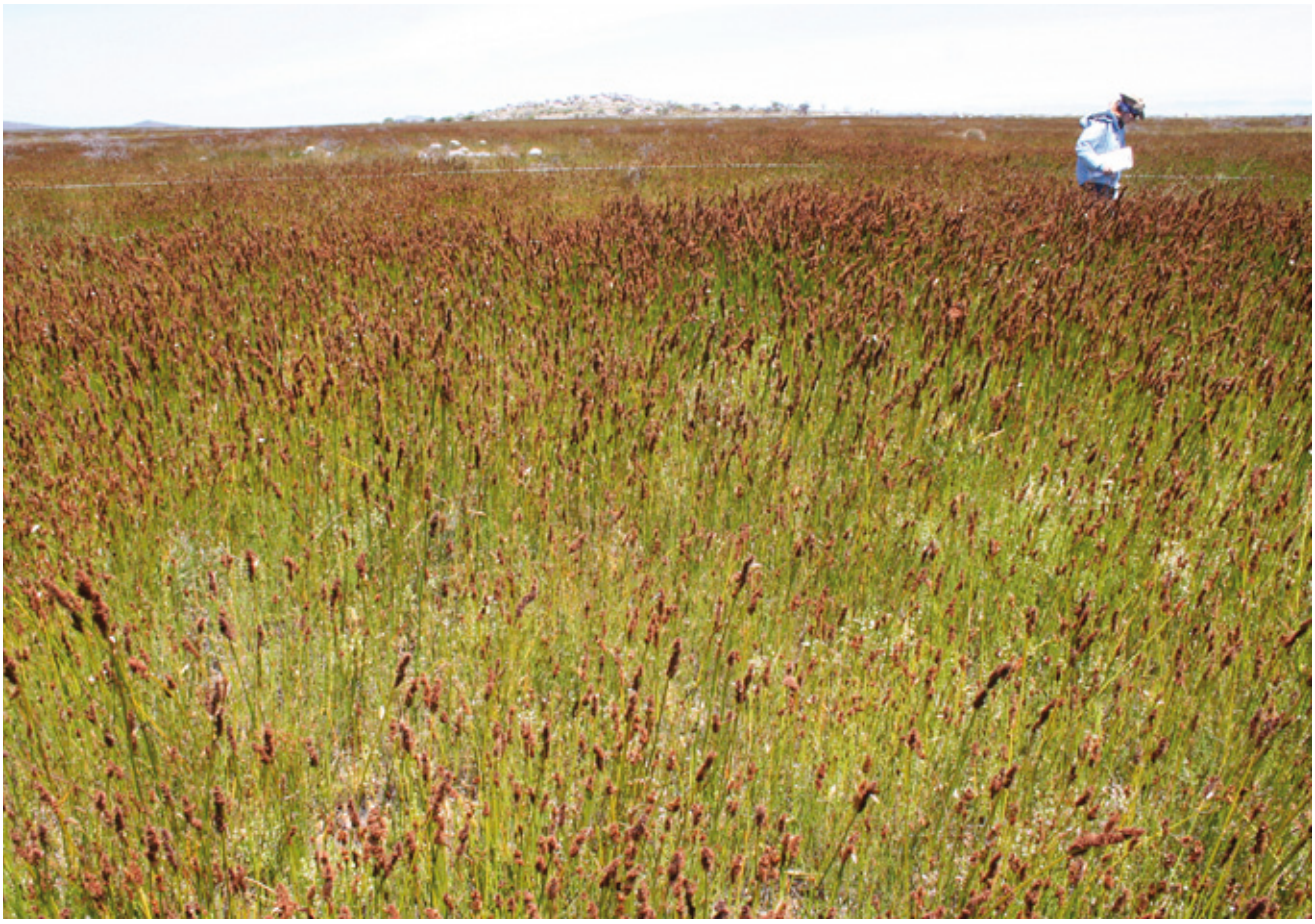


Elegia cuspidata-Restio dodii community (unit 1) showing the dominant *Elegia cuspidata* in the third year after fire. Photo: R. Cozien.

The *Hypodiscus aristatus-Mimetes fimbriifolius* community (unit 2) eight years after fire in 2002 with the white heads of *Syncarpha vestita* and the few larger shrubs *Mimetes fimbriifolius*. Photo: R. Cozien.

include *Erica capensis, E. bruniades, E. clavisepala*, and *E. obliqua*, all of which happen to also be diagnostic species for this community.

The *Hypodiscus aristatus-Mimetes fimbriifolius* community (unit 2) is found extensively on a wide range of sandy to very rocky areas on flats to moderate slopes. Dominant shrubs (P nan) are *Mimetes fimbriifolius* (sometimes P mic), *Leucadendron laureolum*, *Roella decurrens*, and *Aspalathus retroflexa*, *Syncarpha vestita*, and the prostrate shrub (C mic) *Diastella divaricata*. Dominant graminoids (H) are the restionaceous *Hypodiscus aristatus*, *Staberoha cernua*, *Ischyrolepis cincinnata* and *I. capensis*. Main herbs (C mes) are *Prismatocarpus sessilis* and *Edmondia sesamoides*.

Erica cerinthoides. Photo: R. C. Turner.

Aristea africana. Photo: R.C. Turner.

Classification table (continued)

Column		Cover	All	1	2
Number of relevés			**20**	**4**	**16**
Unit 2: Hypodiscus aristatus-Mimetes fimbriifolius community					
Cmes	Erica corifolia	0.17	75	25	88
Pnan	Elegia stipularis	2.57	85	25	100
G	Tritoniopsis dodii	0.01	75	25	88
Pnan	Aspalathus retroflexa	0.81	85	25	100
Hper	Pseudoselago spuria	0.03	75	25	88
Cmes	Edmondia sesamoides	1.03	75	25	88
Cmes	Lampranthus bicolor	0.09	90	50	100
Pnan	Hypodiscus aristatus	1.43	90	50	100
Pnan	Metalasia compacta	0.46	90	50	100
Cmes	Adenandra villosa	0.04	90	50	100
Most frequent companions					
Pnan	Leucadendron laureolum	0.34	100	100	100
Cmes	Ischyrolepis cincinnata	1.96	95	75	100
Pnan	Syncarpha vestita	0.79	95	75	100
Pnan	Struthiola dodecandra	0.57	95	75	100
Cmes	Lobelia setacea	0.24	95	75	100
n.a.	Thamnochortus lucens	1.52	90	75	94
Cmes	Diastella divaricata ssp. divaricata	1.47	90	75	94
Hper	Tetraria bromoides	0.80	90	50	100
Cmes	Osteospermum polygaloides	0.74	90	50	100
n.a.	Tetraria cuspidata	0.32	90	75	94
Cmes	Erica imbricata	0.26	90	75	94
n.a.	Tetraria microstachys	0.26	90	50	100
T/Cmic	Roella decurrens	2.70	85	50	94
Pnan	Stoebe cyathuloides	0.66	85	50	94
T/Cmic	Roella triflora	0.52	85	50	94
Pnan	Staberoha cernua	0.50	85	100	81
Pnan	Diosma oppositifolia	0.06	80	50	88
Cmes	Prismatocarpus sessilis	2.29	75	75	75
Hper	Bobartia gladiata	0.14	75	125	75
Cmic	Thesium capitellatum	0.05	75	50	81
Pnan	Cliffortia subsetacea	0.35	70	175	63
Cmes	Erica pulchella	0.25	70	50	75
G	Aristea africana	0.09	70	25	81
Hper	Ficinia deusta	0.07	70	50	75
Cmes	Penaea mucronata	0.34	65	50	69
Cmes	Agathosma imbricata	0.17	65	25	75
Cmic	Indigofera glomerata	0.03	65	25	75
n.a.	Isolepis marginata	0.26	60	100	50
Cmes	Lobelia pinifolia	0.26	60	25	69
T	Helichrysum indicum	0.03	60	25	69
Cmes	Erica glabella ssp. glabella	0.36	55	50	56
Cmes	Erica muscosa	0.16	55	50	56
n.a.	Thesium viridifolium	0.11	50	25	56
G	Dilatris pillansii	0.09	50	75	44
Cmes	Agathosma hookeri	0.04	50	25	56
Cmes	Anthospermum galioides	0.04	50	25	56
H	Pentaschistis curvifolia	0.02	50	75	44
Cmes	Lobelia coronopifolia	0.01	50	75	44
Cmes	Erica cf. similis	0.73	45	25	50
Cmac	Aspalathus microphylla	0.06	45	25	50
T/Hper	Chironia linoides	0.06	45	50	56
Cmic	Hypodiscus willdenowia	0.04	45	25	50
Pnan	Cyclopia genistoides	0.04	45	50	44
Hper	Senecio umbellatus	0.03	45	.	56
Pnan	Muraltia alopecuroides	0.01	45	.	56
Hper	Itasina filifolia	0.01	45	.	56
n.a.	Acrolophia lamellata	0.01	45	.	56
n.a.	Cyperaceae sp. 9846	0.12	40	.	50

Syncarpha vestita. Photo: R.C. Turner.

Pelargonium longifolium. Photo: R.C. Turner.

Tritoniopsis dodii. Photo: R.C. Turner.

Lampranthus bicolor. Photo: R.C. Turner.

Responsible authors: M.C. Rutherford, L.W. Powrie & L.B. Husted & J. Luther-Mosebach

General data

Number	Name	Alternative name(s)
S45	Nieuwoudtville	Glenlyon, Hantam National Botanical Garden
Implementation	**Country**	**Province/ region**
2007	South Africa	Northern Cape
District/ constituency	**Locality**	**Farm name**
Namakwa	Nieuwoudtville	Glenlyon
Latitude	**Longitude**	**Altitude**
31.390019 S	19.128797 E	722 m a.s.l.
Rainfall season	**Biome**	**WWF Ecoregion**
Winter	Fynbos	AT1322 Succulent Karoo
Agro-Ecological Zone	**Relative intensity of land use**	**Tenure**
n.a.	None	State
Type and history of landuse	**Land owner**	
Conservation area	SANBI	

Nieuwoudtville (S45)

A dense stand of *Bulbinella latifolia* var. *doleritica*. The Nieuwoudtville area is renowned for its outstanding diversity of geophytes. Photo: B. Koelle.

The Observatory Nieuwoudtville is situated on the farm Glenlyon, 3 km southeast of the town Nieuwoudtville, about 720 m a.s.l. The landscape is slightly undulating with a few dolerite koppies on the dolerite and tillite plains. The area, which is part of the Fynbos Biome, falls within a semi-arid winter rainfall zone and receives an average of 350 mm of rainfall per year. Climate, soils, and biotic factors such as grazing are important drivers of the unique species richness of the area, which is renowned for its outstanding diversity of geophytes and is known as the "Capital of the Bulbs".

Two different vegetation types occur on the Observatory, depending on the soils, namely the shrub-dominated Nieuwoudtville Shale Renosterveld (FRs 2) on grey-coloured tillite soils, and the Nieuwoudtville-Roggeveld Dolerite Renosterveld (FRd 1, Rebelo et al. 2006) on heavy red dolerite clay soils. The Nieuwoudtville Shale Renosterveld is dominated by shrubby vegetation, whereas the Nieuwoudtville-Roggeveld Dolerite Renosterveld is dominated by annuals and geophytes with exceptionally high species diversity while shrubs are scarce. The latter vegetation type thus has the appearance of old lands that have been ploughed in the past and left fallow for several years, but in fact the absence of shrubs is natural and is caused by the very heavy soils.

Until 2004, the Conservation Farming Project, co-ordinated by the National Botanical Institute (presently the South

African National Biodiversity Institute, SANBI), has been examining the conservation benefits of different farming practices in South Africa. The project also conducted research on the farm Glenlyon, which was a conservation-orientated sheep farm at that time. In 2007, the farm became the Hantam National Garden, and is managed by SANBI. In the same year, BIOTA established a Biodiversity Observatory on the farm in order to continue the long-standing ecological research and environmental monitoring of the Conservation Farming Project. Since then, the botanical monitoring plots established by the Conservation Farming Project have been revisited by SANBI staff.

Nieuwoudtville-Roggeveld Dolerite Renosterveld and dolerite koppies at the back. Photo: U. Schmiedel.

Flower display with numerous annual Asteraceae. Photo: B. Koelle.

Spectactular display of *Brunsvigia bosmaniae* (Maartblom). Photo: B. Koelle.

Bulbinella latifolia var. *doleritica*. Photo: U. Schmiedel.

Flower display in August 2006 with the Glenlyon farm house in the background. Photo: B. Koelle.

Ixia rapunculoides (Iridaceae). Photo: B. Koelle.

Bulbinella latifolia var. *latifolia*. Photo: U. Schmiedel.

Responsible authors: U. Schmiedel, D.H. Haarmeyer & T. Oliver

Remote sensing and landscape

Geomorphology	Geological units	Lithological units
Plateau	Dwyka group	Tillite and Dolerite
Mean EVI	**EVI absolute range**	**Mean leaf area index**
n.a.	n.a.	n.a.

Responsible author: T. Oliver

Climate

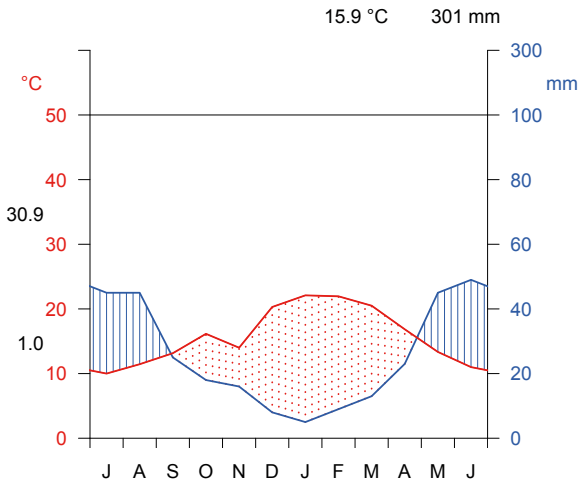
Modelled data

Mean temperature	Mean annual temperature range	Mean diurnal temperature range
16.3 (3.2–30.9) °C	12.1 °C	15.9 °C
Mean annual precipitation	**Precipitation seasonality**	**Percentage winter precipitation**
301 mm	61%	77% (winter)
Climate type	**Length of dry season**	**Aridity index (De Martonne)**
BSk	8 months	11.4 (semi-dry)

Only interpolated data from the WorldClim dataset is available for this Observatory. The climate at the Observatory is characterised by semi-arid conditions. Rainfall shows a pronounced seasonality with the major portion of rain falling during the winter season, peaking in June and July. The mean annual rainfall is 301 mm, which is fairly wet in comparison to the average rainfall recorded at the Observatories in the Knersvlakte. Nieuwoudtville lies on the escarpment about 500 m higher than the Knersvlakte and therefore receives considerably more winter rainfall than the Knersvlakte, which forms part of the much drier Succulent Karoo. Nieuwoudtville is the driest Observatory among the Observatories of the Fynbos Biome. The near-surface air temperatures show a strong seasonal cycle. The mean annual temperature is 15.9°C making this one of the coldest Observatories.

Climate diagrams

Modelled data (WorldClim)



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BIOTA transect and the Biodiversity Observatories in southern Africa.

Boundaries

- International Boundary
- Provincial Border

Hydrography

- River
- Periodical River
- Salt Pan
- Lake
- Wetland

Contour Levels

- up to 300 m
- up to 600 m
- up to 900 m
- up to 1200 m
- up to 1500 m
- up to 1800 m
- more than 1800 m

Communications

- Motorway
- Road
- Railway

Populated Places

- City
- Provincial Capital
- Capital

- Transect
- S32 Elandsberg — BIOTA Observatory

0 250 500 km

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Number, name and respective biome of the BIOTA Biodiversity Observatories.
Page number refers to the description of the Observatory in Volume I.

(S01) Mile 46 ■ Woodland Savanna ..... Vol1 page 70
(S02) Mutompo ■ Woodland Savanna ..... page 92
(S03) Sonop ■ Woodland Savanna ..... page 118
(S04) Toggekry ■ Thornbush Savanna ..... page 168
(S05) Otjiamongombe ■ Thornbush Savanna ..... page 194
(S06) Okamboro ■ Thornbush Savanna ..... page 222
(S08) Niko North ■ Nama Karoo ..... page 372
(S09) Niko South ■ Nama Karoo ..... page 384
(S10) Gellap Ost ■ Nama Karoo ..... page 396
(S11) Nabaos ■ Nama Karoo ..... page 428
(S12) Karios ■ Nama Karoo ..... page 452
(S16) Wlotzkasbaken ■ Namib Desert ..... page 478
(S17) Alpha ■ Thornbush Savanna ..... page 300
(S18) Koeroegap Vlakte ■ Succulent Karoo ..... page 550
(S20) Numees ■ Succulent Karoo ..... page 572
(S21) Groot Derm ■ Succulent Karoo ..... page 594
(S22) Soebatsfontein ■ Succulent Karoo ..... page 614
(S24) Paulshoek ■ Succulent Karoo ..... page 644
(S25) Remhoogte ■ Succulent Karoo ..... page 662
(S26) Goedehoop ■ Succulent Karoo ..... page 680
(S27) Ratelgat ■ Succulent Karoo ..... page 698
(S28) Moedverloren ■ Succulent Karoo ..... page 716
(S29) Rocherpan ■ Fynbos ..... page 736
(S31) Riverlands ■ Fynbos ..... page 748
(S32) Elandsberg ■ Fynbos ..... page 762
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(S39) Narais ■ Nama Karoo ..... page 320
(S40) Duruchaus ■ Nama Karoo ..... page 348
(S41) Sandveld ■ Thornbush Savanna ..... page 280
(S42) Ogongo ■ Woodland Savanna ..... page 140
(S43) Omano go Ndjamba ■ Woodland Savanna ..... page 152
(S45) Nieuwoudtville ■ Fynbos ..... page 790

Biodiversity is important for sustaining life on Earth yet it is threatened globally. The BIOTA Southern Africa project analysed the causes, trends, and processes of change in biodiversity in Namibia and western South Africa over nearly a full decade, from 2001 until 2010. This book, which is comprised of three volumes, offers a summary of the results from the many and diverse subprojects during this first period of long-term observation and related research, at both local and regional scales, and with a focus on sustainable land management options for the region.

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