The influence of thermo-chemical conversion on rangeland condition

13TH NAMIBIAN RANGELAND FORUM

The role of biodiversity in rangeland management & policy

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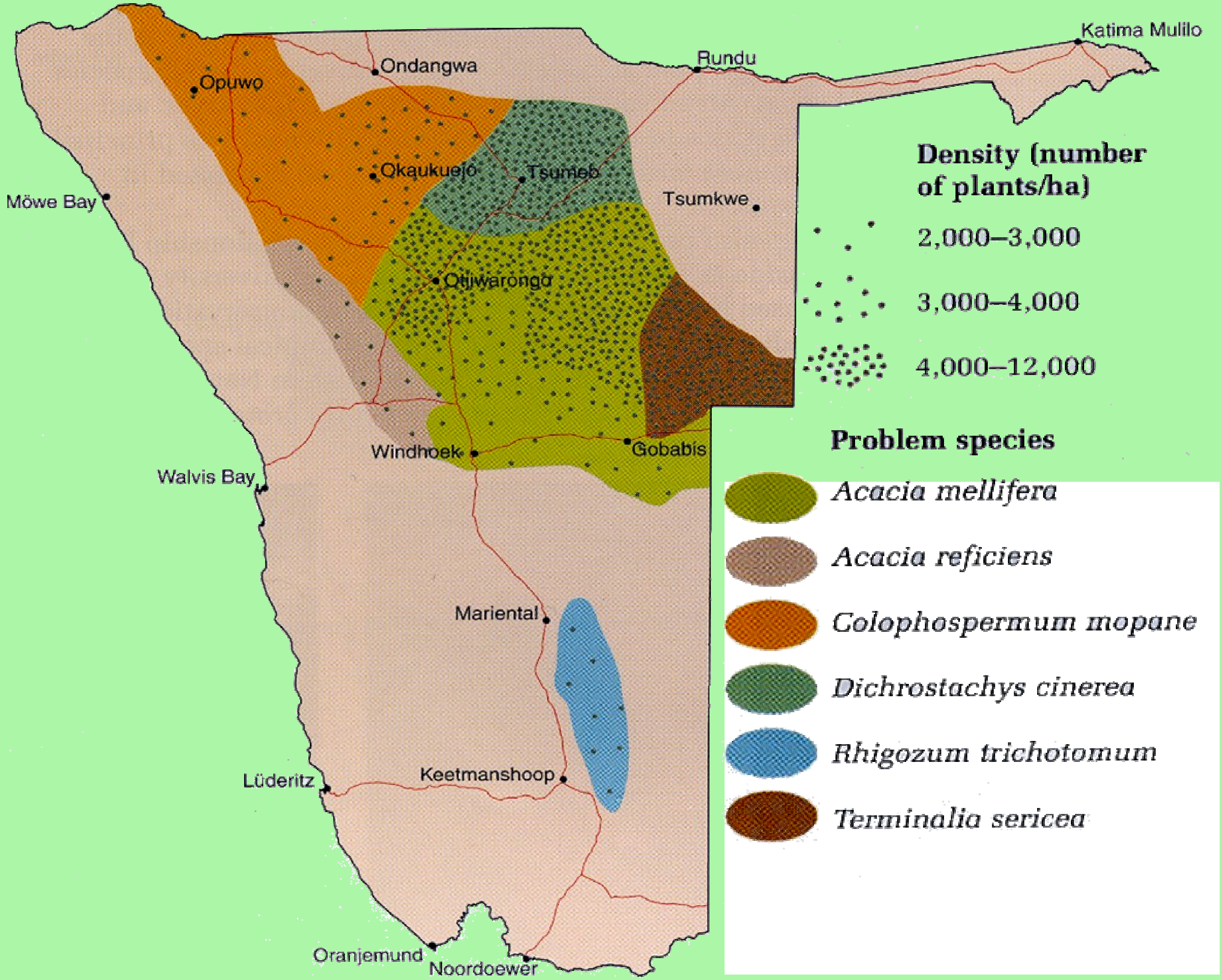
Contents

- Introduction
- Situation Analysis
- Results
  - Bush Clearing Analysis
  - Value Addition Analysis
  - Socio-ecological and Environmental Considerations
- Conclusions, Recommendations
- Discussions

Introduction

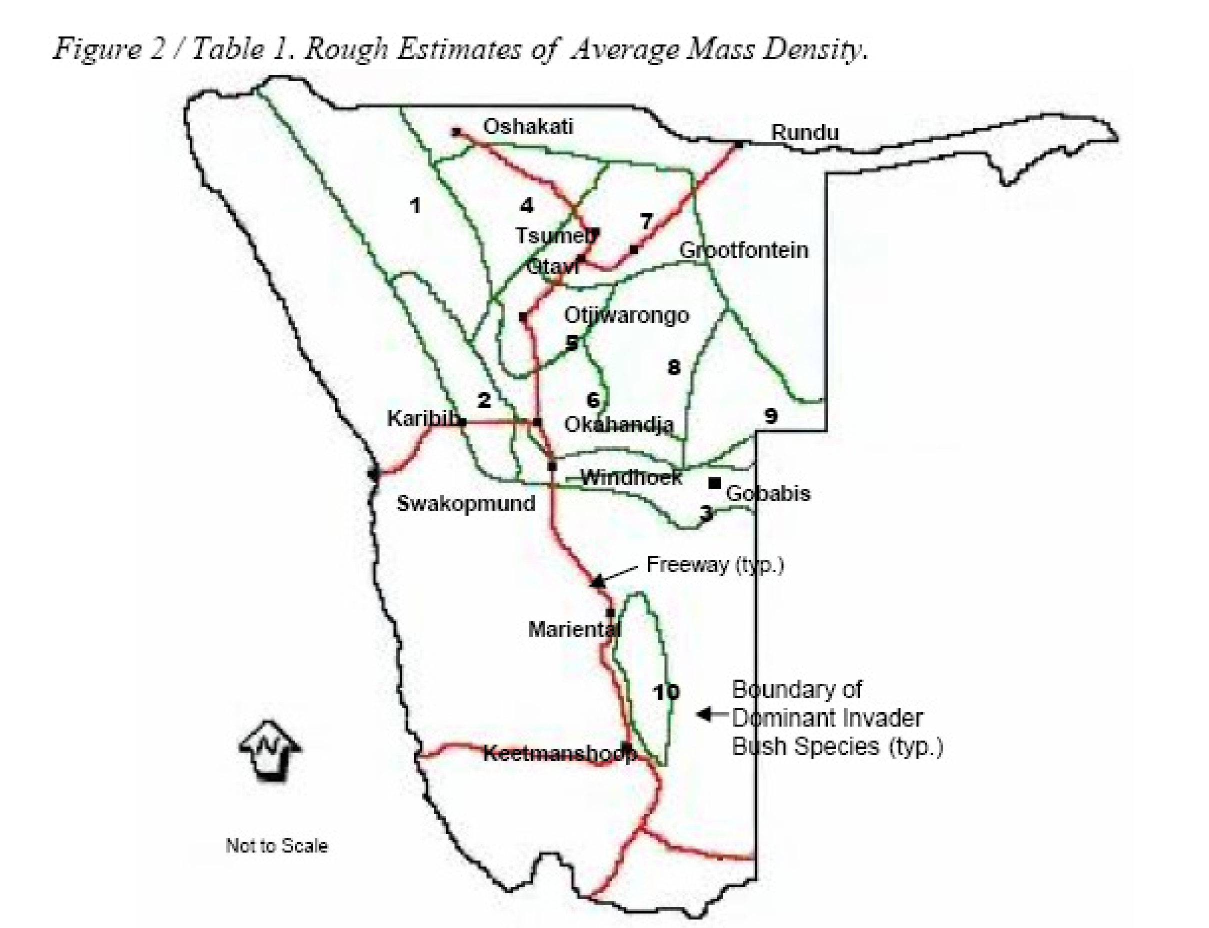
- 1990, at independence, some 15 mil. ha. covered with encroachment bush
- Today, said to be 25 - 26 mil. ha total area (various studies)
- Re-estimation in 2002: some 16 mil ha. in commercial and some 11 mil. ha in communal farming areas
- Estimated 10,000 – 18,000 kg / ha per annum of sustainably harvested woody biomass using the suggested harvesting method of MAWF
- Some 338 million tonnes of woody biomass (2007) with varying densities for specific areas encroached with certain species; seldom monocultures ….
- Species: various types of indigenous, inc. *Acacia spp.* and *Dichrostachys cinerea.*
- Commonly called 'encroachment bush'

Bush Encroached Areas



Source: Bush Encroachment in Namibia (JN de Klerk, 2004)

Bush Encroached Areas



Source: Bush Encroachment in Namibia (JN de Klerk, 2004)

Bush Encroached Areas

Category of thickened bush			Hectares	
No. on Map (Figure 1)	**Main bush species**	**Bush density (avg. no. per hectare)**	**Commercial Land affected**	**Communal Land affected**
1	*Colophospermum mopane*	2,500	1,451,000	2,986,000
2	*Acacia reficiens*	3,000	1,676,000	691,000
3	*Acacia mellifera* subsp. *detinens*	2,000	3,360,000	195,000
4	*Colophospermum mopane*	4,000	482,000	1,090,000
5	*Acacia mellifera* subsp. *Detinens*	8,000	2,067,000	13,000
6	*Acacia mellifera* subsp. *detinens*	4,000	2,692,000	210,000
7	*Dichrostachys cinerea*	10,000	2,513,000	1,220,000
8	*Acacia mellifera* subsp. *Detinens*	5,000	950,000	2,453,000
9	*Termalia sericea*	8,000	586,000	1,624,000
10	*Rhigozum trichotomum*	2,000	No mentionable commercial use	
TOTAL			**15,777,000**	**10,482,000**

Source: Zimmermann & Joubert, 2002

Bush Encroached Areas

- From “encroachment map” selected areas 5, 6, 7, 8 as the areas needing urgent attention
- Areas 5, 6, 7, 8 lie in Grootfontein, Okahandja and Otjiwarongo districts
- These areas cover in excess of 8 million hectares of commercial farmland, i.e. some 50 % of encroached areas
- Primarily, farmers in Grootfontein, Okahandja & Otjiwarongo districts engage in cattle production
- Small livestock, crop / horticulture, game farming, other large livestock and charcoal production are considered secondary

Microeconomic Aspects of Bush Clearing / Thinning
No clearance scenario - base case

NPV	N$
Grootfontein	9,714,965
Okahandja	10,677,382
Otjiwarongo	5,216,119

Namibian economic data for bush clearance CBA

Average size of farm	5000 ha
Area infested per average farm	80%
Area cleared per year	500 ha

Life of project	20 years
Loan Life	10 years
Interest rate	12%
Inflation rate	6%

Beef production as % of stocking rate	38%
Beef production cost as % of turnover	40%
Cattle price [N$/kg]	7.67

Encroachment bush clearance data CBA

Dichrostachys cinerea & Acacia mellifera spp. detinens

	Grootfontein	Okahandja	Otjiwarongo
Bush density TE/ha	>2000	>2000	<2000

Costs / ha treatment

Stem burning	450	450	400
Aerial arboricide	750	405	340
Manual arboricide	262.5	225	175
Manual cutting	675	675	450

Benefits / ha treatment

Grass production	10 fold	10 fold	double
Wood harvest (t/ha)	13	13	10
Stocking rate before [kg/ha]	21.4	23.52	11.49
Stocking rate after thinning [kg/ha]	42.8	47.04	22.98

CBA scenarios

Farm 5000 ha, 80% infestation, land cleared per year 500ha

- Stem burning for initial treatment and aftercare
- Aerial spraying with arboricides for initial treatment and hand application of arboricides for aftercare
- Hand application of arboricides for initial treatment and aftercare
- Manual cutting for initial treatment and aftercare
  - Bulldozing or large scale mechanical cutting has not been considered due to its relatively high adverse impact on the ecological system and relative poor treatment outcome
  - Fire scenario has not been considered as it is not suitable for dense infestation

CBA results

5000 ha farm, 80% infestation, 500 ha/year cleared

	Grootfontein	Okahandja	Otjiwarongo
TE/ha	>2000	>2000	<2000

NPV (N$)

	Grootfontein	Okahandja	Otjiwarongo
Stem burning	-12,337,202	-11,448,619	-10,444,199
Aerial arboricide	-14,900,407	-5,019,581	-5,732,723
Manual arboricide	-3,459,343	-795,188	-1,860,363
Manual cutting	-22,990,634	-22,102,050	-12,351,718

Breakeven bush selling price at NPV = 0

	Bush breakeven selling price (N$/t)
Grootfontein man. arboricide	13.5
Grootfontein stem burning	12.9
Grootfontein aer. arboricide	18.5
Grootfontein man. cutting	35.0
Okahandja man. arboricide	12.0
Okahandja stem burning	10.7
Okahandja aer. arboricide	17.1
Okahandja man. cutting	32.5
Otjiwarongo man. arboricide	7.5
Otjiwarongo stem burning	29.9
Otjiwarongo man. cutting	30.9

Bush Clearing / Harvesting without bush sales or income

Land cleared (ha/year)	500	400	300	200	100
Area	**NPV**	**N$**	**N$**	**N$**	**N$**
Grootfontein man. arboricide	-6,237,352	-5,758,927	-5,206,237	-3,742,917	-1,871,459
Grootfontein stem burning	-3,923,579	-3,714,809	-3,517,068	-2,646,726	-1,323,363
Grootfontein aer. arboricide	-8,584,236	-7,903,409	-7,041,597	-5,095,127	-2,547,564
Grootfontein man. cutting	-15,742,097	-14,365,343	-12,478,570	-8,968,537	-4,484,269
Okahandja man. arboricide	-5,579,814	-5,170,938	-4,736,464	-3,402,309	-1,701,154
Okahandja stem burning	-3,266,042	-3,126,820	-3,047,295	-2,306,118	-1,153,059
Okahandja aer. arboricide	-7,926,699	-7,315,420	-6,571,824	-4,754,519	-2,377,259
Okahandja man. cutting	-15,084,560	-13,777,353	-12,008,796	-8,627,929	-4,313,964
Otjiwarongo man. arboricide	-2,416,986	-2,239,022	-2,055,038	-1,478,653	-739,327
Otjiwarongo stem. burning	-6,997,255	-6,463,381	-5,713,037	-4,238,911	-2,119,455
Otjiwarongo man. cutting	-10,011,181	-9,115,929	-7,877,421	-5,681,834	-2,840,917

Conclusions on Bush Clearing/Harvesting

- All scenarios for the three areas show negative NPV, indicating that bush clearance of 500 ha/y is not feasible, and the no clearance / thinning scenario remains superior.
- The reduction of the area cleared per year from 500ha to 200ha improves the economics, but income from bush harvest makes bush clearing / thinning feasible.
- Inflation has limited effect on NPV.
- Harvesting the wood from bush clearing to generate income, e.g., utilising it for thermo-chemical conversion processes improves the overall economics of rangeland management.

Definitions for Thermo-Chemical Conversion Processes

- **Combustion:** total burning of feedstock in an 'oxygenated environment' at atmospheric pressure; usable product = heat recovery only; end product = ash
- **Gasification:** thermo conversion of a solid feedstock into gas at atmospheric pressure with limited oxygen flow; usable product = gas for heat or electricity production; end product = ash or char
- **Slow Pyrolysis:** an oxygenated (open) thermo-chemical conversion (kilns) process of a solid feedstock into char (& smoke) at atmospheric pressure; usable products = char or ash
- **Fast Pyrolysis:** a closed thermo-chemical conversion of a solid feedstock into mainly liquids at atmospheric pressure; usable products = bio-oil + gas for heat or electricity generation; char; bio-oil is a precursors to syngas, chemicals, commodity products, etc.

Wood available for thermo-chemical conversion

	Initial treatment	1st follow up	2nd follow up	3rd follow up
Wood production (t/ha)				
Grootfontein/Okahadja	13	6.5	3.25	1.62
Otjiwarongo	10	5	2.5	1.25

Traditional charcoal production data

Equipment	Cost	Life span
Kiln	1800 N$/t	1 year
Axe	75 N$/t	1 year
Panga	20 N$/t	1 year

- One kiln per 2 workers
- One axe and one panga per worker
- The equipment costs are covered from the profits of the charcoal production. No loan is considered.
- The number of workers is determined by the amount of charcoal produced.

Traditional charcoal production results

Grootfontein/Okahandja

	Charcoal production (t/y)	Workers per year
Year 1 to 4	975	50
Year 5 to 8	2925	150
Year 9 to 12	1950	100
Year 13 to 16	244	12
Year 17 to 20	122	6

NPV: N$12,784,627

Traditional charcoal production results

Otjiwarongo

	Charcoal production (t/y)	Workers per year
Year 1 to 6	750	50
Year 7 to 8	2250	150
Year 9 to 12	375	100
Year 13 to 14	1125	75
Year 15 to 20	188	12

NPV: N$ 6,504,989

Value Addition Options – Commercial Charcoal (1)

- NPVs for different loan/equity ratios for bush harvesting at a bush price 124 N$/t

Loan ratio (%)		**100%**	**75%**	**0%**
Equity ratio (%)		**0%**	**25%**	**100%**
Area	**NPV**	**N$**	**N$**	**N$**
Grootfontein man. cutting		41,734,336	41,538,670	40,951,669
Okahandja man. cutting		42,391,873	42,196,207	41,609,206
Otjiwarongo man. cutting		30,153,951	30,032,611	29,668,591

Value Addition Options – Commercial Charcoal (2)

- Bush requirements for commercial charcoal production

	Armco Robson Kiln	Nichols Herreshoff Carboniser	AGODA Continuous Retort
Capacity (t charcoal /y)	2,000	16,000	2,000
Bush (t/y)	14,000	64,000	8,000

- Average Charcoal Selling Price (N$/t)

Bush price	**Average charcoal selling price (N$/t)**					
(N$/t)	**100% loan**			**75% loan 25% equity**		
	Armco Robson	**Nichols Herreshoff**	**AGODA**	**Armco Robson**	**Nichols Herreshoff**	**AGODA**
124	2,992	1,143	2,026	2,941	1,160	2,021
248	4,375	1,934	2,816	4,284	1,928	2,789
372	5,758	2,724	3,607	5,628	2,695	3,557

Value Addition Options – Commercial Charcoal (3)

- NPVs for different commercial charcoal processes

Bush price (N$/t)	**Net present value (NPV) (N$)**					
	100% loan			**75% loan 25% equity**		
	Discount rate = 12%			Discount rate = 14%		
	Armco Robson	**Nichols Herreshoff**	**AGODA**	**Armco Robson**	**Nichols Herreshoff**	**AGODA**
124	21,874,452	66,880,513	14,813,429	17,723,377	58,516,550	12,457,062
248	31,989,521	113,120,827	20,593,468	25,678,596	94,883,266	17,002,901
372	42,104,589	159,361,140	26,373,507	33,633,816	131,249,981	21,548,740

Value Addition Options – Small Scale Gasification (1)

- Gasification plant capacity and bush requirements

Capacity (MWe)	**0.235**	**0.477**	**0.736**	**0.986**
Bush (kg/h)	200	400	600	800
Bush (t/year)	1,577	3,154	4,730	6,307

Value Addition Options – Small Scale Gasification (2)

- Average selling electricity price for 100% equity

Bush price (N$/t)	Average selling electricity price (N$/kWh) 100% equity			
	0.235 MWe	**0.477 MWe**	**0.736 MWe**	**0.986 MWe**
124	2.67	2.02	1.63	1.43
248	2.81	2.16	1.77	1.57
372	2.95	2.30	1.91	1.70

Value Addition Options - Fast Pyrolysis

	5 MW [E]	10 MW [E]
Plant output (bio-oil)	40 018 tpa	80 035 tpa
Feedstock (db)	68 996 tpa	137 992 tpa
Energy efficiency	27%*	27%*
products		
char	3 081 tpa	6 163 tpa
Bio-oil (organics)	58 wt%	58 wt%
producer gas	2 001 tpa	4 002 tpa
byproduct re-use	2 001 tpa	4 002 tpa
costs		
investment cost (€ / MW)	533 691	276 447
operating cost (€)	340 695	571 328
Bio-oil to be determined via costing	€ 0.11 / l [€0.009 / MJ]	€ 0.11 / l [€0.009 / MJ]
Revenue (€)		
char	160 430	320 860
producer gas [E]	186 289	372 578
heat recovery [H]	149 031	298 062

Fast Pyrolysis from Namibian Wood Biomass

Biomass Physical properties			**Pyrolysis conditions**	
Water content (wt.%)		7-10	Temperature (°C)	500
Elemental analysis	C	47.0	Gas residence time (s)	0.5
(as received)	H	5.7	Biomass size (μm)	300 - 500
	N	0.76		
	Ash	3.9	Liquids water content (wt.%)*	25.3
	O	42.6	***Yields (wt.%)*** #	
HHV (MJ/kg)		16-19	Organic liquid	58.3
			Water	19.7
			Char	7.7
			Gas	10.8

* Phase separated liquids   # Typical values from encroachment wood, dry feed basis only

Chemical Analysis of Namibian Wood Biomass
(whole tree utilisation; various species)

Elemental analysis (wt%) - XRF			**Gas Composition – pyrolyser gas**	
Aluminium	Al	0.03	Methane	CH_4
Phosphorus	P	0.05	Ethane	C_2H_6
Silica	Si	0.11	Ethylene	C_2H_4
Magnesium	Mg	0.10	Acetylene	C_2H_2
Sulphur	S	0.08	Carbon Monoxide	CO
Chlorine	Cl	0.07	Carbon Dioxide	CO_2
Potassium	K	0.36	Hydrogen	H_2
Calcium	Ca	1.70	Nitrogen	N_2
Iron	Fe	0.02		
Titanium	Ti	0.006		
Strontium	Sr	0.008		

Source: VTT Nambio Report and own testing

Uses for pyrolysis products

- **Commodities:** flavouring agents – liquid smoke™, char for household use
- **Industrial use of char:** fuel, chemical, sequestration agent like biochar, conditioners
- **High Value Chemicals:** preservatives, fertilisers, pharmaceutical products, bonding agents, bio-lime™
- **Fuels:** syngas, green diesel
- **Electricity generation**
- **Heat production**
- **By-Products**

Namibia's Opportunity!

Introduction of the Biorefinery concept

- Integrated production of higher value chemicals and commodities, as well as fuels and energy
- Optimise use of resources, maximise profitability, maximise benefits, minimise wastes

Socio-ecological considerations - harvesting

MANUAL CUTTING

Photo: Dave Joubert

Manual Cutting	Economic	Social	Ecological
+	• basis for charcoal production or other utilisation • can be utilised more than once from same area after 15-20 years.	• Large opportunities for employment, clearing and charcoal production.	• Resprout can be consumed by browsers.
-	• Increase in grass production not as much as with other methods • If regrowth is wanted, application of an arboricide is needed.	• Many social problems. • Large numbers of contracted workers (fires, poaching, etc.) • Uncertainties with Labour Act	• Rapid regrowth results in a worse bush encroachment situation. • If wood removed, nutrients are lost from the system.
MITIGATION/ RECOMMEND	• Regrowth can be pruned. • Goats can contribute to revenue.		• Cutting in autumn? (De Klerk, 2004). • Chop beneath surface (De Klerk, 2004). • Ash (nutrients) should be returned. • Use goats to consume resprouts.

Socio-ecological considerations – thermo-chemical conversion options (1)

- **Combustion** – large-scale open system; low on-site energy efficiency, but all types of solidified feedstocks can be used; by-product usage possible.
- **Gasification** – small to large-scale closed system; good on-site energy efficiency; feedstock to be prepared to process specifications (size & moisture content sensitive); by-products usage possible.

Socio-ecological considerations – thermo-chemical conversion options (2)

- **Slow pyrolysis** – small to large-scale open & closed system; good on & off-site energy efficiency; feedstock to be prepared to process specifications (mainly size); various products and by-products.
- **Fast pyrolysis** – medium to larger scale closed system; process is CO2 neutral; high degree of on & off-site energy efficiency; feedstock to be prepared to process specifications; various products and by-products.

Conclusions

- Rangeland conditions are in particular dependent on soil composition, climatic conditions, topography, average air & soil moisture content, temperature.
- These factors are relatively well researched in Namibian context.
- Available amount of harvested bush and the transport of such process raw material limits process capacity.
- The amount of encroachment bush available in Namibia can sustainably used for the next decades.
- Other aspects of thermo-chemical processes have been studied in Namibian context, but not part of these deliberations.

Conclusions

- Harvesting process of bush marginally influences feedstock quality.
- Solid & liquid thermo-chemical conversion products provide basis for potentially useful soil ameliorants & amendments (most research done abroad)
- Liquid thermo-chemical conversion products deliver fertilisers and arboricides, depending on dosage
- Thermo-chemical conversion processes deliver products, in general, of high socio-economic value, which can improve rangeland condition.

Thank you