Encroacher Bush to Animal Feed

Viability of Bush Based Feed Production in Namibia

GIZ - Support to De-bushing Project

UNDP - Sustainable Management of Namibia's Forested Lands

Ministry of Agriculture, Water and Forestry (MAWF)

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The Bush Feed Pilot Project 2016-2017

This report forms part of a series of publications on bush based feed production in Namibia:

The potential for bush based fodder in Namibia - A literature review (2016)
Survey on Animal Feed Production from Encroacher Bush in Namibia (2018)
Encroacher Bush to Animal Feed - Viability of Bush Based Feed Production in Namibia (2018)
Encroacher Bush to Animal Feed - Community Based Projects (2017)
Manual: Animal Feed from Namibian Encroacher Bush (2018)

The report is based on a research project that ran from April 2016 to July 2017

Executive Summary

As part of the national programme for bush control, the Ministry of Agriculture, Water and Forestry (MAWF) implemented the Support to De-bushing Project in collaboration with Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ). With the aim to provide affordable solutions to combating bush encroachment for farmers in communal and commercial areas, the project developed value chain opportunities. If bush material is not only removed, but also used for value added products, this can finance the bush harvesting. One of the identified value chain opportunities is bush based animal feed production, which holds great potential for the agricultural sector.

Bush based animal feed production is not an entirely concept, such feed is commercially available in South Africa and small number of Namibian farmers have experimented with own feed mixtures, in most cases in order to economically survive prolonged periods of droughts.

Nevertheless, knowledge about the production process and the feed's suitability for various types of animals is poorly documented and doubts about the overall viability of the concept are common among rangeland experts.

It is against this background that a comprehensive bush based animal feed pilot project was implemented. The research project showed that bush based animal feed production is a viable and promising concept, both in terms of animal health and economic viability.

Trials were implemented in in parallel on a commercial farm and a government research station. All trials involved domesticated ruminating livestock, i.e. sheep and cattle. Goats and game are naturally browsing animals, and were thus not tested. A further pilot project was implemented with a group of communal farmers of the Africa Wilddog Conservancy at Okondjatu. The process of these trials had a specific focus on testing the viability of the approach for non-commercial, communal farming groups. The results of these trials are described in a separate report.

The **first phase of the pilot project** was conducted on the commercial farm Langbeen, in the Dordabis District, Khomas Region. The test animals were thirty-six (36) growing sheep and testing was conducted in the time period of July to September 2016. Six different diets were tested, of which one was a control diet (a mixture of grass and Lucerne hay) and five were bush biomass-based diets. All diets containing bush as a main source of fibre, highlighted the potential of such biomass to be included in sheep fodder. The results of the trial indicated that the group fed a bush based fibre mixture with milled camelthorn pods and/or Opuntia chips had the best growth rates. To overcome the generally low organic matter digestibility of the feed mixture, the inclusion of Polyethylene Glycol (PEG) was tested. The effectiveness of PEG remains inconclusive and further research is required.

During the **second project phase**, semi-intensive and intensive feeding trials were conducted with forty (40) crossbred Limousin-Bonsmara weaner cattle at Farm Langbeen and fifty (50) Sanga (Nguni) weaners at Omatjenne Research Station, respectively. The bush biomass used in these trials was pre-treated with sodium hydroxide (NaOH) to test its effectiveness on improving the digestibility of fibre. In addition, the efficacy of bush biomass-based diets to support competitive growth rates of weaners in feedlots compared to conventional diets was evaluated. The results show that pre-treatment with a level of 2.5% NaOH improves digestibility and metabolisable energy. Such pre-treatment is however potentially dangerous if wrong amounts are applied and should only be applied with great care and adequate knowledge. Further, the cattle feed mixtures were successfully pelleted as a measure to increase its storability.

For farmers, it is most practical to either add natural **ingredients**, like Opuntia and Camelthorn Pod meal, or commercial supplements, like Rangeland Grower™ or Bush Improver Lick™ to the bush feed. Molasses should be used in all cases for improved palatability and ease the mixing of the feed components. Where animals need to be fed in periods of drought, the **bush based fibre inclusion**

rate can be as high as 85%. This would then be accounted for as emergency feed. Where bush based feed is to be used as maintenance or growth feed, the amount of bush based fibres should be reduced to some **50%**. The latter however drives the costs for the feed, as more supplements need to be added.

The **techno-economic and social benefits** derived from these trials are equally promising. Even though a very low quantity of sheep fodder was prepared on a daily basis, the feed costs ranged between NAD 1.99 and NAD 4.04 per kilogramme. With more fodder prepared, the prices have the potential to stabilise between **NAD 0.67 to NAD 2.10 per kilogramme** of feed.

With regard to the cattle fodder, the size of the pellets was observed to have an influence on the cost as well as quality in terms of its integrity and fibre length. While in general 10 mm pellets were made, this posed a particular challenge to pelleting feeds which contain hay or grass. The pellet size for the latter had to be reduced in an effort to achieve pelleting. However, reducing the pellet size introduced further challenges, i.e. bloating in animals. As a countermeasure these animals were additionally fed with hay. The costs of these pellets span from **NAD 4.56 to NAD 11.90 per kilogramme** of feed. Costs for pellets where bush based fibre was pre-treated with NaOH, resulted in costs between NAD 4.57/kg (for 2.5% inclusion rate) and NAD 4.61/kg (for 10% inclusion rate). The high costs for the hay-based feed is due to high cost of the hay itself during the drought period experienced at the on-set of the trials, in December 2016. Overall, bush based animals feed pellets compare well to commercially available feed pellets.

The results of the bush based animal feeding trials were promising and suggested that bush feed can be used not only as an emergency drought feed, but also as a supplementary feed throughout the year and in feedlots. However, the feasibility of bush based feed will depend on the inclusion rate of bush biomass, the type and quantity of supplement used, as these factors influence the cost/benefit ratio of feed production.

The direct effect of the bush harvesting for animal feed production, such as an expected recovery of the grass layer, was not analysed. However, at farm Langbeen bush has been utilised for animal feed production since 2012 and a total positive rangeland condition improvement is noticeable in the areas where bush was thinned. According to the farmer's assessment, the rangeland carrying capacity in the relevant farm area improved by 75% in just five years.

Bush based fodder production has transformational potential for agriculture in Namibia, as it leads to improved fodder availability in the short run and improved grazing in the long run. This potential can be unlocked if knowledge about the production process and the feed's impact on animal health and growth is systematically analysed and taken up in ongoing agricultural capacity development and financing programmes.

This report is meant to provide a first solid basis for further research, but also for an immediate roll-out of bush based feed production in the country.

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List of Acronyms

Acronym	Long-Form
ADF	Acid Detergent Fibre
ADG	Average Daily Gain
AgriLASA	Agri Laboratory Association of Southern Africa
AOAC®	Association of Official Analytical Chemists International
BCS	Body Condition Score
Ca	Calcium
CP	Crude Protein
DM	Dry matter
EE	Ether Extract
FCR	Feed Conversion Ratio
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH
MAWF	Ministry of Agriculture, Water and Forestry
ME	Metabolisable Energy
N	Nitrogen
NAD	Namibia Dollar
NaOH	Sodium Hydroxide
NDF	Neutral Detergent Fibre
NPN	Non-Protein Nitrogen
NPV	Net Present Value
OMD	Organic Matter Digestibility
ORS	Omatjenne Research Station
P	Phosphorus
PEG	Polyethylene Glycol
P-value	Denotes the level of statistical significance (not to be confused with "P" above), or confidence interval (e.g., P-value of 5% means that a specific test result should fall within a 95% level of confidence range; all test results should be applicable in 95% of the cases)
SDG	Sustainable Development Goals
TWG	Total Weight Gain
s.e.	Statistical Error
UNDP	United Nations Development Programme

1 Background and Introduction

Livestock contribute at least 75% to total agricultural output in Namibia, with beef production being the most important activity (Sweat and Burke, 2000). Since extensive farming is predominant, the number of cattle in the country depends highly on the annual rainfall. Namibia is considered as having the driest climate in sub-Saharan Africa, with recurrent droughts posing a severe economic threat to producers (Sweat and Burke, 2000). Bush encroachment poses a further challenge for cattle producers, as Namibia is affected by bush encroachment on a massive scale. This currently affects some 26 to 30 million hectares of farmland, amounting to roughly 30 per cent of Namibia's land area. More recent assessments put Namibia's bush encroachment at some 45 million hectares of agricultural land being affected. Bush encroachment has lowered the livestock carrying capacity of rangeland by up to two thirds. This further causes economic losses every year to the livestock industry and agricultural sector in general.

As part of the national programme for bush control, the Ministry of Agriculture, Water and Forestry (MAWF) in collaboration with the German Federal Ministry for Economic Cooperation and Development (BMZ) through the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH implemented the Support to De-Bushing Project. This joint project was aimed to strengthen the restoration of productive rangeland in Namibia by identifying value chain opportunities to trigger large-scale bush extraction activities. One of the identified value chain opportunities is bush based Animal Feed production, which holds huge potential for the agricultural sector. It is against this background that an animal feed pilot project, including different production sites was set up. The main aim was to proof the concept scientifically and develop a showcase for others to learn from.

The animal feed pilot was carried out in the period from April 2016 until July 2017. The pilot built on existing farmers' knowledge and assessed the evidence that bush based fodder is nutritionally valuable and economically viable.

The field research was conducted at different pilot sites and the entire value chain from bush harvesting to the feeding of the bush based fodder was tested. The research focused on three main avenues to obtain research based evidence. The first was to assess the animals' production performance when fed on different bush based rations and mixtures, which also made use of locally sourced supplements. The second line of research was to assess the nutritional quality of the common encroaching bush species found at pilot sites and how their nutritional quality was affected by season and storage. In addition, the nutritional value of prepared mixtures used for trials were also analysed. The last line of research focused on the economic viability of bush based animal feed production, as a means of income generation.

The research was based on a protocol agreed upon by all involved stakeholders. Four pilot trials were carried out, seeking to investigate the effectiveness of bush based ration on ruminants under differing productive systems (intensive versus semi-intensive).

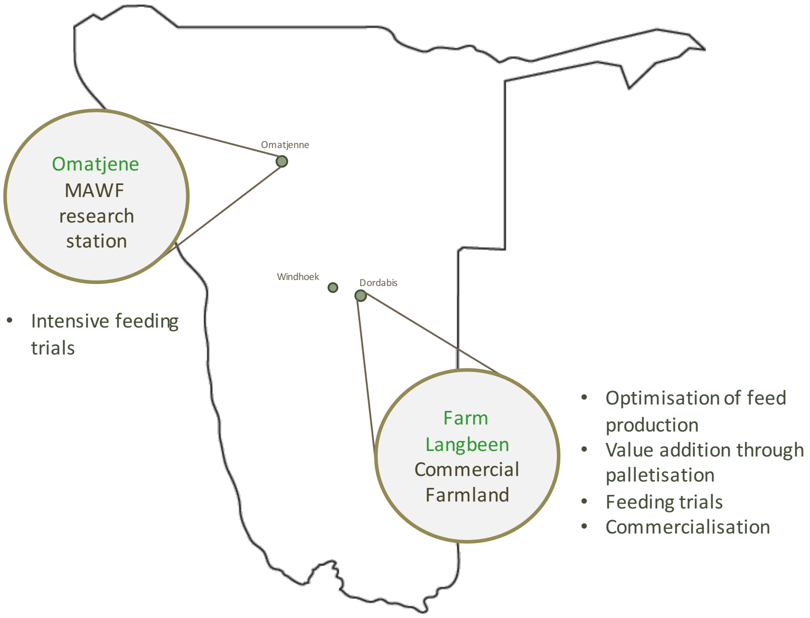


Figure 1: *Map of Namibia, indicating the location of Farm Langbeen, close to Dordabis in the Khomas Region where the animal feed was produced. The map further indicates the location of Omatjenne Research Station in the Otjozondjupa Region (Laufs, 2017)*

On Farm Langbeen, situated in Khomas Region near Dordabis, two trials were conducted, (i) intensive sheep feeding and (ii) semi-intensive cattle weaner feeding. Sheep trials were the first, in a series of four, that were carried out and were conducted in the period July 2016 to September 2016.

At Omatjenne Research Station intensive feeding trials were conducted. The feed pellets used in these trials were produced and supplied by Farm Langbeen. The feed used on both sites was therefore the same.

A third pilot site was at Okondjatu in Otjozondjupa Region, where community-run animal feed production was piloted. The results of these trials are summarised in a separate report and therefore not reflected in this document.

The report is structured according to the flow of the trials, with the particular research question sought to be answered by the pilot being posed at first; followed by a literature review, the socio-economic setting of the pilot site, the details of the research that was carried out, its results obtained and a discussion thereof. The research carried out included feeding trials on animals, as well as techno-economic analysis of the particular feed production system used for the intensive sheep-feeding trials. The report is closed by conclusions, recommendations and lessons learnt.

2 The aim and objectives of the trials

The overall aim of the trials was to scientifically validate that bush based animal feed is a viable option for both sheep and cattle feeding, while taking various aspects into consideration, namely animal health, impact of bush control and utilisation on rangeland improvement, as well as the economics.

For the **sheep** feeding trials, the following objectives applied:

- Evaluate the growth performance of growing lambs fed with different bush based diets, under intensive feeding conditions.

- Compare the effectiveness of different commercially available supplements in improving the nutritional value of bush based diets
- Assess the effects of the use of locally sourced supplements as an alternative for commercial supplements to ameliorate the nutritional value of bush based diets
- Test the effect of Polyethylene Glycol (PEG) on improving the digestibility of bush based diets.

For the growing **cattle** feeding trials, the following objectives applied:

- Assess the effectiveness of two levels of NaOH (2.5 and 10 %) on improving digestibility of the bush based diets
- Evaluate the nutritional value of bush based diets
- Compare the growth rate of animals fed with bush based diets to those fed with conventional diets

For the semi-intensive feeding trial with cattle, the objective was to:

- Evaluate the growth performance of growing female and male cattle fed different bush based diets, as feed supplement in addition to grazing;

For the intensive feeding trial, the objectives were to:

- Evaluate the growth performance of growing female and male cattle (weaners) fed different bush based diets under feedlot conditions
- Compare the feed intake of animals fed bush based diets to those fed a conventional feedlot diet
- Compare the feed conversion ratio (FCR) of animals fed the bush based diets to those fed the conventional diets
- Compare the growth rate of the animals in the intensive system to those on the natural veld
- Establish whether indigenous cattle breeds can effectively be fed under feedlot conditions
- Macroscopic assessment of the health of the rumen (and liver organs), post intensive feeding with diets containing NaOH.
- Test pelleting of bush based feed, for three reasons:
  - Overcome constrains of fresh bush supply due to seasonality of growing bush;
  - Improve storability of bush based diets; and
  - Establish the techno-economic feasibility and viability of a bush based feed pellet production system.
- Establish the parameters required to commercialise a bush based feed productions system, to eventually sell bush based feeds at a large scale.

2.1 Research limitations

The following aspects were not covered by the research and are thus recommended for investigation during future research projects:

The trials were not able to test or prove the following:

- Production patterns of sheep and cattle according to intra- and inter-sheep species variability;
- Effect/impact of excretes on the environment based of certain supplements used in the trials; nor on the metabolic effect the various supplements would or could have on the meat of the sheep;

- The effect of various NaOH pre-treatment concentrations and durations on the wood fibres (nutritional analysis);
- The effect of pelleting to improve e.g. digestibility of bush based animal feeds;
- Tests for cellulose, hemicellulose and lignin and/or tannin composition of the wood based fibres used in the trials;
- Resources were limited to testing *Acacia mellifera* (*Senegalia mellifera)* spp. *detines* only; no other biomass species were tested;
- Health and safety testing of certain supplements used;
- Long-term effectiveness of bush extraction methods; and
- Short and long-term rangeland condition change due to bush extraction.

3 Literature Review

The aim of this literature review is to highlight aspects pertaining to feeding growing sheep and cattle with lignocellulosic biomass. In the Namibian context, the source of lignocellulosic biomass would be mainly encroacher bush.

Lignocellulosic biomass consists of plant cell walls composed of lignin, cellulose and hemicellulose. Bush based feed as well as many crop residues and wood industry waste belongs to this group (Chaturvedi and Verma, 2013). Naturally, ruminating domesticated livestock does not eat such material, unless the animals have an affinity to browse trees, bush or shrubs during the early growth season of such plants. And if these animals browse, they would choose to eat the fresh sprouts only.

A comprehensive literature review on bush based animal feed was carried out as part of the overall pilot project by N. Pasiecznik and completed in September 2016. The report is separately available from the MAWF/GIZ Support to De-bushing Project. This section highlights parts specifically pertaining to feeding sheep and cattle with bush based animal feed and experience of such internationally.

3.1 Sheep feeding

Ensiling of woody forage was assessed in Brazil, using six common forage species*: Prosopis juliflora*, *Mimosa tenuiflora*, *M. caesalpiniifolia*, *Gliricidia sepium*, *Leucaena leucocephala* and *Caesalpinia ferrea* (Silva et al. 2015). Chemical composition of the woody forage silages indicted good nutritional quality and it was concluded that they could be used as animal feed. El-Nasr et al. (1996) found that silaged leaves of *Acacia saligna* and *Atriplex nummularia* contained higher levels of crude protein, ether extract and N-free extract and lower levels of crude fibre and ash than air-dried material, and maximum daily voluntary dry matter intake was seen in sheep fed on ensiled foliage of both species, and the digestibility of dry mater, crude protein, ether extract, N-free extract and neutral detergent fibre nutrients was higher with ensiled shrubs than fresh or air-dried forms.

The following literature describes the use of bush based fibre in feeding sheep:

- Barry TN, Manley TR, Duncan SJ, 1984. The role of condensed tannins in the nutritional value of *Lotus pedunculatus* for sheep. 4. Site of carbohydrate and protein digestion as influenced by dietary reactive tannin concentrations. Br. J. Nutr., 55:123-137.
- El Nasr AHM, Kandil HM, El Kerdawy AD, Khamis HS, El-Shaer HM, 1996. Processing of saltbush and acacia shrubs as sheep fodder under the arid conditions of Egypt. Alexandria Journal of Agricultural Research, 41(2):25-34.
- El Nasr AHM, Kandil HM, El Kerdawy AD, Khamis HS, El-Shaer HM, 1996. Value of processed saltbush and acacia shrubs as sheep fodder under the arid conditions of Egypt. Small Ruminant Research, 24:15-20.

- Jensen TL, Frederick D, Villalba JJ, 2013. Influence of diet sequence on intake of foods containing ergotamine d tartrate, tannins and saponins by sheep. Applied Animal Behavior Science, 144(1/2):57-62.
- Moujahed N, Ben Salem H, Kayouli C, 2005. Effects of frequency of polyethylene glycol and protein supplementation on intake and digestion of *Acacia cyanophylla* Lindl. foliage fed to sheep and goats. Small Ruminant Research, 56(1-3):65-73.
- Pritchard DA, Martin PR, O'Rourke PK, 1992. The role of condensed tannins in the nutritive value of mulga (*Acacia aneura*) for sheep. Aust. J. Agric. Res. 43:1739–1746.
- Reed JD, Soller H, Woodward A, 1990. Fodder tree and straw diets for sheep: intake, growth, digestibility and the effects of phenolics on nitrogen utilisation. Animal Feed Science and Technology, 30: 39-50.
- Salem HB, Nefzaoui A, 1993. Effect of increasing level of *Acacia cyanophylla* Lindl. on intake, digestibility and ruminal digestion on sheep fed straw-based diets. In: Nikolaidis A, Papanastasis V (eds.), Management of Mediterranean Shrublands and Related Forage Resources. FAO, Rome, Italy, pp. 118-121.
- Salem HB, Nefzaoui A, Salem LB, Tisserand JL, 1997. Effect of *Acacia cyanophylla* Lindl. foliage supply on intake and digestion by sheep fed lucerne hay-based diets. Animal Feed Science Technology, 68:101-113.

3.2 Cattle feeding

This section on the one hand highlights the parts from the literature review specifically pertaining to feeding cattle with bush based animal feed and on the other shares experiences of such from elsewhere. The focus is furthermore on the use of NaOH (better known in Namibia as "Rumen Soda") in a feed for cattle, with reference to the levels of inclusion for improving digestibility of the bush based fibres, and its effects on animal health.

Much research has been done on different techniques to increase the digestibility of lignocellulosic biomass (wood waste and straws) due to the fact that these do not compete with human food security (Arisoy 1997; Sarnklong et al., 2010; Kuijk et al. 2015). Despite the fact that bush based feed is a novel area of research, the strategies used to improve lignocellulosic biomass utilisation could also be applied to bush based feeds.

There are different types of treatments that can be used to improve the digestibility of lignocellulosic materials: physical treatments (soaking, pelleting, chipping, milling, and more), chemical treatments (NaOH, KOH, Urea/Ammonia, ash, and thermal treatment to change the chemical composition of the wood), or physico-chemical treatments (combining the afore-mentioned treatments) and biological treatments (enzymes, white rot fungi, mushrooms, or more) (Sarklong et al.; 2010; Kuijk et al.; 2015).

Chemical treatment of lignocellulosic biomass is widely applied in paper manufacturing, i.e. to separate the cellulosic fibres from the lignin (the fibre bonding element). In animal feeding programmes, the use of NaOH is extensive for being the most feasible under small-medium scale farming conditions and for having the greatest effect in increasing the degradability and palatability of lignocellulosic materials. The use of NaOH is applicable despite the fact that it exacerbates the already low nitrogen content of these materials (Moss et al. 1990; Chaudhry and Miller, 1996; Arisoy, 1997; Vadiveloo, 2000). This is why it is advisable to combine it with urea/ammonia treatment.

NaOH has been traditionally used due to its effect to improve fibre digestibility at it is able to lower cellulose crystallinity which results in higher sugar yields (Agbor et al., 2011; Hendriks and Zeeman, 2009; Sarkar et al., 2012) and brakes the ester bonds between lignin, hemicellulose and cellulose which makes the structural fibre swollen (Chenost and Kayuli, 1997; Lam et al. 2001). Besides, it is not only the most effective treatment against strong fibrous bonds in the woody matter, but also increases palatability of such fibres once bonds were broken, and it is the most economically viable option for small-medium farm operations (Moss et al. 1990; Chaudhry and Miller, 1996; Arisoy, 1997; Vadiveloo, 2000).

Trials in Namibia were conducted at the 1989 by MAWF at the Neudamm Research Farm (Kubirske, 1989). It was concluded that NaOH dissolved in water and sprayed or mixed with the biomass dry matter, and left to soak into the biomass for at least between two to four days, improves the digestibility of bush based feed. At the time, trials were done with a NaOH inclusion rate of 3% and 6% on a dry weight basis. The results obtained in 1989 are further discussed section “Results”.

In the Namibian experience for NaOH-use, one of the respondents of the “Survey on Animal Feed Production from Encroacher Bush in Namibia (2016)” reported to have used NaOH with remarkable results. The laboratory analyses revealed that the use of NaOH had positive effects on the NDF, ADF and OMD (MAWF, 2016 (unpublished data)). In these trials, spraying was chosen for its relatively limited amount of water usage and ease of application in a Namibian farming set-up.

4 Socio-economic setting

4.1 National indicators of livestock farming

Analysing the National Accounts of Namibia, livestock farming is considered to be a primary industry. The National Accounts do not make a difference between livestock production in freehold or non-freehold land. However, analysing the National Accounts for the period 1980 to 2016, it is evident that livestock production output has declined in real terms (i.e. irrespective of inflation) (Figure 2). There are many reasons cited for this decline (Honsbein, 2016), but a major factor remains bush encroachment (see Section on Environmental Aspects hereafter).

The current level of bush encroachment in Namibia is already causing substantial agricultural productivity losses, through the compounding effects of land degradation. As it stands, this loss in productivity is estimated to be costing the local economy approximately two billion Namibian Dollars (NAD), or EUR 138 million per year (SAEIA, 2016). In comparison, the preliminary national accounts for 2016 put Namibia’s gross domestic product (GDP) at NAD 159 billion (or EUR 11 billion), equating these losses to 1.25% of total GDP (Namibia Statistics Agency, 2016). Furthermore, these losses will undoubtedly continue to increase, in line with the spread and worsening of the bush encroachment problem.

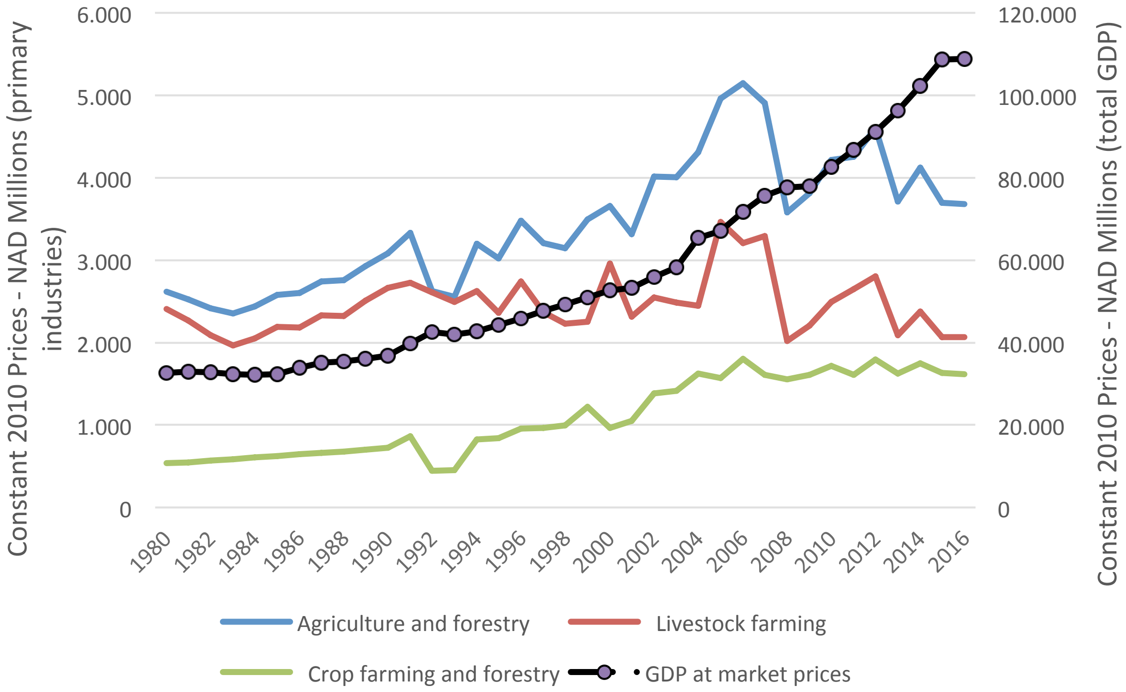


Figure 2: *Contribution of livestock production to primary industries, and total GDP, 1980 to 2016 (NSA, 2017).*

Contribution of labour in the agriculture sector is very important. The Labour Force Survey of 2016, however, does not make a distinction between freehold and non-freehold areas. At 20.1% of the total workforce, the survey notes agriculture, forestry and fisheries as the most important employer in the country. Nevertheless, this represents a decline from 29.2% which was still noted in 2014. Average wages paid in these sectors are by far under par of sector like manufacturing or mining and quarrying; but on par with accommodation & food service activities; and better than private household activities. Minimum wages are set annually for persons employed in freehold land activities, negotiated between the bargaining unit representing such workers and the Agriculture Employers Association of the Namibia Agricultural Union (AEA, 2017). These minimum wages are valid from each 1st March, and for the period 2017/18 were set at NAD 3.87 per hour, excluding benefits like rations, water, electricity and housing.

4.2 The commercial farming context in Khomas Region

The animal feed production took place at Farm Langbeen, near Dordabis in Khomas Region. Khomas region is located in the central area of Namibia, and accounts for only 4.5% of the total land area of Namibia, but for over 15% of Namibia's population. The land area of the Khomas District spans 3.7 million hectares, excluding urbanised areas like Windhoek, Hosea Kutako International Airport and villages like Dordabis. This area however, still includes land, demarcated for agricultural purposes as per delimitation report of 2013 (Government Gazette, 2013). Namibia's administrative, legislative and judicial capital Windhoek is situated in the region. Most of the land is under freehold ownership, and for administrative purposes allocated to the City of Windhoek. Cattle and wildlife farming is prominent in the Khomas region; small stock (goats and sheep) are mostly reared for on-farm consumption only. Tourism, practiced on farmland has become a very important contributor to economic output in the region, and consequently many people seek jobs here too.

Farm Langbeen is situated in the Khomas region, and cattle rearing and wildlife/ tourism activities are the main sources of income. A piggery and sheep farming is practiced for recreational purposes and on-farm consumption. The farm infrastructure is well developed, with access to water being freely available at all animal water points. The farm is not connected to the electricity grid, and power is generated by either a Diesel-driven generator, or solar panels. A total of 16 people are employed on the farm; the owner, Mr Dresselhaus manages the farm himself, and is assisted by a farm manager and his wife who stay on the farm.

With the joint experience of the owner, the manager and the workers, commercialisation of bush to animal feed production is possible. The farm infrastructure and competencies available there were supportive of the pilot project.

5 Environmental aspects

5.1 The national bush encroachment challenge

Bush encroachment in Namibia is defined as the densification and rapid spread of native bush and shrub species, resulting in an imbalance of biodiversity. Infestation of an area should have persisted for at least 20 consecutive years. Additionally, invasion of exotic tree or shrub species such as *Prosopis* species also pose a threat.

This bush encroachment phenomenon is said to be caused by a number of interlinked and potentially compounding factors: including overgrazing caused by historically high stocking rates; preference of grazing livestock (cattle and sheep) over browsers (game and goats); increased atmospheric CO_2 levels (Ward, 2005; Easmus and Palmer, 2007), which seem to favour growth of bush over grasses; suppression of regular high-intensity fires (Joubert and Zimmermann, 2002); prolonged drought periods followed by high rainfall years; fewer periods of frost (Honsbein, 2016); and perhaps other factors that have not yet been fully understood. However, if bush encroachment in Namibia is not actively controlled, it will soon become an insurmountable economic, social and environmental problem (Figure 3).

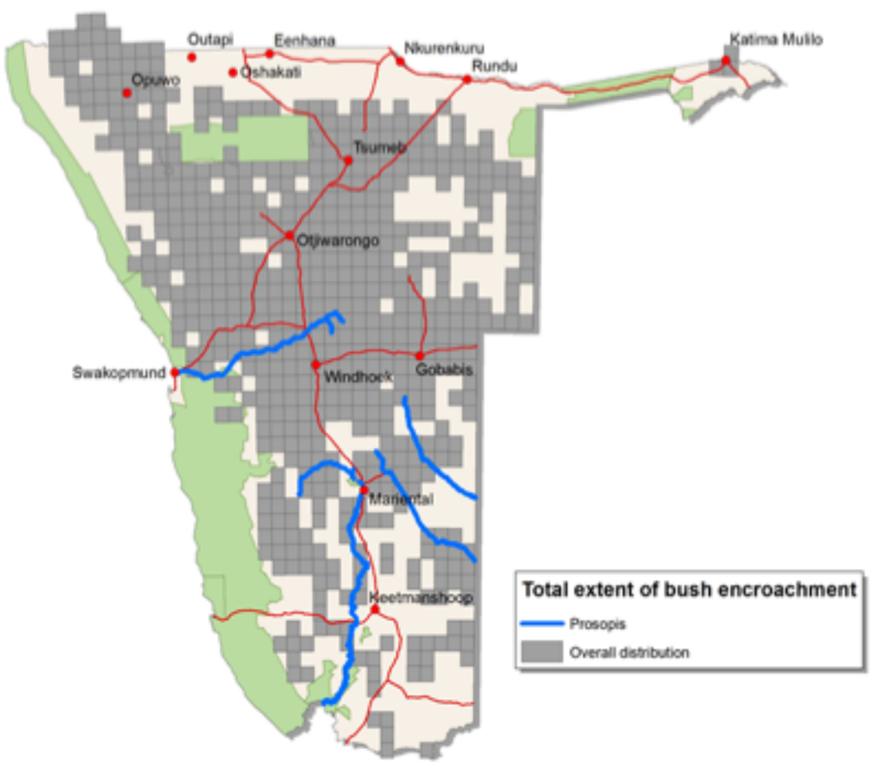


Figure 3: *Map of Namibia, showing the extent of bush encroachment measured in 2016 (SAIEIA, 2016).*

The latest estimations indicate that bush encroachment affects up to 45 million hectares of land in Namibia [5]; of which some 30 million hectares are dedicated to agriculture land (Honsbein, 2016). The area demarcated for agricultural activities in Namibia spread over some 52 million hectares (Honsbein, 2016). To give some perspective, this encroached area is equivalent to the entire surface areas of Germany, Belgium and Switzerland combined.

Furthermore, it has been estimated that bush encroachment in Namibia is increasing each year by approximately 3.2%, regardless of any ongoing efforts to extract the bush (Honsbein, 2016). In comparison, bush encroachment in South Africa expands by some 2.5% per annum (Ward, 2005). Simply stemming this spread of bush encroachment each year would require extraction of biomass across 1.4 million hectares per annum, while substantially reducing bush encroachment over Namibia's rangelands is a far greater challenge.

It should be emphasised that the utilisation of the resultant biomass from bush encroachment will have significant benefits in line with a number of critical national development efforts (National Planning Commission, 2017), while also contributing to several of the United Nations' Sustainable Development Goals (SDG).

5.2 Impacts of bush encroachment

Bush encroachment has been linked to negative impacts within the agricultural and associated sectors, substantially suppressing agricultural productivity, while also posing challenges to food security and climate change resilience. Furthermore, it is important to note that over 20% of Namibia's workforce is employed within the agriculture sector (Namibia Statistics Agency, 2016).

Heavily encroached areas are characterised by denuded, bare soils with sparse grass cover, thereby negatively affecting carrying capacity of farmland. The resulting economic loss to farmers is inescapable. Many downstream on-farm activities are negatively affected, such as reduced labour opportunities, reduced livestock, and thus, less production of slaughter-ready cattle for national and international beef markets, ultimately all leading to reduced tax revenues to the government. The knock-on effect of bush encroachment to an already vulnerable sector is aggravated by climate variability, price fluctuations, diseases and other disaster events such as uncontrolled bush fires.

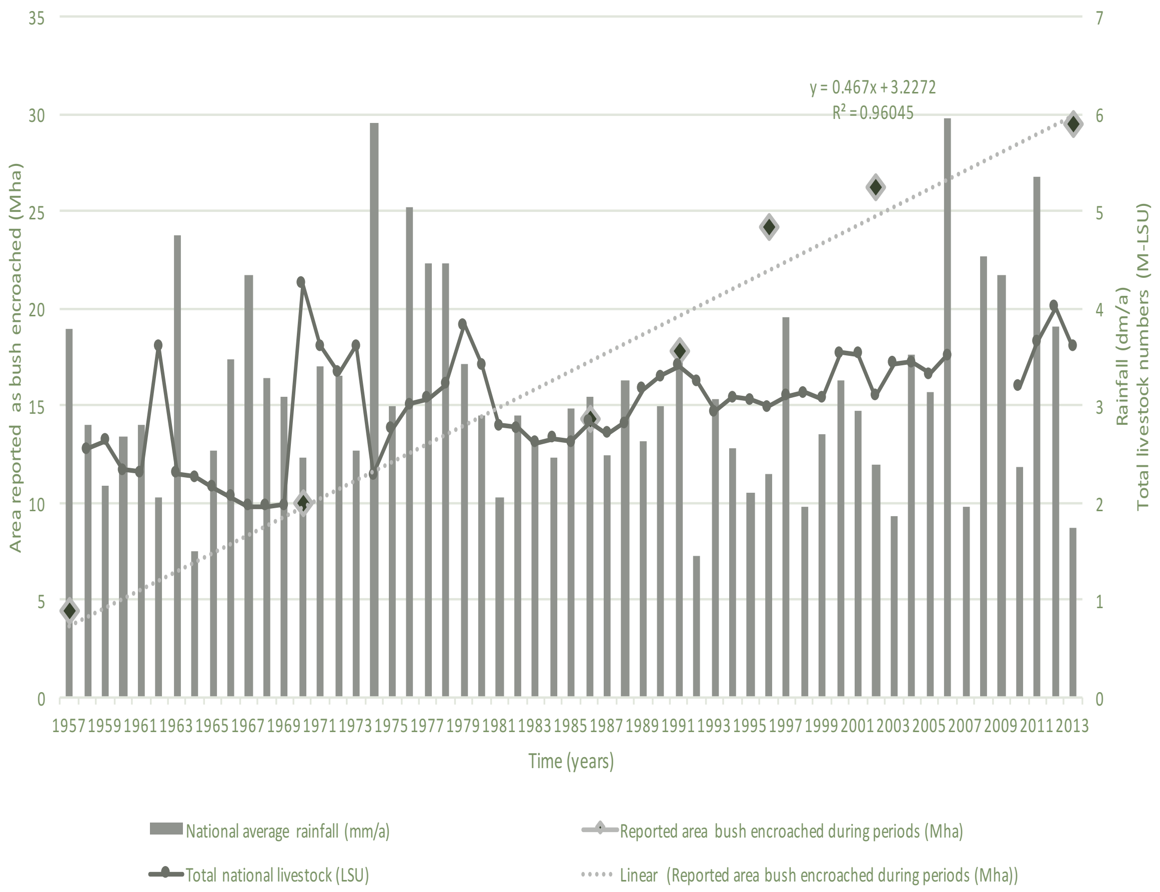


Figure 4: *Bush encroachment expansion since 1957, compared to total livestock related biomass roaming on the land, and annual average rainfall (Honsbein, 2016).*

Figure 2 presents rainfall, livestock stocking and bush coverage graphically for the period of 1957 to 2013. Although rainfall and livestock data is available from as early as the late 1890s, bush encroachment coverage is only noted sporadically from 1957 onwards. The data can be used to extrapolate the growth rate of bush encroachment spread, yielding a rate of increase of 3.18% per annum. An Analysis of Variance (ANOVA) using EViews®8 to analyse the relationship between these three parameters (with bush coverage as the dependant variable) resulted in very low reliability of the relationship between rainfall, stocking rate and bush spread (R^2 = 0.2897). Thus, it was concluded that bush encroachment increases over time regardless of rainfall and livestock stocking rates (Honsbein, 2016). Ultimately, at the bush-growth rate of 3.18% per annum, disregarding any harvesting interventions in the future, it is predicted that the entire livestock production area, equalling 51.7Mha will be bush encroached by approximately 2035 (Ward, 2005).

The data in Figure 4 also indicates that livestock stocking rates seem to follow rainfall events very closely, which suggests that farmers use rainfall as their primary gauge to determine stocking rates on their land, rather than considering the available grazing, which, is negatively correlated to the level of bush encroachment prevalent on their land. Without due consideration of encroachment and available grazing, future stocking rate decisions will not be sustainable on rainfall alone, causing even further risk of overgrazing and overstocking, which may, in turn, increase the rate of spread of bush encroachment within these productive areas.

Namibia, being an arid country, and prone to long spells of extreme dryness or drought, risks becoming desertified in areas that were previously considered productive. In addition, adverse climatic events or changing weather patterns aggravate this problem. Furthermore, bush encroachment can be considered a form of desertification (Easmus and Palmer, 2007).

Table 1 summarises adverse climatic and rangeland events that are linked to the spread of bush encroachment within the affected areas. In support of this, Namibian farmers have reported that after two or three consecutive drought years, followed by heavy rains, the rate of bush encroachment is observed to increase drastically. This is especially noted within younger bush, under approximately five years of age, which show rigorous growth given these conditions. Additionally, periods with low frost incidences during the dry season are also reported to favour the spread of bush encroachment. Moreover, farmers typically attempt to mitigate their reduced returns during dry years by increasing stocking rates during years of good rain, pressuring their rangelands, which in turn, favours bush encroachment, as previously indicated. This vicious cycle of rangeland degradation can only be broken once bush encroachment is properly accounted for, and addressed by the Namibian farmers, to ensure that their stocking rate decisions are accurately based on the available grazing, so as not to further exacerbate the bush encroachment problem on their lands.

Table 1: Climatic events that adversely affected the rangeland condition as documented, 1897 – 2016 (Honsbein, 2016)

Type of event	Recurrences	Number of consecutive years it occurred in total
Drought	9	33 years; a drought would last for 3 years, on average
Lack of surface and/or ground water	3	38 years; this mostly happens as a consequence of drought
Pests and plagues affecting crops and/or natural vegetation	5	6 years; typically occurs after spells of drought, followed by good rains
Animal diseases	5	30+ years; intermittent
Floods/ flooding	6	12 years
Large spread of bush fires	2	4 years; fires occur after the dry and cold season, prior to the next wet season

Besides the effects on grazing, ground water recharge is also significantly affected by bush encroachment (Christians, 2010; Christelis and Struckmeier, 2001). A single 2.5-meter-tall *Senegalia mellifiera* spp. *detines* (Black Thorn, previously known as *Acacia mellifera*) bush is estimated to draw up over 60 litres of water from the ground into the air, through evapotranspiration every day. The exposed root system of a small specimen spans several square-metres, as showcased in Picture 1 (MAWF, 2017).

Picture 1: *The extensive network of roots of Senegalia mellifera explains how bush encroachment can affect groundwater resources, to the extent that groundwater availability in bush encroached areas is significantly reduced (MAWF, 2017, Photo courtesy of G.N. Smit).*

An average bush encroached hectare of land can host over 4 000 bush specimens, encompassing various height classes (MAWF, 2017), therefore, the loss of soil moisture into the atmosphere is significant. This, in turn, also reduces the available soil moisture for grass growth and for the replenishment of the groundwater systems. Over large areas of land, billions of cubic meters of water loss can be attributed to bush encroachment each and every year. The frequency of droughts and water shortages highlighted in Table 1 beg the question, can Namibia spare such a loss of water, especially considering the ever-increasing national demand for fresh water and the impending climatic unpredictability brought on by climate change?

It is now common place for once productive land to be so densely bush encroached that the movement of animals, livestock and wildlife alike, is impaired. Table 2 highlights the reduction in carrying capacity in selected livestock production areas over time. However, it should be emphasised that bush encroachment was not the only reason for the substantial reduction in commercial livestock numbers (head counts). Some political events may have also contributed to such. For example, the intentional political interventions by the South African government, to convert the then South West Africa from a predominantly dairy producing country to a meat producing country from 1962 to 1965 (Rawlinson, 1994). While the numbers of cattle seem to have been reduced, the live mass of livestock has increased (Honsbein, et. al., 2010), as male animals typically weigh more than their female counterparts within the same age group (Rawlinson, 1994).

*Table 2: **Agricultural Land's Carrying Capacity vs Stocking Rates in selected bush encroached areas from 1970s to 2010 (Joubert and Zimmerman, 2002; Honsbein et. al., 2010).***

Agriculture area	Carrying Capacity, 1970s (live mass, kg/ha)	Carrying Capacity, 2010 (live mass, kg/ha)	Stocking rate, 2010 (produced live mass, kg/ha)
Gobabis	37.1	25.6	17.4
Grootfontein	44.0	17.8	21.4
Mariental	16.7	13.4	11.8
Opuwo	36.0	20.0	>1,000
Otjiwarongo	42.2	23.0	11.5
Tsumeb	42.3	16.3	94.7
Windhoek	31.0	17.5	12.2

Numerous other sectors are also negatively affected by bush encroachment. Consumptive tourism, such as hunting, and non-consumptive tourism, such as wildlife viewing, are both impacted, as the density of wildlife in bush encroached areas is greatly reduced. This affects the level of tourist satisfaction, which may in turn have negative impacts on the future of Namibia's tourism industry, an industry intrinsically linked to Namibia's wildlife and scenic beauty, which accounts for about 3% of the national GDP (National Planning Commission, 2017). Game farming is equally affected by bush encroachment through reduced stocking rates, and thus, reduced off-take capacities.

Bush encroachment truly seems to be suffocating productive lands in Namibia, sucking soils dry, shading out grasslands, and driving out ecological diversity. If business as usual continues, all of Namibia's most productive lands will be blanketed in bush, hindering important socio-economic contributors, such as the beef and small stock production industries, the tourism industry, and the game farming and hunting industries, to name but a few. The mere 200,000 hectares of land that are currently being bush thinned per annum is not sufficient to stem the negative impacts of bush encroachment. Therefore, this supports the need to extract the encroacher bush at a vastly accelerated rate, which, in turn, presents interesting opportunities for the establishment of a bush-biomass based industry in Namibia, including bush based animal feed production.

5.3 Environmental indicators in the Khomas Region

This paragraph constitutes a description of environmental indicators which bear relevance for the bush thinning and animal feed production process. It is focussed on Khomas Region, since all bush harvesting took place in this region, whereas activities at Omatjenne Research Station in Otjozondjupa the trials were limited to feeding only. A similar analysis applies for any other region in which bush harvesting takes place.

The Khomas Region is largely characterised by highland shrub lands or highland savannah. The region has a rainfall range of 200 mm to 350 mm per year, with average maximum temperatures of between 28°C to 32°C and average minimum temperatures of 2°C to 8°C. Groundwater availability is moderately productive and much of the water used in Windhoek is pipelined into the central region from northern Namibia.

The all-encompassing savannah category refers to those areas of dry, thorny woodland that occur when trees and shrubs have encroached in open grassland, often because of some disturbance like cultivation, fire or over-grazing. It could be subdivided further into Thorntree, Bush and Mixed Tree and Shrub Savannah. Some form of savannah covers much of the Namibian highlands and the dominant families of trees and bushes are the *Senegalia* and *Vachellia* (formerly known as *Acacia*), *Terminalia* (bearing single-winged seeds) and *Combretum* (bearing seeds with four or five wings), but many others are also present. The average bush encroachment level of the Khomas region was estimated at 2560 tree equivalent units per hectare with a total of 882 thousand hectares of land being considered as bush encroached. The potential first time harvest yield at this rate of bush encroachment in the specific areas amounts to between 21 and 43 tonnes per hectare (Honsbein, 2016). According to Forestry Regulations[1], half of that amount can be considered as harvestable biomass, rendering 10 tonnes per hectare of biomass, under whole tree utilisation considerations.

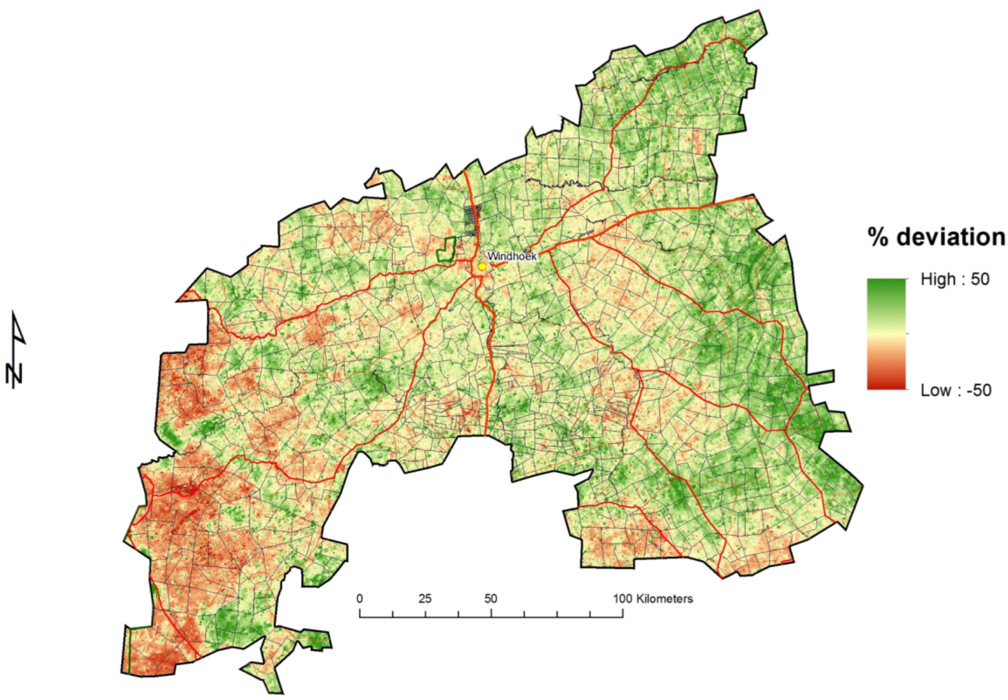
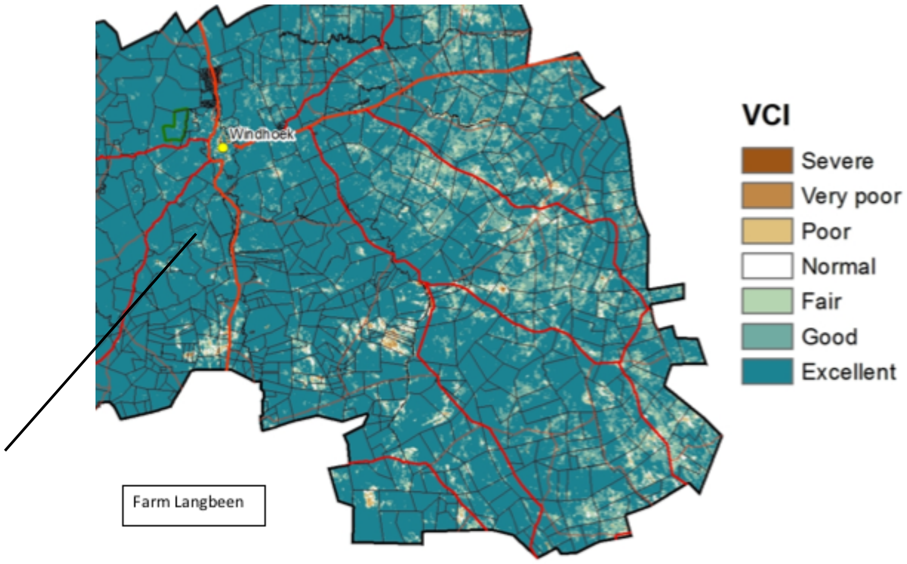


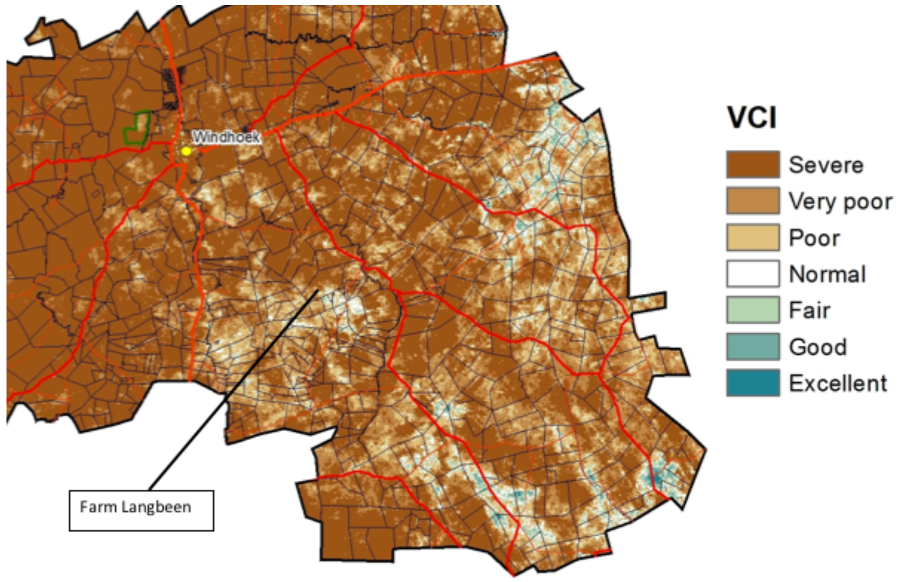
Figure 5: *Net Deviation Vegetation Index (NDVI) of the Khomas Region for the period 2001 to 2017 (Source: www.namibiarangelands.com)*

Particularities on Farm Langbeen's long-term vegetation condition are provided in the following pictures. The figures following are examples how the vegetation condition on Farm Langbeen has changed between 2011 (after an exceptionally good rainy season) and 2016, when bush feed was a solution to a severe drought situation.

[1] MAWF/MET Forestry and Environmental Authorisations Process for Bush Harvesting Projects (2017) http://www.dasnamibia.org/download/

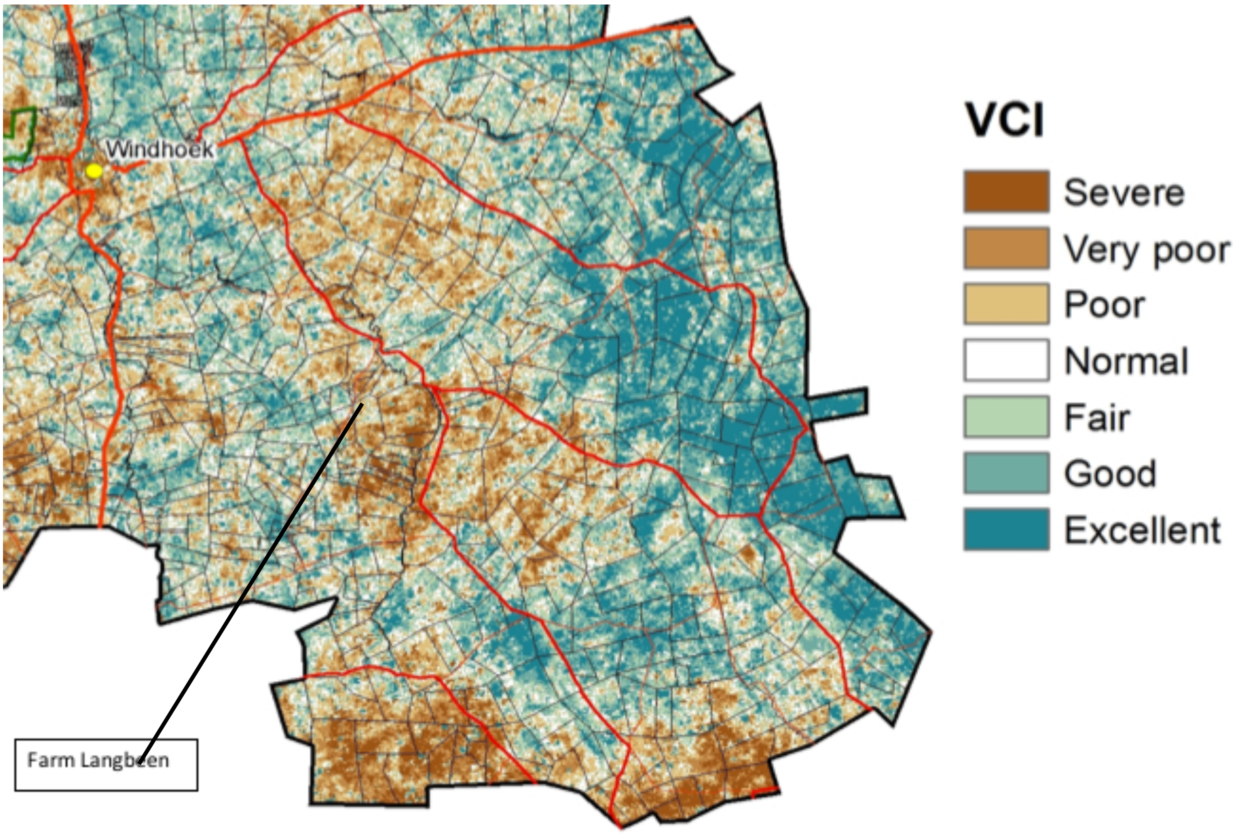


Vegetation Condition Index, for the period 16 to 31 May 2011 (rangeland is luscious)



Vegetation Condition Index, for the period 16 to 31 May 2016 (rangeland is depleted)

Figure 6: *Farm Langbeen No 86, vegetation condition index (VCI) comparison between 2011 and 2016. All VCI are indicated for end of vegetation growth season, i.e. end May for each year. (source, modified from www.rangelandsnamibia.com)*



Vegetation Condition Index, for the period 16 to 31 May 2017 (rangeland is recovering)

Figure 7: *Farm Langbeen No 86, vegetation condition index (VCI) in 2017. All VCI are indicated for end of vegetation growth season, i.e. end May for each year. (Source, modified from www.rangelandsnamibia.com)*

5.4 Caterpillar attacks on bush

On farm Langbeen, the *Acacia mellifera* (*Senegalia mellifera)* was attacked by Silver Caterpillar from mid-February to the beginning of March 2017 (Pictures 2 and 3). The same type of caterpillar was reported to be active in the Khomas Highland, but feeding exclusively on Yellow-Bark Acacia (*Vachellia erubescens*). The consequence was that no bush could be harvested during that period, as the bush did not have leaves. Once the caterpillars died, the bush grew leaves again quickly within days and harvesting could recommence.

Picture 2: *Silver caterpillar, feeding on exclusively Senegalia mellifera at Farm Langbeen.*

Picture 3: *Silver caterpillar, after feeding on a Senegalia mellifera at Farm Langbeen.*

5.5 Health and safety aspects

5.5.1 The use of polyethylene glycol (PEG)

For the sheep bush based feed trials, polyethylene glycol (PEG) in crystalline form was used to improve the palatability of the bush based feed. The amount of PEG that can be included in such feed is limited to a few grams (normally less than 5 g) per kilogramme of dry bush based feed. It is important that the instructions for inclusion of PEG in the feed are followed exactly, else animals could die. Consumption of pure, undiluted PEG is deadly. PEG may only be administered as part of a diet, and is destined for ruminant feed only.

5.5.2 The use of Sodium Hydroxide (NaOH)

For the cattle bush based feed trials, Sodium Hydroxide (NaOH) in diluted form was used to improve the digestibility of the bush based feed. NaOH was used as a pre-treatment to the bush fibres, and should not be included directly to the feed mixture. The amount of NaOH which can be used as pre-treatment is established on a total dry weight-basis of the biomass. These trials were conducted based on a 2.5% and 10% inclusion rate on a dry biomass weight basis. The method of diluting NaOH as was used in these trials was described in below section Treatment of bush with NaOH.

It is important that the instructions for inclusion of NaOH in the feed are followed exactly, else animals could die. Consumption of pure, undiluted NaOH is deadly. NaOH may only be administered as part of a diet, and was trialled in Namibia for ruminant feed only. An extensive safety data sheet is included as Annexure 2, and must be read by everyone intending to use such as fermenting agent in bush based feeds.

6 Methodology

6.1 Research Site Description:

6.1.1 Farm Langbeen

Farm Langbeen No. 86 is located in the commercial farming area close to Dordabis and measures 6,998 hectares. The owner, Mr Anton Dresselhaus, after large scale veld fires in 2011, has experienced serious droughts in the period from 2012 to 2016. Having Limousin and Bonsmara cross-bred commercial cattle from his former stud breeding programme in that period, he had the choice to either see his animals starve to death, or seek for a solution to maintain them until such time the grazing situation improved. Having a farm where mixed agriculture and wildlife production is practiced, including rare wildlife species, he also saw wildlife suffering from hunger. In order to find a solution to the drought situation, he started harvesting bush to prepare animal feed. Mr Dresselhaus has been practicing bush to animal feed production on his farm since 2013.

It is due to this intensive experience with bush to animal feed production as well as the vicinity to Windhoek that the farm was chosen for the trials. Furthermore, Mr Dresselhaus also had all necessary infrastructure and equipment available on his farm, i.e. bush harvesting and processing machines as well as drying and storage facilities.

The feeding trials for Phase I of the bush to animal feed pilot project were conducted on the commercial farm Langbeen. The farm is situated near Dordabis in the Windhoek Rural Constituency of the Khomas Region, Namibia. The average annual rainfall on the farm is 350 mm per annum, while the temperatures range between -14°C and 26°C in winter and between 12°C and 37°C in summer. The vegetation type on the farm is mostly Highland Savannah.

The bush and shrub species prevalent on Farm Langbeen are *Senegalia mellifera*, spp. *mellifera*, *Vachellia reficiens*, *Dichrostachys cinerea* and several *Combretum* species. For the trials, only *Senegalia mellifera*, spp. *mellifera* were used.

Because of the severe droughts experienced on the farm between 2012 and 2016, and a large-scale veld fire that cleared the land in 2011, Mr Dresselhaus resorted to utilising bush as basis for animal production. He ameliorated the bush based feed by utilising various supplements. By utilising the bush as animal feed, he also saw the opportunity to lessen the extent of bush encroachment prevalent on the farm. To date, a total of 150 hectares were bush thinned, equally making space to expand his wildlife and tourism activities. In mid-2017, he changed the income generating activities from largely cattle rearing to now wildlife and tourism activities only.

The sheep trials were carried out from 4 July to 29 September 2016.

The semi-intensive cattle feeding trials, based on pelleted bush based feeds, were carried out from 18 January to 3 May 2017.

6.1.2 Omatjenne Research Station

The intensive feeding trials were conducted at Omatjenne Research Station of Ministry of Agriculture, Water and Forestry in Otjozondjupa Region, Namibia, from the 11 January to 3 May 2017. The station is located at S20° 25.297´ and E16° 28.046´, approximately 25 km west of Otjiwarongo on the main road to Outjo.

According to general classification, Omatjenne Research Station is situated in the summer rainfall area and receives an annual average rainfall of about 453 mm, usually from October to April, with the highest peak during January and February. The rainfall has been recorded for the past 59 years and 32 of these were below average.

The veld type can be described as thorn bush Savannah, with many palatable shrubs and bushes and a good coverage of perennial grasses also known as “sweet” veld because of its high nutritive value even during winter time. A large variation of soil types is found, ranging from sand to lime and dolomite (Geiss, 1971).

Omatjenne Research Station was selected to conduct the intensive feeding trial because of the available registered Phase C facility.

6.2 Equipment selection

In preparing the bush based diets, various equipment was required. All equipment for the harvesting of bush, milling, mixing and storage facilities were available at Farm Langbeen. The equipment consisted of the following:

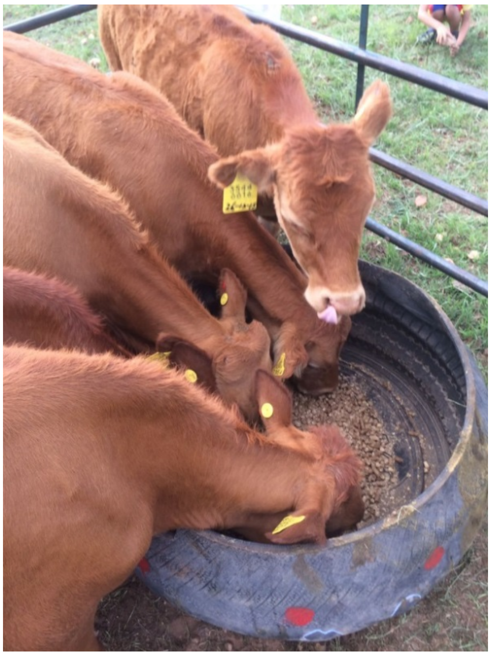
- Front-end loader (bush harvesting)
- Power tools to de-branch bush stems (e.g. Stihl brush cutter or chain saw)
- Refurbished hammer mill
- Feed-mixing drum and 1m^3 storage bags (holding the wood fibres pre- and post-drying)
- A tractor for feedstock transport

A Jones 2 t/day-Pelletiser (Picture 4) was procured and set-up on Farm Langbeen to produce bush based animal fodder in pellet form for both, the semi-intensive feeding trials conducted on Farm Langbeen, as well as the intensive feeding trials that were conducted concurrently at Omatjenne Research Station.

Picture 4: *Complete "Jones" pelleting set-up – pellet cooling tower; pellet conveyor; pelleting press; loose feed conveyor; feed mixing bin. (Photo: J. Laufs, Support to De-bushing Project)*

In addition to the feed preparation equipment required, holding pens for each group of sheep to be fed on a daily basis were already available on the farm. On Farm Langbeen, animals were weighed using TruTest™ electronic livestock scale.

Picture 5: *Temporary holding pens for feeding cattle on a daily basis.*



Picture 6: *Cattle feeding from bin with bush based pellets*

At ORS, the Phase C facilities were utilised. The Facility allows for individual feed intake of cattle to be measured and compared to the growth rate so that feed efficiency estimates can be calculated. The Phase C facility was established in 2014 to provide central performance testing for bull calves. Prior to the project, two sets of bull calves successfully underwent the Phase C growth test in the facility. This gave an opportunity to ensure that the software on the machines ran correctly and provided the workforce on the Station with experience on how to manage the animals in the facility. No additional equipment was procured specifically for the actual feeding of the animals during the trials.

Picture 7: *Phase C facilities at ORS. An animal at the feeding station, while its feed intake is being measured.*

Picture 8: *Cattle at ORS, receiving grazing only as feed*

6.3 Animal Selection and Trial Design

All the feeding trials (sheep and cattle) were carried out over a period of 112 days, consisting of a 28-day adaptation period and 84 trial days.

6.3.1 Sheep trials

Since Farm Langbeen was recently converted to a wildlife farm, there were not a sufficient number of lambs for the experiment. Therefore, the majority of the lambs used in the trials were brought in from other farmers. It was challenging to get all 36 lambs of the required breed (Dorper), weight (average weight 20 kg) and sex (male, preferable wethers). Hence in the end, the sample group used consisted of a mixture of breeds, variable weights and differing sex. However, efforts were made to ensure that the starting average weight of all treatment groups were comparable and similar.

The thirty-six sheep were mixed breeds; predominantly Damara, Dorper and Dormer. The trials were conducted using a completely randomised design with six (6) sheep per treatment. This provided the minimum sufficient number of animals needed for accurate statistical analysis of data.

6.3.2 Semi-intensive cattle trials

A group of forty (40) cross-bred Limousin and Bonsmara growing cattle (15 heifers and 25 steers), approximately 12 months old were randomly allocated to five treatment groups, with 5 steers and 3 heifers per group. All treatment groups grazed on natural pasture as their basal diet, with 4 groups receiving an additional 3 kg daily per animal of the respective diets feed, while one group only grazed as a control.

6.3.3 Intensive cattle trials

A group of fifty (50) Sanga weaners were selected for the feeding trial and were between 11 and 13 months old.
The weaners were divided into the four treatment groups for intensive feeding, and a fifth grazing group as a control. The animals were grouped to have similar average weights at the onset of the trial. Each group consisted of five steers and five heifers.

Activities on Farm Langbeen included the harvesting and milling of bush, and mixing of bush based diets.

Animals were fed on a daily basis. The weighing of animals was carried out either by Mr Dresselhaus or his farm manager (or his wife) on a weekly basis. Tuesdays was chosen for weekly weighing of animals. Weight data was captured electronically and shared with the project team using an online data sharing service.

6.4 Feed Preparation:

6.4.1 Harvesting and milling of bush

For the sheep trials, bush material was harvested and processed on a daily basis from July to October 2016 The bush material was restricted to leaves and branches with a maximum diameter of 2 cm. Harvesting and milling was done in the field, not further than 5 km from the central processing site. The chipped bush material was passed through a hammer mill with a 6 mm sieve then transported to a central location, where it was mixed with other ingredients. The harvesting and milling process is illustrated in Pictures 9 to 12. .

For the cattle feeding trial, the bush harvesting took place from April 2016 to April 2017. Fresh milled branches, twigs and leaves were transported to a central location where drying, storage and feed mixing took place. , The chipped bush material was fed through a stationary hammer mill with a 10mm sieve before being treated with NaOH and mixed with other ingredients.. A 16 mm sieve would have been better suited for pelleting bush based, since there is further breakage of the bush material during the pelleting process which reduces the essential particle size required for rumination. However, a 16mm sieve was not available for the trials. The Buffalo stationary hammer mill is displayed below (Picture 11).

***Picture 9**, top left:*	*The bush resource material – standing bush, of which only twigs and leaves are used to be converted to animal feed*
Picture 10,** top right**:	*Harvesting of the bush*
Picture 11,** bottom left**:	*Twig material, no larger than a broomstick and twigs, prepared for milling (for the sheep feed)*
***Picture 12**, bottom right:*	*Hammer mill components showing the wheel & hammers, and milled bush before being conveyed to the cyclone (for the sheep feed)*

Picture 10: *The luscious bush chips material, ready to be milled.*

Picture 11: *Buffalo stationary hammer mill installed at Farm Langbeen. The hammer mill is driven by 3-phase electricity and has a throughput capacity of at 0.5t/hr. Due to its size, it is more power and capacity efficient than e.g. tractor-driven types of hammer mills.*

6.4.2 Treatment of bush with NaOH

NaOH is also known as caustic soda, or when used in ruminant feed, "Rumen Soda". It is an inorganic chemical compound with a highly caustic metallic base and alkali of sodium which is used in the different industries for different purposes (strong chemical base in the manufacture of pulp and paper, textiles, drinking water, soaps, detergents, drain cleaner etc.).

In animal feed, it is used to break the bonds between lignin, and cellulose / hemicellulose parts in the complex wood structure (or bush based fibres) for animals to easily digest the fibre component in the feed. Furthermore, NaOH lowers the crystallinity of the cellulose resulting in a higher glucose yield. Due to the high fibre content of the bush feed, it was decided to treat the milled bush with 2.5% and 10% NaOH in two diets that were used in the cattle feeding trials..

The purity of the NaOH was 99.9% and was sourced from Protea Chemicals in Windhoek. The NaOH solution was prepared as described in

Table **3** and then sprayed over the milled bush, mixed and left to ferment the bush-biomass for between two and four days. Care must be taken when NaOH crystals are added to water because the. The mixture is highly exothermic and will therefore become hot. Therefore, it PPE is compulsory to wear Personal Protective Equipment (PPE) when mixing NaOH with water. The mixture must be cooled before use. Easiest is to take a 25-litre bucket, add the water first, and then add the NaOH dry mater into the water, while stirring. Please note that a wooden object is recommended to stir the mixture with; an object made with metal would result in an unnecessary chemical reaction between the stirring element and NaOH solution. Make sure all crystals were are diluted dissolved and before the mixture has cooled down before is being added to the bush-biomass material. For the 10% NaOH inclusion rate, the same amount of bush biomass is treated as for the 2.5% rate. Only two diets were designated to contain wood fibres pre-treated with NaOH (Diet 2 at 2.5% and Diet 3 at 10% NaOH inclusion rate).

The easiest manner to mix the water with the NaOH crystals was to use 25L buckets (e.g. old paint buckets). It was found that if NaOH is mixed in larger quantities, the mixture becomes easily saturated and forms hard sediment at the bottom of the bucket. The pH of the mixture should be 14.

Table 3: Description on how to mix dry, crystalline NaOH with water to obtain the right quantity of 2.5% and 10% dry basis inclusion rate for each batch of 400kg of bush biomass pre-treatment. The method was adapted from Kubirske (1989).

	2.5% NaOH mixture	10% NaOH mixture
Dry, crystalline NaOH	9 kg	4 x 9 kg
Water	10 L	4 x 10 L
Mass of NaOH-mixture	21.1 kg	84.4 kg
Mass of biomass used for pre-treatment (on a dry matter basis)	390 kg	360 kg

The abovementioned amount of approximately 400 kg of bush biomass to be treated was determined by the holding capacity of the feed mixer that was already available on Farm Langbeen and can vary if other mixing equipment or methods are applied. If less bush needs to be treated at the same concentration levels, the easiest would be to multiply the required quantity by the fraction of (21.1/390) kg and (84.4/360) kg for a 2.5% and 10% concentration level respectively. This would for example result in using 23.4 kg of NaOH-mixture for 100 kg bush to render a 10% concentration level; and 5.4 kg NaOH-mixture for a 2.5% concentration level accordingly.

6.4.3 Drying and Storage of the Bush Biomass

Bush material destined to become animal feed material must be stored in a dry, protected environment to shield it from rodents, insects and other types of pests which could compromise its quality. Furthermore, biomass pre-treated with NaOH, must also be sufficiently dried before mixed with supplements, and then mixture can be pelleted.

Picture 12: *Drying of milled (and in some cases, NaOH pre-treated) material, before mixing into an animal feed. Drying in the sun, open air is practiced widely. However, as 2017 was a very wet rainy season, this step posed many problems.*

Picture 13: *Storage of the milled, dried feed is usually done in 1m^3 bags, thereafter weighing some 350 kg. The bags are second hand and can usually be obtained from break-bulk operators, e.g. sugar packers.*

6.4.4 Supplements and Feed Mixing

6.4.4.1 Sheep feed mixtures

The following supplements were selected to be added to the milled bush in the different diets for sheep, depending on the main nutrient source they contain and on their availability:

- *Opuntia ficus-indica* (prickly pear) cladodes
- Camelthorn pods
- Urea
- Molasses
- PEG (PEG 6000), in the form of pure crystals
- Rangeland Grower™
- Bush Improver Lick™

Opuntia was bought from Ben-Hur Farm, near Gobabis. Camelthorn pods were either collected from Farm Langbeen, or procured from neighbouring farmers. The other supplements are commercially available and were procured in quantities as determined by the diets.

OPUNTIA

Opuntia ficus-indica commonly known as prickly pear, is a cactus species widespread in semi-arid and arid regions of the Americas, Africa, Asia, Southern Europe and Australia. This crop is a multipurpose crop and it is a valuable source of forage, water and energy for livestock in dry areas. Prickly pear does not need to be excessively watered and has shown to be a good source of energy being able to replace maize chops in the feed in Namibia (Shiningavamwe et al., 2010). Hence it was included in a diet at 10% of inclusion. The clods were cut and dried prior to the mixing.

In accordance with the procedures described by Zeeman (2005), Einkamerer (2008), Menezes (2009) and Shiningavamwe (2010) fresh harvested *Opuntia* cladodes were cut into strips of about 15 to 20 mm and dried in the sun. Cutting of fresh cladodes into strips was done using a panga (machete) and pieces were laid flat on plastic sheets to dry in the sun. Longer periods (about 14 to 21 days) were needed to dry the cladodes because of more cold days and moist nights in winter months (July and partly August) than it would have taken in summer months when the sun is hot and the air is dry. The cladode strips were spread by placing them in a single layer to allow space between strips and enhance air movement around them for faster drying.

Due to the fact that the sun-dried cladode strips were not thoroughly dried by the time of use because of the cold weather, grinding them in a hammer mill to pass through a 6 mm sieve was challenging. In agreement with Zeeman (2005), Einkamerer (2008), Menezes (2009) and Shiningavamwe (2010), experience showed that sun-dried *Opuntia* cladodes tended to clog up the hammer mill during the grinding process and thus required the hammer mill to be opened and cleaned regularly. Hence, instead of grinding the sun-dried cladode strips in a hammer mill, they were chopped further into small pieces with a panga (machete), although this proved to be labour intensive. Moreover, not having uniform particles of cladodes enabled dominant animals to feed the bigger pieces selectively, which disadvantaged other animals.

CAMELTHORN PODS

Vachellia erioloba pods, or commonly known as Camelthorn pods were sourced from farmers in the vicinity. They have been used by farmers for decades as a protein supplement for ruminants especially in winter months. These pods contain high protein content ranging between 14-18%.. The pods were hammer-milled like the bush, to ensure that they are sufficiently crushed for maximum nutritional value.

UREA

Urea is a non-protein nitrogen (NPN) source for ruminants. Microbes in the rumen are able to metabolise NPN compounds to produce ammonia which is used by the microbes for their protein synthesis. This protein will be available for absorption through the gastrointestinal tract. Feed Grade Urea usually has a typical value of 287.5 percent equivalent crude protein for ruminants. Since protein is one of the liming factors it was decided to add urea.

MOLASSES

Molasses is a by-product of the sugarcane industry. It is used as feed supplement since it is inexpensive, increases palatability and decreases the dustiness in the feed. Its ME is usually around 9 MJ/Kg and protein content around 6%..

CRYSTALLINE PEG (PEG 6000)

Polyethylene glycol (PEG) is a polyether compound with many applications from industrial manufacturing to medicine. It is used in the animal feed industry to improve protein digestibility due to its tannin binding ability. Tannins are considered to be anti-nutritional factors that can bind proteins hampering their utilisation by the animals..

RANGELAND GROWER™

This is a commercial supplement based on natural protein sources (mainly oilcakes). It also contains abundant sources for energy; hence it can be used both as energy and protein source. Its protein content is around 17

BUSH IMPROVER LICK™

This commercial supplement is a ready-mixed maintenance lick for ruminants that utilise bush resources. It contains tannin inhibitors which bind tannins in the bush and improves the nutritional value. Its protein content is around 25%. However, it contains non-protein nitrogen (NPN), hence it should be used with caution and fed according to instructions.

6.4.4.2 Cattle feed mixtures

A feedlot concentrate used in both the Bush Feed and Commercial Trial Feed mixes was formulated with the assistance of Feedmaster™ in order to emulate the concentrates that are commonly used by Namibian farmers when finishing animals on grass as a roughage source. The combination and inclusion levels of the different ingredients were selected to ensure that the nutritional requirements (based on the NRC tables for Beef Cattle) of the fed animals were met. The ingredients of the concentrates used to complement the commercial and bush based pellets can be found in the Tables 4 and below.

Table 4: *Ingredients of the concentrate used in the bush based Bush and Commercial Trial Feed mixes.*

	Inclusion rate (%) in Bush Trial Feed Mix	Inclusion rate (%) in Commercial Trial Feed Mix
Ingredients		
Biosaf SC47	-	0.17
Molasses (liquid) with RMS liquid	5	5

Gluten 20	12.78	12.78
Hominy chop 8.0%	29.1	29.1
Wheaten bran 15%	39.84	39.84
Grift fine tuff bags 35% (feedlime)	3.88	3.88
Salt (coarse)	1	1
Sodium bicarbonate	1	1
Ammonium sulphate	0.2	0.2
Urea	1.2	1.2
Whole cotton seed	5.7	5.7
Beesvoer PMX 30kg (x1)	0.1	0.1

As indicated in 4, the commercial pellets contain Biosaf SC47. This is a yeast and was excluded from the Bush Feed Trial Mix for it not to interfere with the effectiveness of NaOH on the bush fibre digestibility.

6.4.4.3 Feed Mixing and Diets

SHEEP FEEDING TRIALS

The treatment diets used were mixed at Farm Langbeen using a concrete mixer (Picture 15), following predetermined quantities of ingredients for each diet (Picture 14).

Picture 14: *Mixing quantities for all diets displayed on a white board, for sheep feeding.*

Picture 15: *Mixing experimental diets, with a regular, self-propelled concrete mixer; for sheep feeding.*

Six experimental diets including five bush based diets and one non-bush based diet as a control diet were tested. The control diet (Diet1) consisted of a mixture of grass and Lucerne hay; while the other 5 diets (Diet 2 to Diet 6) consisted of milled bush material as roughage at levels of 50 to 85%. The remaining 15-50% constituents of the diets consisted of supplements listed in Table 6. Molasses, Opuntia cladodes and Rangeland Grower™ were mainly added as energy sources as well as to improve the palatability of the diets. While feed grade urea, camelthorn pods and Bush Improver lick™ were added as nitrogen sources. PEG was added to one of the bush based diets to evaluate its effectiveness on improving the digestibility of protein as a tannin binding agent.

The sheep were fed with a loose feed mixture, as a pelletiser was not available to the project at that point in time. It was furthermore considered sufficient to feed such loose feed mixtures, as opposed to pelleting the feed. The composition of the six treatment diets is presented in the table below.

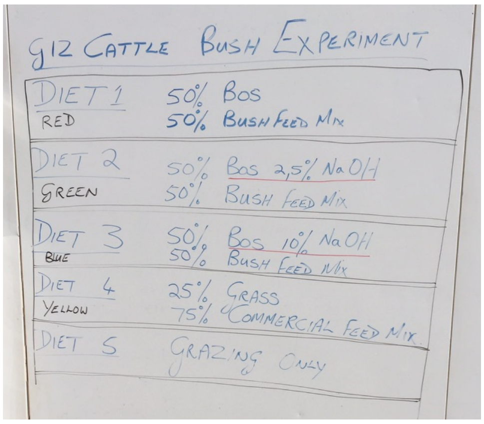
Table 5: *Composition of the six treatment l diets, fed to sheep*

	Treatment diets* inclusion rates (%)					
	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5	Diet 6
Feed Ingredients						
Grass hay	80	-	-	-	-	-
Lucerne hay	20	-	-	-	-	-
Milled bush (*Acacia mellifera*)	-	85	85	50	50	65
Sun-dried and chopped *Opuntia* cladodes	-	-	-	-	10	-
Camelthorn pod meal	-	-	-	40	40	-
Bush Improver Lick	-	-	-	-	-	15
Rangeland Grower	-	-	-	-	-	10
Feed grade urea	-	2	2	-	-	-
Molasses	-	13	13	10	-	10
PEG 6000 (0.5g/sheep/day)	-	-	**	-	-	-

* Diet 1: control diet; Diet 2-6: bush based diets; ** PEG 6000 included

CATTLE FEEDING TRIALS (SEMI-INTENSIVE AND INTENSIVE FEEDING)

The treatment diets were mixed at Langbeen Ranch using a large scale feed mixer prior to pelleting (see image below). The quantities of the ingredients for the diets were predetermined and the feed were prepared on a needs basis, while pelleting took place a daily basis.



Picture 16: *Mixing quantities for all diets displayed on a white board*

Picture 17: *Mixing experimental diets, with a special (large scale), self-propelled feed mixer. This mixer has a capacity of ±6m³ mixing volume, approximately 400 kg per feed/ diet to be mixed.*

Four experimental diets including three bush based diets and one non-bush based diet as a control diet were tested. The control diet (Diet1) consisted of a commercial feed mix as outlined in Table 5 at an inclusion rate of 75% and the remaining 25% of grass. The other 3 diets (Diet 1 to Diet 3) consisted of NaOH pre-treated bush material as roughage at a 50% inclusion rate. The NaOH pre-treatment was done with two inclusion rates (2.5% and 10%) as outlined in "7.4.2: Treatment of bush with NaOH". The other 50% consisted of a Bush Trial Mix (Table 7). NaOH was also added to Diet 2 and 3. The feed was produced as a Total Mixed Ration in the form of pellets being 10 mm. The pellets of Diet 1 and 4 later changed to 6 mm in size.

The change in pellet size was necessitated by the fact that pellets containing feed sorghum or 'grass' disintegrated rather quickly and transport between Farm Langbeen and Omatjenne aggregated the problem. As suggested by the manufacturer of the pelleting equipment, the pellet dye was changed to 6 mm in order to achieve better pellet coherence. This seemed to work well, especially with pellets for Diet 4.

However, within smaller pellets the bush based fibre length is reduced significantly, which can contribute to bloating, if animals feed on these pellets exclusively. This was observed among animals of Diet 4. In response, the animals of this diet were additionally provided with grass for roughage to prevent bloating. Diet 1 was again set to 10 mm pellet size.

It was noted that wood based feed pellets of sizes smaller than 10 mm need more power during production and thus more fuel was needed to operate the pelleting equipment.

Farmers also engaged in producing bush based animal feed pellets reported that an 8 mm pellet is the preferred pellet size. At this size, power consumption during processing is stabilised and thus no excessive fuel is needed. Furthermore, the bush based fibre length (as determined by the milling process, using a 16 mm or 10 mm sieve) is not further reduced.

Table 6: *Composition of the four treatment diets, fed to cattle*

	Treatment diets* inclusion rates (%)			
	Diet 1	Diet 2	Diet 3	Diet 4
Feed Ingredients				
Milled bush (*Acacia mellifera*)	50	50	50	-
NaOH		2.5	10	-
Bush Trial Mix	50	50	50	-
Commercial Feed Mix	-	-	-	75
Grass	-	-	-	25

6.5 Trial Management:

6.5.1 Feed Management:

Sheep trials Treatment groups were kept in separate open pens with a shaded area in one corner throughout the trial period. All treatment groups were adapted separately in the kraals to the respective treatment diets for 28 days. Water and treatment diets were provided on an *ad libitum* basis. After the adaptation period, all treatment groups continue receiving their respective diets and water ad libitum while evaluating their growth performance for a period of 84 days.

The amount of feed given daily was divided into two portions, with one portion given in the morning and the rest given in the afternoon. The amount of feed given to each group was determined by the average group weight.

CATTLE TRIALS

For the semi-intensive trial, all cattle were grazing however four of the five groups received 800 g of the respective diets (1, 2, 3 and 4) in holding pens (Picture 5) on a daily basis.

Prior to the onset of the trial, good rains on Farm Langbeen in late December 2016, resulted in the increase of available grazing which diminished the affinity of cattle for bush based diets. It was also challenging to feed the diets containing NaOH pre-treated bush material to the animals. It was observed that it often took the animals fed this diet, over 8 hours to consume all of the feed, while animals assigned to eat Diets 1 and 4, complete their rations within 2 hours or less. It was suspected that Diet 2 and 3 had an unpleasant smell and bitter taste due to the inclusion of NaOH. To circumvent these challenges, the cattle assigned to feed on these diets were kept in the pens until they consumed all the bush based feed provided on the day. Only then were they released from the pens and allowed to graze.

For the intensive feeding trials at ORS, four groups were fed their respective diets (1 to 4) in the in feedlot while one group grazed on natural veld. The grazing group of animals was given a lick on a daily basis to supplement the natural grazing. Five kilograms of the Bush Improver Lick™ was provided in beginning so that each animal consumed about 500 grams. It was then later replaced with the Rangeland Grower™ once the grass in the camps had grown to approximately 10 cm in length, after the first rains were received in February 2017. The animals were supplemented with the Rangeland Grower™ until the end of the feeding trial.

During the adaptation period the animals in the feedlot were accustomed to their respective diets, while also receiving grass. The amount of grass was gradually decreased over time as the animals began to consume more of the experimental feed. This was done to avoid any digestive disruptions by allowing the rumens of the animals to adapt to the new feed and to allow the animals to become accustomed to the feeding system. As a precaution, bags of feed were inspected for mould before use then all spoilt feed was discarded. The software of the feeding system was set to release feed from the bin, into the feeding trough once the amount of feed in the troughs fell below two kilograms to ensure that feed was constantly available in the trough for the animals to feed on an *ad lib* basis.

However, monitoring of feeding behaviour indicated that dominant animals prevented the smaller ones from entering the crush and feeding freely from the troughs. This had a negative impact on the growth rates of smaller animals and also led to minor injuries. Hence, smaller animals were identified, removed from the groups and fed separately in order for them to have adequate access to feed.

In addition to the diets, clean water was available to the animals in both the semi-intensive and intensive systems on an *ad lib* basis.

6.5.2 Weighing of Animals

For both the sheep and cattle trials, the initial body weights were obtained by weighing all animals at the start of the adaptation period. Thereafter, the animals were weighed weekly on the same day of the week in the mornings during the trial period. All weighing was done with the animals being withheld from feed and water for at least 8 hours or more (usually overnight) before weighing. Weights of the animals were used to determine the growth rate, which was indicated by means of the Average Daily Gain (ADG). Calculation of the FCRs and ADGs allows comparison of the growth rates and the feed efficiencies of the animals in the different diets. Animal Health Management and Monitoring

6.5.3 Animal Health Management

SHEEP TRIALS

Upon arrival at Farm Langbeen, all lambs were vaccinated with Multivax P™ before the beginning of the trials to protect them against botulism, black quarter, pulpy kidney and clostridium. They were also treated against internal parasites.

Either on a daily basis, or at least during weekly weighing sessions, the health status of animals was monitored. It was required to observe and note any changes in health condition which could possibly be ascribed to the new feed.

One sheep from diet 2 was found dead in the pen early morning of 20 August 2016. Unfortunately, the case was reported too late for a veterinarian to do post-mortem and determine the cause of death. However, no obvious evidence could be gathered to indicate that the death could be attributed to the diets because other sheep in the same diet group looked healthy.

CATTLE TRIALS

Prior to the commencement of the semi-intensive trial, all the weaners, were vaccinated with Supervax™ to immunise them against Anthrax, Botulism and Black quarter as well as treated with Dectomax™ to control external and internal parasites. All heifers were additionally vaccinated with OVP Brucellosis vaccine.

To affirm the animals' health throughout the trial period, stool samples were taken every 28 days during a weighing exercise. The stool samples were inspected macroscopically for any blood or parasite larvae. Animals received a clear bill of health throughout the trial period. No test animals in this group got sick during the trials, nor had they to receive a repeat treatment for internal or external parasites.

Similar to the semi-intensive trials, all weaners at ORS were also treated with Supervax™ for immunisation against Anthrax, Botulism as Black Quarter and Dectomax™ for internal and external parasites. The treatment against Brucellosis in female cattle took already place at weaning and was not carried out as part of these trials. The weaners were monitored on a daily basis for bloat and any health abnormalities. Interventions were taken if animals were seen to be lethargic, having decreased appetite and weigh loss. Veterinary advice was sought for suitable interventions. The animals were also visually assessed for external parasites and were treated accordingly with pour-on medication.

Faecal samples were also taken from animals and tested at the Central Veterinary Laboratory to determine internal parasitic and coccidial infestation levels. Animals exceeding set thresholds of infection were treated against the internal parasites and to alleviate the effects of coccidiosis.

Animals fed Diet 4 experienced frequent bloating. These animals were treated for the bloat with medication such as Bloat Guard™. Stomach tubes were also passed into the rumen and rumen punctures were performed to alleviate frothy bloat. One animal from this group died and the veterinarian determined excessive bloat to be the cause of death. Thereafter, the Diet 4 animals were given an additional 1 kg of hay per animal as additional fibre to minimise the incidence of bloat.

6.6 Data collection

6.6.1 Bush biomass, mixed diets and grass

Laboratory analysis of feed is essential in order to determine the level of nutrients in the feed and match them to the nutritional requirements of animals to be fed. Representative samples of milled bush and experimental diets were collected every third week during the trial period for nutritional analysis at the Agricultural Laboratory of the Ministry of Agriculture, Water and Forestry (MAWF)..

The milled bush and experimental diets were analysed to determine the chemical composition before and after adding supplements to the milled bush. Since different batches of milled bush were harvested every day, it was necessary to sample at a certain interval to determine if there was any variation between batches over the trial period.

Samples of the grasses were collected at regular intervals in the two camps where the grazing group was grazing. (The samples were used to determine the grazing value of the camps and monitor changes in the nutritive content of the grass. A veld condition assessment was conducted to determine the overall condition of both the camps. The assessment included the collection and identification of the grass species. Laboratory analysis was used to determination of the grazing value of the grass specie composition in the camps.

The nutritional analysis done on the collected samples included the following: Dry matter (DM), Crude protein (CP), Crude fibre (CF), Acid detergent fibre (ADF), Neutral detergent fibre (NDF), Ether extract (EE), Ash, Metabolisable energy (ME), organic matter digestibility (OMD), Calcium (Ca) and Phosphorus (P). For details on the analytical methods used, refer to Annexure 1.

All methods used in the laboratory of the MAWF (Agric Lab), are standard analytical methods approved by AOAC. In addition, the competency of the lab is assessed by AgriLASA every quarter through participation in the Proficiency Testing Programme.

6.6.2 Slaughter data

At the end of the intensive feeding trials conducted at ORS, the animals were slaughtered at an abattoir to determine if the diets had differential effects on the condition of the digestive tracts of the animals. Macroscopic evaluation included the measurement of ruminal pH and visual appraisal of the colour, rumen-fill and any other noticeable characteristics. Liver and rumen samples were also collected for possible future laboratory testing

6.7 Statistical analysis

The following data was collected during the experiments and subjected to statistical analysis:

- live body weights
- feed intake
- carcass information
- data on the nutritional value of milled bush
- data on all experimental bush based diets

The data was cleaned before analysis by removing all outliers. Least Square Means (LSM) of all variables measured were obtained using One-way ANOVA of STATISTICA for the sheep trials.

For the cattle trials, all measured variables were analysed by Proc GLM and GLM Proc Mixed of the SAS software.[2] Significance was declared at a confidence level of 5% (P-value < 0.05).

[2] For explanations of these analytical functions, refer to the user manual of the Statistical Analysis System (SAS) software, version 2008

7 Results and Discussion

7.1 Nutritional analysis

7.1.1 Milled bush biomass

The results of the nutritional analysis of the milled bush, as displayed in Table 8, shows that the crude protein (CP) was 8.5% which is theoretically sufficient to meet the maintenance requirements of ruminants. However, due to the low organic matter digestibility (46.48%) of the milled bush, not the entire CP is available for the animal to utilise. It is assumed that the low digestibility was due to the high (46.57%) Acid-detergent fibre (ADF) in the bush.

The following table presents the results of the analysis of the milled bush material used to constitute animal feed as fed to the trial animals.

Table 7: *The average (LSM ±SE) chemical composition of the milled bush used in the bush based diets on dry matter basis*

Chemical constituents	Milled Bush
Dry matter (%)	94.92±0.41
Crude Protein (%)	8.51±0.64
Acid-detergent fibre (%)	46.57±1.90
Neutral-detergent fibre (%)	57.91±2.67
Fat (%)	1.50±0.12
Ash (%)	7.08±0.58
Organic matter Digestibility (%)	46.48±1.57
Metabolisable energy (MJ/kg)	6.18±0.20

7.1.2 Experimental diets

SHEEP FEEDING TRIALS

The results of the nutritional analysis of six treatments used in the sheep feeding trials are summarised in Table 8.

Table 8: ***The average Ls(mean ±SE) chemical composition of the six treatment diets fed during the experiment on dry matter basis***

Chemical constituents	Treatment diets*					
	Diet 1	Diet2	Diet3	Diet4	Diet 5	Diet6
Dry matter (%)	94.64±0.41[a]	94.65±0.41[a]	94.55±0.41[a]	93.71±0.41[a]	94.43±0.41[a]	94.23±0.41[a]
Crude protein (%)	9.84±0.64[a]	11.77±0.64[b]	11.61±0.64[bc]	9.90±0.64[ac]	9.45±0.64[a]	10.66±0.64[ab]
Acid-detergent fibre (%)	34.20±1.90	37.87±1.90	39.15±1.90	34.39±1.90	36.94±1.90	31.03±1.90

	ab	a	a	ab	a	b
Neutral-detergent fibre (%)	52.74±2.67^{a}	48.04±2.67^{a}	48.47±2.67^{a}	44.64±2.67^{cb}	45.71±2.67^{a}	42.88±2.67^{b}
Fat (%)	1.45±0.12^{a}	0.92±0.12^{a}	0.96±0.12^{a}	1.04±0.12^{a}	1.22±0.12^{a}	1.08±0.12^{a}
Ash (%)	7.81±0.58^{a}	7.15±0.58^{a}	6.47±0.58^{a}	6.83±0.58^{a}	7.45±0.58^{a}	11.13±0.58^{b}
Organic matter Digestibility (%)	55.52±1.57^{a}	47.46±1.57^{b}	45.42±1.57^{b}	47.55±1.57^{b}	45.89±1.57^{c}	51.92±1.57^{ac}
Metabolisable energy (MJ/kg)	7.61±0.20^{a}	6.36±0.20^{a}	6.13±0.20^{a}	6.43±0.20^{a}	6.14±0.20^{a}	6.69±0.20^{a}

Diet 1: control diet; Diet 2 to Diet 6: bush based diets

[a,b,c] Means with different superscripts within a row are significantly different ($P < 0.05$)

Irrespective of the type of supplements used, the DM of the bush based diets was fairly similar to each other (Table 9) and to the milled bush (Table 8). The analysis had shown that the added supplements had boosted the crude protein (CP) levels of the experimental diets, with the ones containing non-protein nitrogen (NPN) as nitrogen source being significantly higher. The high levels of CP in the bush based diets with NPN mainly feed graded urea, could be attributed to the fact that urea contains more percentage of nitrogen (N %) than most true protein sources. Since CP is a calculated value derived from multiplying the N % in the feed with the constant factor of 6.25, the observed trend in the experimental diets could be expected. However, it should also be noted that irrespective of the nitrogen percentage in the feed, true proteins are efficiently utilised by ruminants than NPN (Misra et al., 2006), especially if they are undegradable protein, because of their amino acid profile. The later scenario, could also be the possible explanation to the observed growth rate differences between the groups fed Diet 5 and 4 containing camelthorn pods which is natural protein compared to the groups fed Diet 2,3 and 6 containing NPN but indicate high CP contents.

The total fibre (NDF) for the control diet (Diet 1) was high than all the bush based diets but only significant compared to Diet 4 and Diet 6. However, indigestible fibre fraction (ADF) seem to be fairly the same across all experimental diets except for Diet 6 which was significantly lower than that of Diet 2, Diet 3 and Diet 5.

Since roughage constituted a big fraction of energy source in experimental diet, it was expected that more energy would be released as the roughage get digested. However, the analysis had shown that addition of supplements to the milled bush had not significantly improved the digestibility to improve metabolisable energy levels in the diets. The estimated Organic matter digestibility (OMD) of all bush based diets was below or just average of 50%, while ME values remained below the recommended 8 MJ/kg for maintenance. These observed results could be an indication that the inclusion levels of supplements added to the milled bush was beneficial in topping up the required nutrients by the animals such as protein but was not significant enough to break down the indigestible fibre fraction.

When the milled bush analysis results were compared to those of bush based diets, the analysis showed that addition of supplements to the milled bush had significantly lowered the ADF of bush based diets. On the other hand, only the total fibre (NDF) of bush based diets with inclusion levels of supplements between 35–50% was reduced.

CATTLE FEEDING TRIALS

The results of the nutritional analyses of the commercial supplements provided by Feedmaster for the trial can be found in Table 10. These commercial supplements were used to complement the roughage fraction, which was grass in the commercial diet (Diet 4) and bush in the bushed based diets (Diet1, 2 and 3). Diet 4 composed of 25% grass and 75% Commercial Feed Mix while the bush based diets composed of 50% bush and 50% Bush Trial Feed Mix.

Table 9: *Comparison of the Chemical composition of the Trial mixes on a dry matter basis. Analyses were provided by Feedmaster™.*

	Commercial Feed Mix	Bush Trial Feed Mix
Moisture (%)	12.10	12.10
Ash (%)	10.16	10.17
Fat (%)	4.75	4.79
Crude protein (%)	16.43	16.47
Crude fibre (%)	8.37	8.45
ADF (%)	-	-
NDF (%)	30.31	30.40
OMD (%)	-	-
ME (MJ/kg)	9.92	9.94

The commercial and bush trial feed mix analyses were provided by Feedmaster™ and the analyses were run only once. Therefore, they could not have been subjected to statistical analyses. The analyses of the various compositions of the 4 experimental diets were conducted by using the statistical analyses as described in section 7. The results can be found in Table 11.

Table 10: *Chemical composition (LSM ±SE) of the experimental diets.*

	Treatment diets				
	Diet 1	**Diet 2**	**Diet 3**	**Diet 4**	**P-value**
Moisture (%)	8.3±0.7[a]	9.1±0.6[a]	8.9±0.6[a]	8.7±0.6[a]	0.9
Ash (%)	8.7±0.6[a]	9.5±0.5[ac]	13.7±0.5[b]	10.2±0.5[c]	<0.0001
Fat (%)	4.1±0.4[ac]	3.0±0.6[ab]	2.1±0.5[b]	4.8±0.5[c]	0.0002
Crude protein (%)	14.2±0.4[ac]	13.4±0.3[a]	11.6±0.3[b]	14.4±0.3[ac]	<0.0001
Crude fibre (%)	16.2±1.8[ab]	14.5±1.5[ab]	17.8±1.5[a]	12.2±15[b]	0.1
ADF (%)	23.5±1.0[a]	22.6±0.9[a]	21.0±0.9[a]	14.6±0.9[b]	<0.0001
NDF (%)	45.7±2.6[a]	39.9±2.2[ab]	37.0±2.2[b]	35.8±2.2[b]	0.04
OMD (%)	63.2±0.3[a]	62.8±1.0[a]	63.4±0.0[a]	71.0±1.0[b]	<0.0001
ME (MJ/kg)	9.0±0.2[a]	8.6±0.2[ab]	8.2±0.2[b]	10.3±0.2[c]	0.0001

Diet 1 to Diet 3- bush based diets; Diet 4-control

[ab] Means with different superscripts within a row are significantly different (P<0.05)

Table 11 shows that NaOH did not have any effect on the moisture content. Ash content increased with the NaOH inclusion similarly to the findings of Arisoy (1997) and Moss et al. (1990). NaOH does neither have a significant effect on crude fibre, nor on ADF. However, it did have effect on the NDF at the 10% treatment rate, but was less effective than the values observed by Arisoy (1997) where there was a greater effect on the NDF.

The effect of pre-treating the bush with a 2.5% NaOH solution did not affect the CP, OMD and the ME significantly, but the 10% NaOH treatment did affect the CP and ME negatively. Table 11 indicates that with the increase in the NaOH treatment rate, the CP content decreased from 14.2% in Diet 1 to 11.6% in Diet 3. This effect could be attributed to the denatured protein by the exothermic reaction of NaOH (Warner, 1941) during the pre-treatment of the bush material.

The protein content (CP) in all the experimental diets ranged from 11.6 to 14.4% (Table 11) which is above the requirement (10% CP) needed for growing beef steers with an initial average weight of 150 kg. The expected growth rate was 700 g/day (NRC, 1984). In terms of energy, all bush based diets contained less energy than the level required by growing and finishing cattle (9.6 MJ/kg), with Diet 3 being significantly lower than Diet 1 and 2.

Although Diet 4 had higher nutritional content than the bush based diets, it should be noted that the inclusion rate of the concentrate trial mix was higher (75%) than that in the bush based diets (50%). However, the inclusion rate of bush material was limited to 50% to be used as a benchmark to explore its potential as a roughage source. Therefore, higher inclusion rates of concentrate mix could be explored to increase the nutritional value to match the Commercial diet (Diet 4) used in this study.

For interest sake, the findings from Kubirske's (1989) experiments using NaOH are presented in the table below. However, it should be noted that the basis of research were different, and the comparison of the results between the two trials, i.e. the one conducted in 1989 and this report, is difficult. Conclusive arguments on the comparison are not possible. The inclusion of test results from 1989 are aimed at providing the reader additional information.

The Table eludes that the diets provided to the cattle contained higher energy levels than the ones tested during the recent trials. While cellulose content could not be measured during these trials, it seems that the NaOH pre-treatment had a positive effect on reducing cellulose content. This means, the complex lignocellulosic biomass structures were opened up and fibres were laid free to become better digestible for the animals, which need them as a source of energy.

Table 11: *Chemical composition of the diets administered during the Neudamm trials, done in 1989 (Kubirske, 1989) (dry wt. %)*

	0% NaOH	**3% NaOH**	**6% NaOH**
Dry matter (inverse of moisture)	96.11	95.53	95.13
Organic Matter	94.84	91.55	89.26
ME	18.44	18.04	17.41
CP	6.90	6.57	6.47
NDF	74.21	72.72	68.52
ADF	59.61	57.45	54.18
Hemicellulose	14.60	15.28	14.35
Cellulose	44.20	42.74	40.28
ADL	15.41	14.70	13.89
Phosphate	0.047	0.040	0.045
Calcium	1.56	1.56	1.53

7.1.3 Overall feed quality of the bush based diets

SHEEP FEEDING TRIALS

The quality of the bush based diets was generally good in terms of improved chemical composition. The CP ranged between 9 and 12% which is sufficient for maintenance. The fibre content also ranged among acceptable levels (ADF between 31 and 40% and NDF between 42 and 48%). However, the digestibility of the five bush based diets was poor (OMD below 50%) affecting the ME which was also low (around 6MJ/Kg). This might have been caused by the indigestible fibre in the bush and the possible presence of anti-nutritional factors.

CATTLE FEEDING TRIALS

Generally, the bush based diet without the NaOH treatment (Diet 1) was comparable to the Commercial diet (Diet 4) in terms of the nutritional value. However, pre-treatment with the NaOH seemed to have negatively influenced the quality of the bush based diets in terms of the nutritional value and palatability. This may indicate that the 10% treatment rate of NaOH was too high and may not be viable for ruminant feed. In addition, NaOH pre-treatment cannot substitute the need for the addition of supplements in ruminant feed to increase the nutritive value of the bush material. During the duration of the trial, it was observed that the animals fed Diet 3 seemed to have a higher water intake than the other groups. Picture 18 and 19 show the difference in the dampness of the soil between the two groups with animals fed Diet 3 urinating more frequently. The same was not observed with the animals fed Diet 2 which also contains bush material pre-treated with NaOH. It is suspected that the 10% NaOH inclusion level caused greater thirst in the animals. Similar findings were observed by Koes and Pfader (1975).

Although Diet 4 showed the highest nutritional value of all the experimental diets, animals fed that diet consistently experienced bloat during the duration of the trial. Several factors can contribute to frothy bloat, such as, small feed particle size and rapidly digestible feedstuff (Howarth et al., 1991). The diet was formulated correctly since the roughage portion of the feed was 25% which should have been sufficient as effective fibre. However, the milling and pelleting process may have led to the particle size of the constituents of the pellets to be too small to stimulate rumination.

Picture 18: *Condition of the soil in the pen of the animals fed Diet 3 (Photo: J Iikela, Ministry of Agriculture, Water and Forestry, 2017)*

Picture 19: *Condition of the soil in the pen of animals fed Diet 4 (Photo: J Iikela, Ministry of Agriculture, Water and Forestry, 2017)*

7.2 Animal production and growth

SHEEP FEEDING TRIALS

The effects of the diets being fed on a daily basis to the sheep on the live body weight of experimental groups are shown in Table 13, Figure 8 and Figure 9. The latter reflects the average daily weight gain; total weight gain (TWG), and a comparison of diets.

Overall, Diet 5 has outperformed all treatment diets including the control (Diet 1) which is a non-bush based diet. The diets' effect on the live body weight of experimental groups is shown in Figure 8.

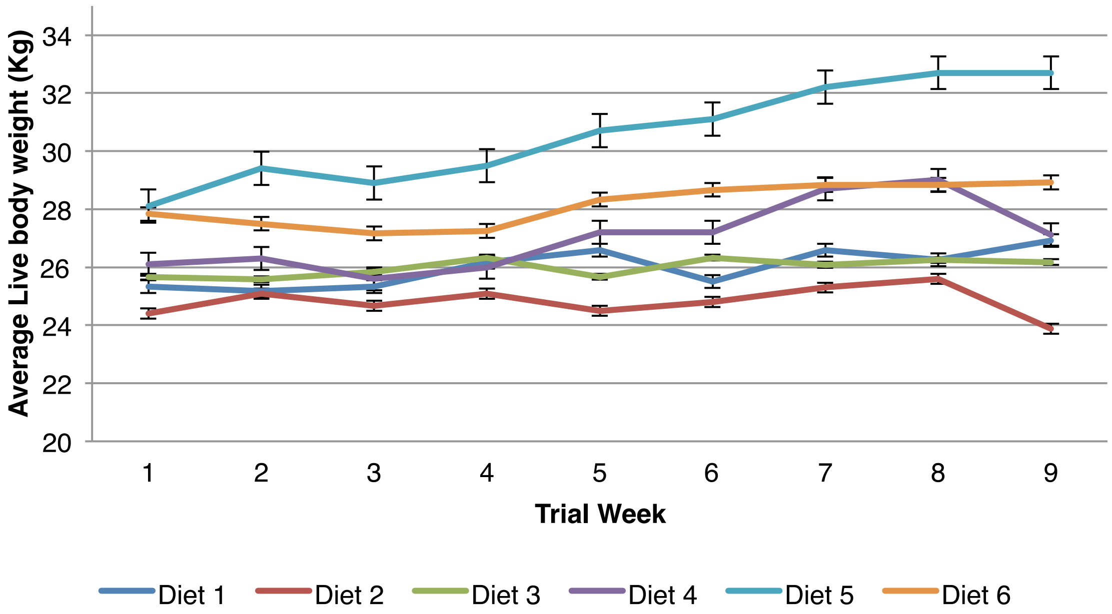


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Figure 8: *Average live body weights of sheep during the feeding trial period*

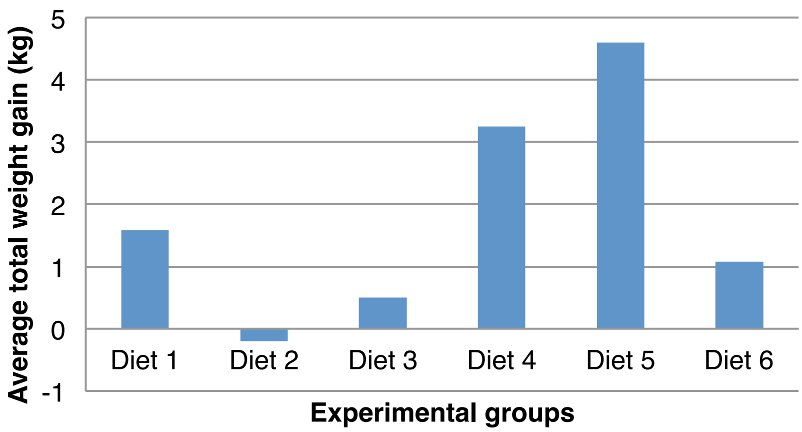

Figure 9: *The average total weight gain of different experimental groups which received those respective diets*

The growth performance results show that all experimental groups either maintained their body conditions or gained weight over a feeding period of 9 weeks (Figure **8**), except the experimental group fed with Diet 2, which had a slight negative growth of 200 g on average (Figure 9).

Table 12: *The average daily gain (ADG) (LSM ±SE) of experimental groups fed different diets during the feeding period*

	Treatment diets *					
	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5	Diet 6
ADG (g)	27.85±12.76 ^{ac}	-10.28±12.02 ^{a}	4.25±13.22 ^{a}	59.22±19.10 ^{c}	73.36±7.01 ^{b}	16.80±7.15 ^{a}

* Diet 1 – Control diet; Diet 2 to Diet 6- bush based diets

^{a,b,c} Means with different superscripts within a row are significantly different (P < 0.05)

The growth rate differed between treatment groups, with Diet 5 being significantly higher (P-value < 0.05) than Diet 1, Diet 2, Diet 3 and Diet 6. Although, experimental group fed Diet 5 slightly outperformed those fed Diet 4, there was no significant difference in growth performance between the two groups. Diet 4 and Diet 5 were all supplemented with 40% Camel thorn pods, the only difference being that Diet 5 had additional 10% of sundried *Opunti*a cladodes instead of 10% molasses added to Diet 4 as energy source.

The average total weight gain of experimental group fed Diet 4 was significantly higher (P-value < 0.05) than those fed Diet 2, 3 and 6 but not those fed Diet 1.

Diet 2 and Diet 3 had similar composition with the only difference that PEG was added to Diet 3. It was expected that the experimental group fed Diet 3 would show better performance than the group fed Diet 2 without PEG. This was based on the assumption that addition of PEG would have improved the protein digestibility of Diet 3, making it more available to animals. However, the difference in growth performance between the two groups was not significant. In that case, it is possible that the quantity of PEG added was not effective enough or the underlying assumption that the bush material contained tannin was wrong. However, no analysis to determine the tannin levels was conducted.

A comparison of Diet 1, Diet 4 and Diet 5 with Diet 2, Diet 3 and Diet 6, suggests that lambs fed diets supplemented with natural protein sources such as Camelthorn pods and Lucerne hay perform better than those fed diets containing urea as a source of nitrogen.

The results also indicate that the groups fed bush based diets with the inclusion levels of 65-85% milled bush (Diet 2, Diet 3 and Diet 6) had lower growth rate compared to the groups fed bush based diets containing 50% of supplements (Diet 4 and Diet 5). Furthermore, it was expected that lambs fed with Diet 6 containing 35% supplements would have better growth than those fed Diet 2 and Diet 3 containing 15% molasses as the only supplement. However, the results have shown that there was no significant difference in growth of lambs fed those three diets. This possibly suggests that the combination of molasses, Rangeland grower™ and Bush improver lick™ at 35% inclusion rate is just sufficient for maintenance and not to support growth.

The low growth performance of Diet 2 and 3 as compared to other bush based diets was, however, expected since they contain high inclusion levels of bush material (85%), while others contain 50-65%. The milled bush materials are associated with high indigestible fibre as shown in in Table 8, which also seems to have a negative relationship with organic matter digestibility of bush based diets (Table 7). As a general rule of thumb, the more digestible the feed is the more nutrients are available to be absorbed by the animals, thereby allowing for a better growth performance.

Diet 6, in comparison to Diet 4 and 5, was also meant to allow for the evaluation of the effectiveness of the local supplements as compared to commercial supplements. The results of this experiment show that the group fed bush based diets with local supplements had a better growth performance than the group fed bush based diets with commercial supplements. On the one hand, it must be taken into consideration that the bush based diet with commercial supplements contained 15% more bush material than the diets with local supplements, which could have been a contributing factor to the differences in growth performance. On the other hand, the given composition of diets in this experiment was also meant to keep the prices of different diets comparable in order to guarantee that they are eventually meaningful (i.e. affordable) to the end-user; the inclusion of commercial supplements hence required a higher inclusion ratio of bush to balance costs.

Therefore, the overall observed growth performance among the treatment groups could be attributed to the type and inclusion rate of supplements added in the different diets.

CATTLE FEEDING TRIALS

The data for the semi-intensive feeding trials presented in Figure 10 includes data from the adaptation period. To reduce feed costs, the number of animals per group was reduced from 8 to 6. Although the data in Figure 10 suggests that the Grazing group (control) had outperformed the other groups, in terms of the Total Weight Gain (TWG) and Average Daily Gain (ADG), there was no significant difference (P value>0.05), see Table 14. In group 5 the baseline weight was somewhat higher, as the animals were older than the average of the total group. If these older animals (which in many cases also become the dominant animals) were to be spread among the groups fed with bush based feed, feed-time aggression may have impacted feed intake by other animals negatively. As group 5 animals were grazing only, the risk of feed-time aggression was excluded.

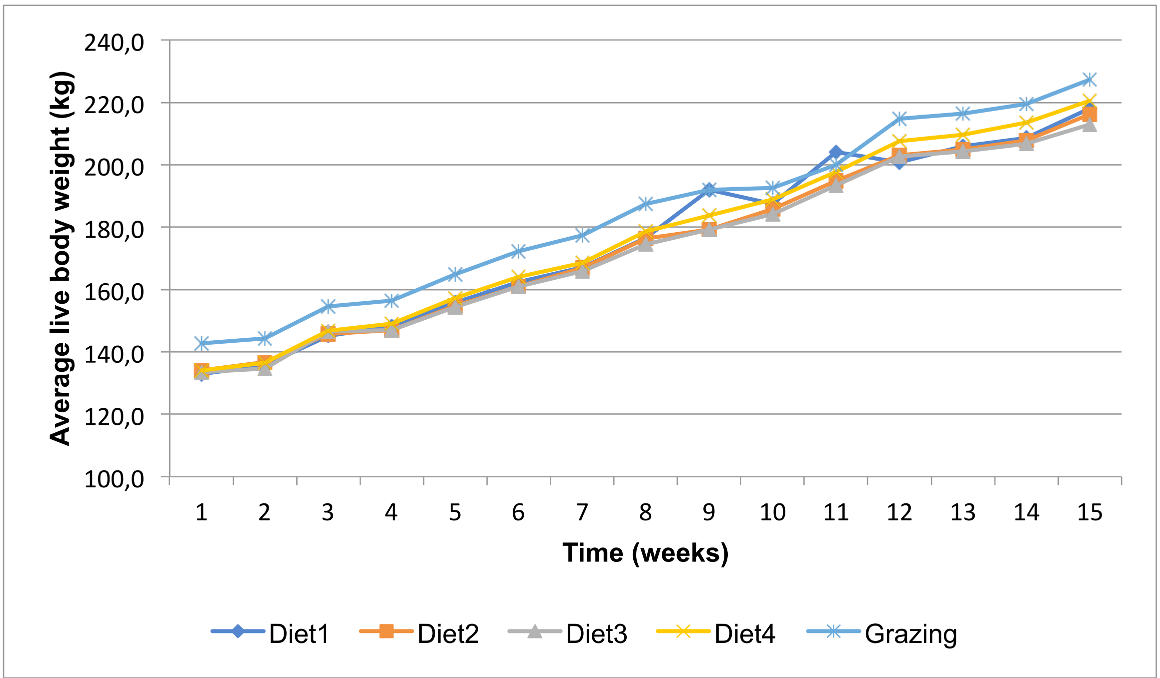

Figure 10: *Average live body mass of the weaners during the feeding period.*

Table 13: *Growth rate **(LSM ±SE)** of cattle on Farm Langbeen during the trials*

	Treatment diets					
Variable	Diet 1	Diet 2	Diet 3	Diet 4	Grazing	P-value
Initial live body weight (kg)	132.92±8.1[a]	134.08±8.1[a]	133.50±8.1[a]	134.67±8.1[a]	163.08±8.1[b]	0.06
Weight after adaptation (kg)	148.25±8.1[a]	147.08±8.1[a]	147.00±8.1[a]	151.42±8.1[ab]	174.00±8.1[b]	0.1
Final live body weight (kg)	218.08±11.3[a]	216.17±11.3[a]	213.00±11.3[a]	229.50±11.3[a]	242.92±11.3[a]	0.3
Total weight gain (kg)	69.83±5.4[a]	69.08±5.4[a]	66.00±5.4[a]	78.08±5.4[a]	68.92±5.4[a]	0.6
Average daily gain (ADG) (g)	0.83±0.06[a]	0.82±0.06[a]	0.79±0.06[a]	0.93±0.06[a]	0.82±0.06[a]	0.6
Feeding period (days)	112	112	112	112	112	

[a,b] Means with different superscripts within a row are significantly different (P-value<0.05)

7.2.1 Cattle feeding trials at Omatjenne Research Station

The data presented for the intensive feeding trials at ORS only included the 84 trial days after the adaptation period. All groups showed a positive growth trend (Figure 11) with those fed Diet 2 and 3 performing significantly lower in terms of the total weight gain (TWG) and average daily gain (ADG) (Table 16).

There were significant differences (P value <0.02) in the TWG with the animals fed Diet 3 gaining the least amount of weight, while those in Diet 4 had the biggest weight gain. The growth trend coincides with nutritional value of the diets in Table 11 where that Diet had the highest nutritional value and Diet 3 had the least. Indeed it was expected that the animals in Diet 4 would gain more weight than the other groups since the Diet contained 75 % of the feed-concentrate while the other three diets only contained a 50% inclusion rate. In terms of TWG and ADG, the Grazing group out performed Diet 1 although not significantly, but the difference was significant if compared to the results for both Diet 2 and 3. These findings could be explained by the trend of the nutritional values in Table 11 where the treatment with NaOH seemed to have decreased the CP and ME. In addition, the performance of the Grazing group could be attributed to their access to green grazing, which was nutritious at the onset of the trial (January). As the trial progressed, the grass began to mature and the value decreased. As is common in Namibian farming practice, the animals were then provided with 500 g of the Rangeland Grower™ daily. Despite the low quality of grazing, the growth performance of this group continued to be strong.

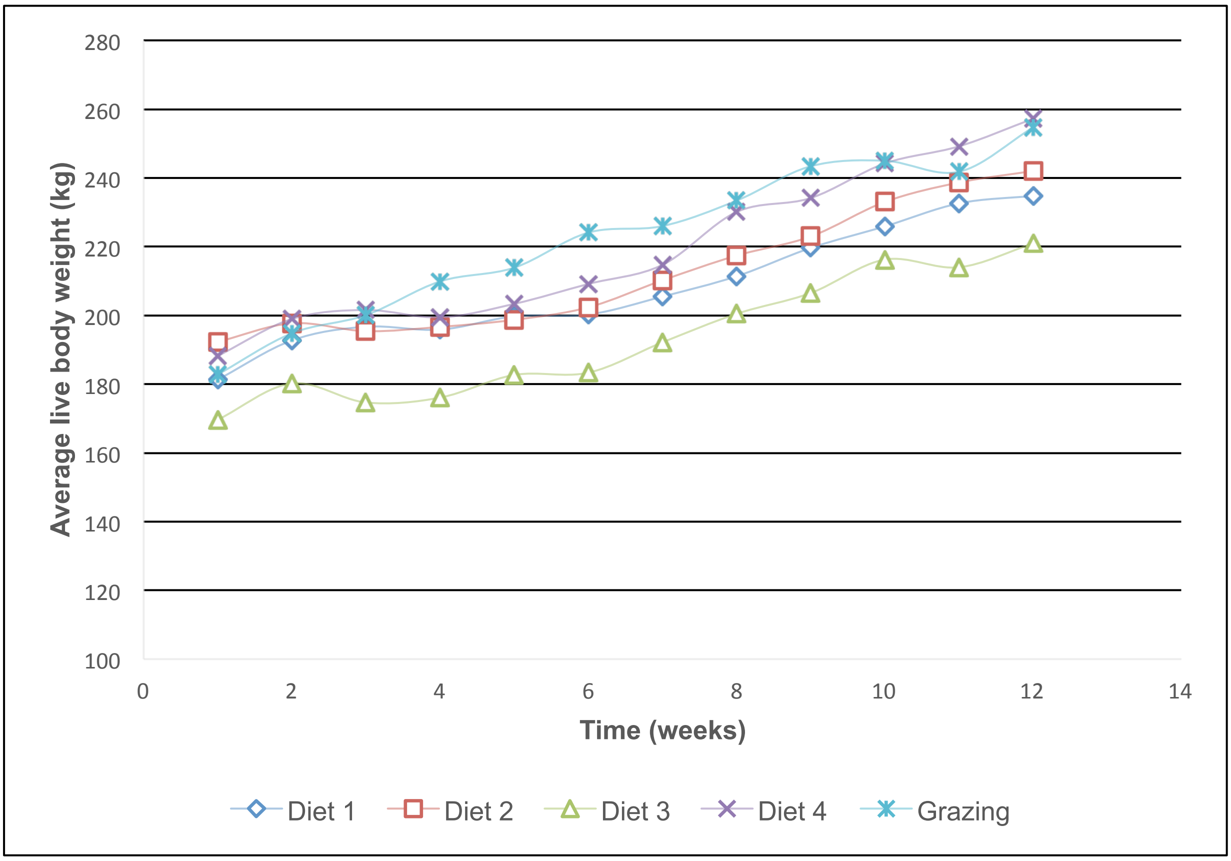

Figure 11: *Average weight (LSM) of the weaners during the feeding period at Omatjenne Research Station*

The animals fed Diet 4 (Commercial diet) had lower feed intake levels when compared to those fed the bush based diets (Diets 1 to 3) (Figure 12). This is probably due to the higher nutrient density of Diet 4 (Table 11), which would explain why these animals had a better feed conversion ratio (FCR) compared to the other groups. However, all the groups were less efficient (Table 16) than Nguni tested in feedlot conditions as reported by the Bester et al. (2001) which on average had a FCR of 6.68. The feed efficiency could be improved by decreasing the roughage (bush) to concentrate ratio so that the diets are comparable to a typical feedlot diet as the one used in the reported study above.

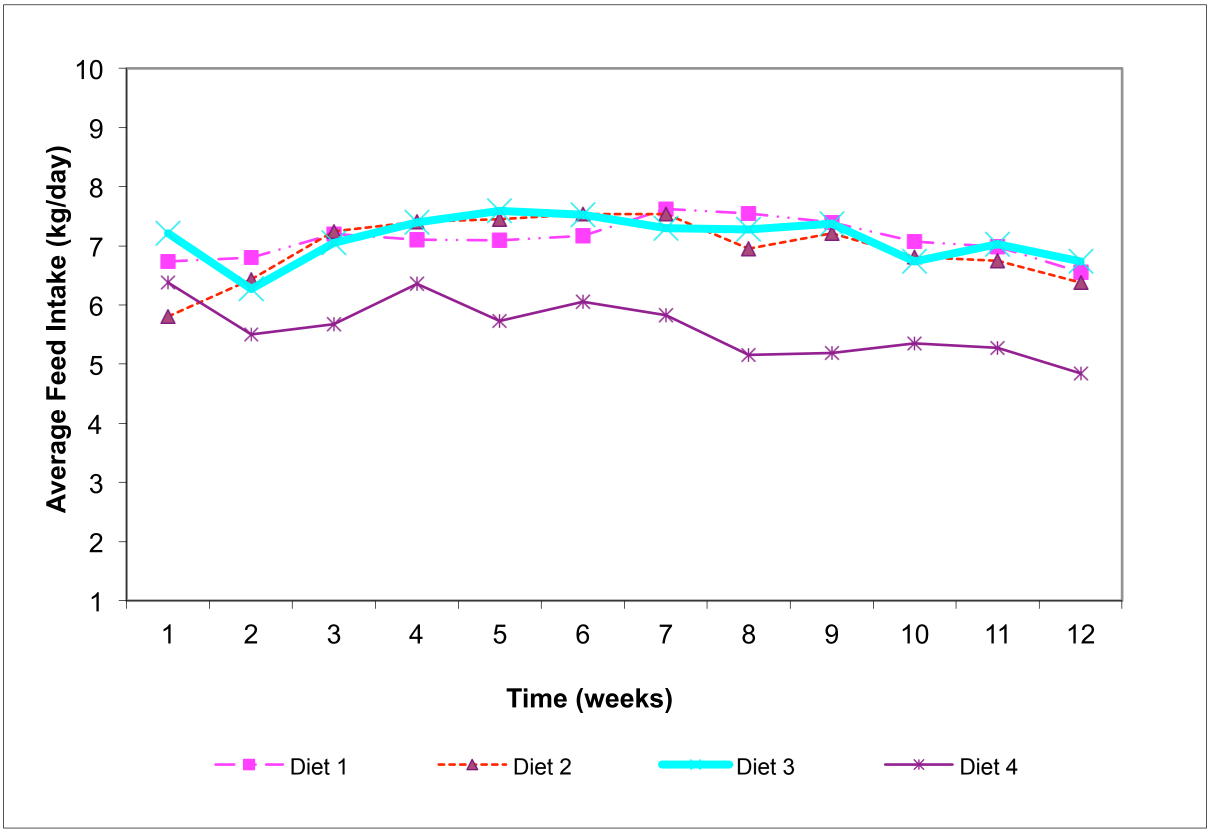

Figure 12: *Average feed intake (LSM) of the weaners during the feeding period*

Table 14: *Performance of the cattle (LSM ±SE) at Omatjenne feeding trial*

	Treatment diets *					
Variable	Diet 1	Diet 2	Diet 3	Diet 4	Grazing	P-value
Initial live body weight (kg)	150.15±8.0[a]	150.35±8.0[a]	151.10±8.0[a]	150.67±8.5[a]	151.75±8.0[a]	1.0
Body weight after adaptation (kg)	177.50±9.8[a]	186.40±9.8[a]	166.10±9.8[a]	182.00±10.3[a]	182.80±9.8[a]	0.6
Final live body weight (kg)	238.00±13.2[a]	245.60±13.2[a]	222.85±13.2[a]	256.00±13.9[a]	254.70±13.2[a]	0.4
Total weight gain (kg) (after adaptation period)	60.50±4.4[ab]	59.20±4.4[a]	56.75±4.4[a]	74.00±4.6[b]	71.90±4.4[b]	0.02
Average daily weight gain (ADG) (g)	0.72±0.07[ab]	0.70±0.07[b]	0.68±0.07[b]	0.88±0.08[c]	0.86±0.05[ac]	0.02
Feed intake (kg DM/day/head)	7.11±0.2[a]	6.96±0.2[b]	7.12±0.2[b]	5.61±0.2[c]	-	0.0001
FCR (kg DM intake/kg gain)	10.61±0.4[a]	10.35±0.4[a]	13.20±0.4[b]	9.06±0.4[c]	-	<0.0001
Cost of diet/kg (N$)	4.56	4.57	4.61	11.90	5.71	-
Cost of diet/head/day (N$)	32.42	31.81	32.82	66.76	-	-
Feeding period (days)	84	84	84	84	84	-

[a,b] Means with different superscripts within a row are significantly different ($P < 0.05$)

*Diet 1- 50% Bush (0% NaOH) + 50% concentrate Diet 2- 50% Bush (2.5% NaOH) +50% concentrate Diet 3- 50% Bush (10% NaOH) + 50% concentrate, Diet 4- 25% Grass +75% Concentrate

**Concentrate in all the diets are the same commercial concentrate provided by Feedmaster but in Diet 4 which contains also yeast. Yeast was removed from the other diets not to interfere with the effect of NaOH

[a,b] Means with different superscripts within a row are significantly different ($P < 0.05$)

CARCASS CHARACTERISTICS:

Similar to the average final live body weight (Table 16), the animals fed Diet 4 and the Grazing group had the highest subsequent dressing % which was significantly different from the groups fed bush based diets. The carcasses of all the animals fell in the A Grade which is the most preferred due to the tenderness of the meat, while the Fat classification scores were between zero (no fat) and three (medium fat). There were differences, however in the number of animals under each Fat score. Majority of the animals in Diet 1 and the Grazing group had a Fat score of 1 which were 70 and 60 %, respectively. While majority of the animals in Diet 3 had a score of 2 and the ones in Diet 2 had an equal number of animals scored 1 and 2. Diet 2, 4 and the Grazing groups had no animals with a score of 0 (no fat), while Diet 4 was the only group to have some animals graded with a score of 3. The fat content of meat is associated with the saleable meat yield, so the increase in fatness indicates a lower percentage of edible meat on the carcass. All the animals were classified as 2 (flat) or 3 (medium) on the Conformation classification scale, which indicates muscle thickness in carcasses.

Table 15: *Slaughter weight (LSM ±SE) and carcass characteristics of cattle at Omatjenne Research Station*

	Treatment diets *					
Variable	Diet 1	Diet 2	Diet 3	Diet 4	Grazing	P-value
Carcass weight and dressing percentage						
Slaughter weight (kg)	221.30±13.2^{a}	232.10±13.2^{a}	214.90±13.2^{a}	234.11±13.9^{a}	231.80±13.2^{a}	0.8
Hot carcass weight (kg)	110.58±7.3^{a}	114.80±7.3^{a}	114.77±7.6^{a}	131.36±7.6^{b}	125.92±7.3^{a}	0.3
Cold carcass weight (kg)	107.20±7.0^{a}	111.36±7.0^{ab}	109.91±7.0^{ab}	127.42±7.4^{b}	122.12±70^{a}	0.2
Dressing percentage (%)	48.35±0.56^{a}	47.94±0.6^{a}	50.52±0.6^{b}	53.08±0.6^{c}	52.72±0.6^{c}	<0.0001
Carcass Grading						
Grade A0 (%)	10	-	10	-	-	
Grade A1 (%)	70	50	20	11	60	
Grade A2 (%)	20	50	70	56	40	
Grade A3 (%)	-	-	-	33	-	
Conformation						
Score 2 (%)	80	90	50	33.3	30	
Score 3 (%)	20	10	50	66.6	70	

[a,b] Means with different superscripts within a row are significantly different ($P < 0.05$)

8 Business case

8.1 Total production achieved during the trials

All of the feed produced for the sheep and cattle feeding trials was produced at Farm Langbeen. The template matrix to calculate the resultant costs is presented in Figure 12.

The costing in this model highlights the importance of producing large enough quantities to either diversify the bush based feeds or lower production costs. It makes commercial sense to harvest large enough quantities of bush during the plants' active growth season, dry such, and pre-treat it with NaOH and dry it again, where after the bush material can be stored and used as and when necessary to mix it with supplements and pellet it into fodder. The elements of this costing approach are presented in Table 16, including the total quantities of bush and pellets produced during the trials, according to the required diets.

Table 16: *Feed production quantities at Farm Langbeen, catering for feeding trial executed at Farm Langbeen, and Omatjenne Research Station*

Description	Quantity	Observations
Bush harvested	37,000 kg	Harvest period – sheep feed, 1 July 2016 to 30 September 2016 Harvest period – cattle feed, 2 January to 31 March 2017
Bush material milled	15,500 kg	Milling sheep feed, 1 July 2016 to 30 September 2016 (no drying required; direct feeding after mixing with supplements) Milling cattle feed, 2 January to 31 March 2017
Bush pre-treated with an NaOH-mixture	9,700 kg	For cattle feed only; according to methods described above
NaOH-crystals	800 kg	Available in 25 kg bags
Hay (Feed Sorghum)	216 bales	Each bale weighed approx. 18 kg; due to severe shortages of grass in Nov/Dec 2016, the project had to resort to use feed sorghum hay, which was obtained from a farm near Outjo; the most expensive resource mainly due to transport costs (NAD184/bale!)
Sheep feed mixtures (	4,480 kg	Loose feed, not pelleted
Pellets (all types) produced	38,000 kg	Of which 35,900 kg were delivered to Omatjenne Research station

8.2 Underlying assumptions

The basis of the model assumes that the farmer/ livestock producer has all essential equipment readily available on the farm to prepare bush based feed and could commence with production immediately in e.g. a drought situation. If specific equipment still needs to be bought, a scenario to flexibly switch between commercial feed and bush based feed becomes questionable in especially a drought situation. The capital layout was considered too high in such situation, as it was assumed that the farmer is already cash stricken due to the drought situation, that it would make little commercial sense to invest a substantial amount of funds into equipment, instead of utilising such funds to sustain the livelihood of the farming enterprise as a whole. A small profit margin was built into the model to cater for capital accumulation to enable the farmer, to over time consider the purchase of essential equipment to make animal feed at some commercial scale, and to make the costing of the animal feed comparable to its commercial equivalents (in terms of feed energy content). Furthermore, the below model does make provision for such equipment being rented for a specific duration, as the fixed costs are part of it.

The following assumptions are underlying the costing model:

BUSINESS MODEL

- Equity model; this means equipment and supplements are not bought on credit and thus no loan amortisations were taken into account; equipment is amortised and has between 3 and 10 years of useful lifespan; its resale value is put at 10% of the original purchase price, with straight-line depreciation when bought new
- All equipment is available on-farm, with only maintenance parts needed in case of forced stoppages or breakage
- Profit margin of 20%
- No synergies between production models, e.g. charcoal and animal feed production combined to lower overall production costs
- Feasibility and viability tested as standalone on-farm enterprise, based on an equity model
- Seasonality of feed production was taken into consideration, where the highest production levels for bush based feed would be achieved in the period December to March of each rainy season

INPUT COSTS

- Power for equipment was either supplied via the grid, or equipment was self-propelled using diesel as fuel; each instance would be indicated
- Power or fuel utilisation was taken as measured, or as per equipment specifications provided with the such equipment purchases
- Direct equipment and operational costs associated with feed production only; no land or buildings costs, no transport equipment/ vehicles costs
- Labour-based processes, remunerated at minimum wage level and according to regulatory requirements, currently standing at NAD3.87 per hour for farm workers.
- Manager salary included
- 5 permanent staff members are required to run a bush based animal feed production line, from bush harvesting up to feed mixing. The pelleting process was led by the manager, with 2 permanent staff, assisting with pelletiser feeding, and bagging of pellets.
- Insured, amortised costs for all equipment
- Local supplements, based on prices for seasonal products
- Commercial supplements, costed at retail or wholesale prices as per quotes from suppliers

PRODUCTION

- The maximum production levels of milled bush were set at 2t/day, with an 8-hour working day; at 5 days per week
- 5 permanent staff members are required to run a bush based animal feed production line, without pelleting
- Harvesting takes place at 3.5ha/day, delivering a total (whole-tree harvesting method) of 35t/day of wood material (wood, twigs and leaves combined)
- Milling accounts for 10-15% of the bush material usable for animal feed, i.e. 3.5t/day of bush-material is milled; the moisture contest at harvest was measured at between 15% to 22% at the beginning of the bush-growth season (i.e. October/November), and between 30 and 35% during

December to March. Parts of such milled bush was pre-treated with NaOH, and fermentation of the bush material required two to four days, with subsequent drying required before supplements could be mixed with the bush material, and thereafter pelleting.

- The amount of feed that was required for the trials was much less, than latter mentioned production capacity level; a penalty for lesser production of 25% was considered to account for reduced production levels.
- The costing model took into consideration that only feed for the Farm Langbeen trial animals were produced, but also for the intensive feeding trials executed at Omatjenne Research Station. The total quantity of feed produced was divided into daily feed production capacities, which then resulted in the costs per kilogram of feed made.
- The amount of feed that was required for the trials was optimal for the equipment lay-out available at Farm Langbeen. However, the major bottleneck experienced was pre-treated bush drying. Due to the rather wet rainy season, this factor weighed negatively on pelleted bush feed production.
- Where local supplements are available on the farm, the prices were based on seasonality of such products.
- Commercial supplements were costed at retail and wholesale prices as per quotes from three different suppliers; the average of such prices was taken into consideration. It is also acknowledged that during 2016, the prices for such supplements were very high in comparison to the price levels prevalent in 2017. Such price adjustments may further need to be taken into consideration.
- Seasonality of feed production was taken into consideration, where the highest production levels for bush-to-animal would be achieved in the period December to March of each rainy season.

OTHERS

- Inflation set at the target band provided by Bank of Namibia, set at 6% for future planning; current inflation levels stand at 6.7% for the period 2016/17
- Tax rate, at corporate level of 32%
- No synergies between production models, e.g. charcoal and animal feed production combined to lower overall production costs of both types of products that could be obtained from bush harvesting.
- Feasibility and viability was tested as standalone on-farm enterprise models, based on an equity model.
- Unforeseen stoppages of production were experienced due to caterpillar attacks on the bush at Farm Langbeen, and such being beyond seasonality. This loss of production was penalised by 10% in additional cost (less than optimal production).
- The socio-economic and environmental benefits were summarised in improvements in rangeland condition and stocking rate capacities for the sites where bush was extracted, extrapolated to a period of over 20 years. In monetary terms, this means that stocking rates would e.g. double. Livestock prices cannot be improved as these are daily or weekly commodity price items, but the body condition scores (BCS) of animals were assumed to improve from e.g. BCS 1 or 2 to at least BCS 3.

The template matrix to calculate the resultant costs is presented in Figure 12.

Bush cost calculation for bush feed - always assuming optimal production							
Investment and/or fixed costs (per hr)							
Bos tot Kos machine	585.00					kg bush harvested per day =	
Mower	18.97					kg bush produced per day =	
Chainsaw	10.69					kg bush harvested per day =	
Brush cutter	13.36					kg bush produced per day =	
Circular saw	19.78					kg bush harvested per day =	
Front-end loader	152.86					kg bush produced per day =	
Excavator	980.00					kg bush harvested per day =	
Mixer	2.85					kg bush produced per day =	
Pellitiser	38.52					kg bush produced per day =	
Bush costs (all prices will be per kg)							
Bush harvesting labour (total)	2	persons x	24.97	cost per person per day ÷		kg bush harvested per day =	
Bush harvesting fuel (Diesel)	10.71	price per liter x		liters used per day ÷		kg bush produced per day =	
Bush harvesting fuel (Petrol)	10.82	price per liter x	8.565	liters used per day ÷		kg bush produced per day =	
Bush harvesting (hour)				cost per equipment per day ÷		kg bush produced per day =	
Bush chipping/ milling labour	2	persons x	24.97	cost per person per day ÷		kg bush harvested per day =	
Bush chipping / milling (diesel)	10.71	price per liter x	14.54	liters used per day ÷		kg bush produced per day =	
Total bush harvesting cost per kilogram bush						(Sum of all of the above)	
Total bush per 100kg feed	84	kg x		price per kg			
Additives cost (all prices will be per total of 100kg)							
Enermol	192.00	Price per bag ÷	40	kg per bag x		kg added per 100kg feed =	
Bush Improver Lick	206.16	Price per bag ÷	50	kg per bag x		kg added per 100kg feed =	
Camel thorn pods	2.50	Price per kg				kg added per 100kg feed =	
Rangeland grower	222.33	Price per bag ÷	50	kg per bag x		kg added per 100kg feed =	
Urea	195.00	Price per bag ÷	50	kg per bag x		kg added per 100kg feed =	
Molasses w/o Urea	152.88	Price per bucket ÷	25	kg per bucket x		kg added per 100kg feed =	
Opuntia	1.30	Price per kg				kg added per 100kg feed =	
Browse Plus (PEG)	1480.37	Price per bucket ÷	10	kg per bucket		kg added per 100kg feed =	
NaOH	14.91	Price per bag ÷					
Grass	80.50	Price per bale ÷	18	kg per bale		kg added per 100kg feed =	
Lucerne	95.65	Price per bale ÷	18	kg per bale		kg added per 100kg feed =	
Feedlot feed mix	277.23	Price per bag ÷	50	kg per bag x		kg added per 100kg feed =	
Special bush supplement mix for pellets	310.00	Price per bag ÷	50	kg per bag x		kg added per 100kg feed =	
Transport	32	Total cost for transport ÷	8000	kg per load x		total kg additives per 100kg feed =	
Total cost of additives per 100kg total feed						(Sum of all of the above)	
Bagging cost per 100kg feed							
Large bags	7.80	Price per bag x	5	bags per 100kg feed			
Drying and mixing cost per 100kg feed							
Feed Mixing (Petrol as fuel)	10.82	price per litre x	8.00	litres used per day		kg feed mixed per day x 100kg =	
Transport to drying yard	5.00	km travel to drying yard x	12.60	price per km ÷		kg total weight transported x 100kg =	
Drying labour to spread bush	2.00	hours to spread bush x	3.12	price per labour hour ÷		kg total weight to dry x 100kg =	
Drying labour to collect bush	2.00	hours to collect bush x	3.12	price per labour hour ÷		kg total weight to dry x 100kg =	
Transport back to mixing	5.00	km travel to drying yard x	12.60	price per km ÷		kg total weight transported x 100kg	
Mixing labour	1	persons x	24.97	cost per person per day ÷		kg feed mixed per day x 100kg =	
Total cost for mixing 100kg						(Sum of all of the above)	
Maintenance cost for machine per 100kg feed							
Lump sum per 250 hour service		Per service incl traveling ÷		Bush produced in 7880hrs x 100kg (=1 year)			
Overhead cost per 100kg feed							
Manager or owner & other administrator costs					7	% of total feed costs	
Total cost per 100kg feed							
						(sum of all totals above)	
Add penalty for less than optimal production	25	% of production for penalty					
Add profit, at least 20%	20	% profit					
Total sales price per 100kg							

Figure 12: *Costing matrix with all costing indicators already presented*

8.3 Feed preparation costing results

8.3.1 Sheep feeding trials

The following table presents the costs for the feed diets prepared for the sheep, on a per kilogramme basis.

Table 17: *Costs of feed diets prepared for sheep over the trial period; costs are provided on a per kg basis, considering that only 40 kg were mixed per day*

	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5	Diet 6
Total Costs (NAD/kg)	1.99	2.49	2.97	2.60	2.60	4.04
Cost of wood fibres (loose; NAD/kg of feed)	0.00	1.07	0.63	0.63	0.63	0.78
Cost of supplements or additives (NAD/kg of feed)	1.99	1.42	2.34	1.97	1.97	3.26

The costs in Table 17 seem excessive, if compared to commercial feeds available. However, it should be noted, that costs were calculated based on a limited amount of feed provided to sheep on a daily basis. The main cost driver was the labour necessary for mixing the diets and providing it to the animals.

If for example at least 100 kg of each diet were to be prepared on a daily basis, the costs would reduce proportionately as per the following table. This means, the more feed could be prepared per diet per day, the lesser the proportion of labour cost becomes. The following table presented the alternative scenario in which 100 kg and 2,000 kg could be mixed per day.

Table 18: *Costs of feeds provided to sheep over the trial period; costs are provided on a per kg basis. These considered that 100 kg and 2,000 kg of feed could be mixed per day, respectively*

	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5	Diet 6
Costs for a 100 kg mixture (NAD/kg)	1.44	1.95	2.43	2.05	2.05	3.49
Costs for a 2,000 kg mixture (NAD/kg)	0.91	0.67	1.34	1.03	1.03	2.10

Please note, the price provided for Diet 1 is based on average, commercial prices for Lucerne and grass. During periods of drought the prices are normally adjusted upwards, and thus the price for such as exampled by Diet 1 could easily reach between NAD 4 to 6 per kg.

8.3.2 Cattle feeding trials

The cost to produce one kilogramme (1 kg) of milled bush material, including pre-treatment with NaOH, drying and pelleting, came out as NAD 2.11, or NAD146.75 for 50 kg, including all overheads and a profit margin. This cost includes all fixed costs (capital, insurance, amortisation, replacement and labour) and variable costs (fuel, maintenance and unforeseen stoppages).

The following table presents the costs for the feeds prepared for the four different diets for the semi-intensive and intensive cattle feeding trials, on a per kilogramme of feed basis. The costs for grazing were assumed to follow the general costing model for livestock farming in Namibia. That means, feeding cattle on natural grazing is costed at 40% of the market value of each live animal with a higher value for steers, than for heifers, plus lick supplementation. In a drought year, supplementation and feeding costs would be higher than in normal years, and thus automatically accounted for. The average market value of animals would be lower. Thus, the production price was assumed to remain rather stable, regardless whether it is a normal or drought stricken livestock production year. Farm Langbeen falls within the Khomas Highland biome type, and Rangeland Grower™ was considered to be the applicable lick supplement for the trial animals. Additional supplementation with a phosphate lick is not necessary for such biome type.

The table below summarises the cost on a per kilogramme of feed basis for each diet with which the growing cattle were fed during the trials on Farm Langbeen, as well as Omatjenne Research Station (ORS). For the semi-intensive feeding trials at Farm Langbeen, the aim was to feed each animal with approximately 3 kg of pelleted feed daily; and for ORS approximately 9 kg. The description of the diets is presented in chapter 6.4. The costs presented below do include fixed and variable costs, associated with feeding the animals on a daily basis.

Table 19: *Costs of feeds provided to cattle weaner over the trial period; costs are provided on a per kg basis, considering that in total an amount of approximately 40 tonnes of pelleted fodder was produced, with different specifications for each diet.*

	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5
Total Costs of feed (NAD/kg)	4.56	4.57	4.61	11.90	5.71[a]
Cost of fibres (loose; NAD/kg of feed)	0.35	0.35	0.35	5.11[b]	0.00
Cost of wood fibres, soaked with NaOH, dried and mixing with supplements (loose; NAD/kg of feed)	0.00	0.61	0.66	0.00	0.00
Cost of pelleting (NAD/kg of feed)	1.16	0.51	0.50	2.63[c]	0.00
Cost of supplements (NAD/kg of feed)	3.10	3.10	3.10	4.16	0.00

[a] = not a feed, but only a supplement to augment the diets of grazing cattle; both Bush Improver Lick™ and Rangeland Grower™ were used.

[b] = Feed sorghum fibres had to be sourced for the trials; due to the drought situation, no hay or Lucerne was available for the project to be bought. The feed sorghum was sourced from Outjo; the majority of the costs were attributed to transport costs from Outjo to Farm Langbeen.

[c] = the high pelleting costs for this feed stems from the difficulty to pellet hay-type of materials, the frequent stoppages and breakage of pellets, that were first tried to be re-pelleted. When this didn't work, a smaller pellet mould was used, for which power usage then increased significantly.

The costs for bush based animal feed pellets highlighted in Table 19 are comparable to those of commercial feeds available. Please note though, that the supplements used in the fodder were special mixtures provided by Feedmaster to the project. The cost driver was fuel (Diesel, Petrol and oil) to generate power to chipping, milling, mixing and pelleting of the feeds. The exorbitantly expensive costs for the complete feedlot pellet of Diet 4, was the high costs of transport to obtain hay (a substitute for grass or Lucerne) from Outjo to Farm Langbeen. The usual costs for such pellet are rather in the vicinity of NAD5.54 kg and it is typically delivered in 40 kg bags. It should further be noted that rearing livestock by providing them with "only" grazing and licks, also costs money and the price driver in the trials were the high costs of the lick itself.

9 Lessons learnt and Conclusions

It was the first time that intensive bush based feeding trials with sheep were carried out in Namibia. During the Phase I feeding trials, several lessons were learned. As for feeding cattle with bush based material, the structured trials as Neudamm (Kubirske, 1989) highlighted the need to improve wood-fibre palatability. Several farmers have also attested the use of bush based fibres as an alternative feed (GIZ Survey Report, 2017). Building on the available knowledge was therefore key in conducting further research on bush based animal feed. The below outlines the key lessons learnt from the pilot project, as well as recommends further research necessary to assist in fully understanding the interaction between bush encroachment, bush control, rangeland management, and utilising bush based fibres as alternative feed in periods of fodder shortage.

Bush based animal feed is a valuable substitute for a diminishing resource, i.e. grasslands. Nevertheless, when rangelands are recovering, or have recovered during a good rainy season, the contribution from bush based feed towards maintaining the condition of livestock becomes negligible. Cattle in a semi-intensive bush based feeding programme will not voluntarily eat such fodder. However, this can be overcome by lick supplementation or adding additional sources of energy and animals gain weight rather easily. On the one hand, the usefulness of bush based feed during a good rainy season becomes questionable. On the other hand, bush based feed during the dry (winter season) or a drought year is a sought after and valuable additional source of energy for the animals. Each potential bush based feed producer must therefore assess the viability of such production based on the context-specific circumstances.

While the bush based feed is to be produced during the rainy season, when the bush and shrubs carry an abundance of leaves and cambial lignocellulosic biomass, the drying of such biomass after harvest in the open (sun drying) remains challenging. A balance between costs and maximisation of quantities of such material needs to be found.

9.1 Preparation of the bush material

It was determined that the branch size used for feed production has a major influence on the nutritional value of the bush feed. At the beginning of the experiment bush feed samples of different branch sizes were analysed and it was revealed that bigger branches have more wood and therefore dilute the nutrients. When the branch size was reduced to less than 2 cm the nutritional value of the feed improved.

To demonstrate this, a laboratory analysis was conducted on two samples of the same bush specie, harvested in the same season with the only possible difference being the quantity of wood included in each sample. This may be interpreted to represent the proportion of leaves to wood. The result clearly indicated the dilution effect of wood on the nutritional content (fat, CP, ME) and the digestibility of bush feed. Similarly, the more the wood materials is included in the feed, the higher the total fibre content of the feed (NDF), which will eventually have an influence on the intake (how much of that feed is voluntarily eaten by the animal). The ADF indicate the amount of cellulose and lignin in the feed which is less digestible.

The same applies to the age of the bush, which also has an effect of the nutritional value of milled bush. Younger bushes are less lignified and are more nutritious, especially due to their higher protein content.

Therefore, during harvesting it should be taken into consideration that for the nutritional value of the product to be consistent, the harvested bush should be uniform in terms of age and branch size. Alternatively, if practicalities do not allow this, it is encouraged that laboratory analyses are conducted on the harvested bush so that variations in nutritional values can be balanced through the addition of supplements.

Thorough mixing of the different diet components is essential to avoid selective feeding by animals. For example, it was observed during the feeding trial that molasses tends to form balls with parts of the mixtures when not mixed well. Large particles sizes also allow for selective feeding. During the trials Opuntia was not grinded to the same particle size as the other components of the mixture and was easily picked up by the sheep.

9.2 Supplements and additives

Although NPN can be used as an alternative nitrogen source, farmers should not compromise on using natural proteins, because their effects on the growth are not comparable (natural protein gives better results).

The addition of liquid or watered molasses powder makes the bush based fodder (also in pellet form) more palatable for the sheep and cattle. In addition, a mixture with liquid molasses must first be dried again for pelleting, else the pelletiser becomes congested with sticky biomass, which cleans with great difficulty.

Wood based biomass fodder should be ameliorated with supplements, even if the feed was pre-treated with NaOH to make it more digestible. When NaOH is used to improve the digestibility of the bush based fibres, they do not become palatable though. As supported by the Kubirske's research (1989), this research found that palatability should be improved by using supplements, e.g. already available on-farm, like maize or milled chop and maize or other grain stover. Even, mixing with molasses and lick supplements like Rangeland Grower ™ assists.

9.3 Preparation of bush based animal feeds

The production steps of bush based animal feed are not complex, but the process requires appropriate knowledge, an optimised production system as well as capital. The trials described in this report were conducted on a commercial farm where all required infrastructure was already available. Under such framework conditions, bush based animal feed can be an immediate solution to adverse farming conditions, such as droughts. An initial investment of at least NAD 1.5 million is required if no bush harvesting and processing equipment is available.

For the pelleting process to function optimally, the biomass mixture should have a moisture content of at least 6-7%. As soon as the mixture is too dry, the pelleting process becomes difficult and pellets have no adhesion capacity as happened with Diet 4 pellets. For large and small livestock fodder, a pellet size of 10 to 12 mm works well. It was observed, that when feed fibres became too short, cattle became bloated (6 mm pellet sizes), as the feed seemed to have been metabolised without being ruminated. The effect of short feed fibres on the rumen itself was not tested.

Larger pellet sizes also assisted in keeping birds away from the feed. Smaller sized pellets, as tried for Diet 4 during the cattle feeding trials (6 mm), attracted birds to feed on such.

NaOH, apart from being a dangerous chemical to work with, does not readily dissolve when large quantities of powder or crystals are used to mix them with water. Mixing it in containers of 20 litres capacity worked well (i.e. 9 kg of NaOH-crystals with 11 kg of water). Stirring of the water-NaOH mixture should be done using a wooden tool only. Metal reacts readily with diluted NaOH.

9.4 Animal health and production

Based on the trials conducted, none of the animals contracted health problems that may have been caused by bush based feed. The sheep that died seemed to have been ill before the trials, of which the cause could not be determined. In addition, that sheep was fed with a diet containing PEG, and the PEG itself seemed to have aggravated the deteriorating health of the sheep. For sheep, it seems that diets containing PEG should be avoided.

The death of the cattle weaner at Omatjenne Research Station was diagnosed to have been caused by excessive bloat. The bloating of the cattle can be connected to the feedlot feed, which contained too little fibre (only 25%). After feeding additional fibre (hay) to the respective group of weaners in the feedlot, bloating problems subsided. This thus means that the fibre content in feedlot feeds should be increased to levels above 30%.

Animal health and production can substantially be improved in sheep by feeding bush based diets, especially in absence of another feed, like grass. Whether bush based feed can also be used for co-feeding, i.e. the provision of bush based feed as a supplementary feed while animals also graze, was not tested.

The addition of 2.5%-NaOH solution to ferment the bush based fibres prior to feed mixing has worked well. After the "grazing only" diet, animals feeding on a diet containing fibres pre-treated with 2.5%-wt. basis NaOH, performed well. If trials were to have continued at ORS, it seems that animals feeding on that diet would have outperformed the "grazing only" ones over time.

In terms of cost-benefit considerations, the same diets that showed good animal production results were considered cost efficient too. It should however be noted that feeding sheep with Lucerne and grass in a drought period may be a futile exercise, as in such periods these resources would be very expensive, if and when even available. Thus, the reasoning for trials was that acceptable substitutions could be found to use bush based feeds instead.

9.5 Essential considerations for formulating bush based feeds

Bush-biomass is a source of fibre. It is to be considered as a feed, either as complete or partial source of nutrition. Bush cannot be considered as a lick or supplement. The nutritional needs of commercial livestock, large (e.g. cattle) and small (e.g. sheep) differ and must be considered when formulating a bush based animal feed diet. There are also differing nutritional needs for growing, beef producing or lactating animals. There are six (6) core considerations to note:

- Palatability
- Digestibility
- Protein content
- Phosphorus
- Nutritional (energy) content versus anti-nutritive factors
- Productive value of the feed, i.e. is the animal to maintain itself, or to grow/ gain weight

The characteristics of the biomass, which is to form the basis of the feed, need to be considered, too. There is a difference in the content of the elements which are to provide animals with the energy and minerals they need to maintain themselves, grow and gain weight. These differences are based on:

- Seasons and growth patterns of the plants
- Species (e.g. grass versus wood)
- Soil composition where the plants and bush grow (e.g. Sandveld versus clay soils)
- Access to sustainable water resources for growth (e.g. rain); this has a general effect on the energy content of the plant

When designing bush based feed mixes, various feed characteristics are to be considered. The following list provides an overview, including hints on how to influence the respective characteristics:

- Palatability (<15% wt.): molasses, salt
- Digestibility (<3% wt.): NaOH, PEG (be careful)
- Protein: urea (be careful), Bush Improver Lick™, Rangeland Grower™, pods (camelthorn, sickle bush, *Prosopis*), vegetable or fish oils, Lucerne, etc.
- Phosphorus (<1% wt.): commercially available P-supplements
- Nutritional (energy) content: molasses, Bush Improver Lick™, Rangeland Grower™, *Opuntia* (prickly pear), Treber (Brewers' Spent), various food oils, crop rests, etc.
- Anti-nutritive factors (<2% wt.): PEG (be careful), ash, charcoal

Feed must always be very well mixed. Livestock can selective feed from a through by using their tongues as sorting mechanism. If the feed is not well mixed, the feed may only be half-eaten, thereby losing efficiency and effectiveness of having prepared the bush based feed mixtures. When including molasses (liquid or in powder form), the feed obtains a sweet smell and becomes very attractive for the animals. Especially animals suffering of feeding-time aggression would be prone to gulping too much of the highly fibrous material (if not served as pellets) and this may lead to the affected animals getting choked.

The feeding ratios, i.e. how much of bush based fibres should be used for a specific feed are also important. The following are suggestions:

Bush based feeds, as maintenance feeds (e.g. during periods of drought, or cows for which their calves have been weaned in the dry or winter season)

- Bush based fibre content up to 85%
- Best augmented with urea, milled pods and molasses

Bush based feeds, as growth & fattening feeds (e.g. weaner feeds, or beef production finisher feeds prior to slaughtering)

- Reduce the bush based fibre content to ~50%
- To be augmented by various supplements, commercial & local inputs, like milled tree pods

Important: there is no general feed composition that can be recommended. Each producer must carefully test the own feed mix before its application, in order to account for variabilities that are caused by the characteristics of the biomass as well as used supplements. Farmers/producers are encouraged to request details from their supplement suppliers as well as consult with livestock production experts or extension officers of the MAWF.

9.6 Business case for bush based ruminant feeding

For the sheep feeding trials, a limited amount of bush based animal feed was produced on a daily basis, thus not providing a comprehensive economically viable proposition for large-scale production. It was however proven that sheep can be economically reared using bush based feeds under intensive feeding conditions, especially when such feed is combined with locally available supplements like Opuntia and Camelthorn pod meal.

For cattle weaner feeding trials, using pellets, a large amount of feed was produced which influences the business case favourably. For all diets, the bush based feed costs compared favourably with commercially available feeds.

The semi-intensive feeding programme for weaners in the rainy season was challenged by the good rains received on Farm Langbeen between February and May 2017. The animals preferred to feed on grazing only and had to be “forced” to actually eat the bush based pellets. This shows that producing and feeding the animals with bush based feeds during a period where an abundance of grazing is actually available does not provide a sensible business case. In the case of intensively feeding weaner cattle at Omatjenne, two matters were proven to work well; that is, Sanga or Nguni cattle adapted well to the feedlot situation and can therefore be feedlotted. However, the excessive urination of animals feeding on Diet 3 and their limited weight gain over the period, begs the question whether such high amount of NaOH are rendering optimal cost-benefits. As high concentrations of NaOH bear significant risks, it is suggested to limit the use of NaOH to an inclusion level of 3% on a wood-fibre weight basis. The latter is confirmed by the research done by Kubirske (1989) and these pilot trials. Limiting the use of NaOH also saves on costs.

A possible further benefit can be realised when bush is harvested, milled and dried during its active growth season and stored for the dry season. This is reasoned, as the project saw prices of commercially available feeds fluctuating substantially in periods of drought, mainly due to high demand and limited supply of such. Grass and Lucerne bales cost close to NAD 160 per bale during the trial phase, when available. Under normal conditions, bush based feed can cost less than half of the abovementioned cost per bale.

Bush based animal feed production should especially be attractive to farmers that are challenged by high bush encroachment infestation levels, regardless of whether they farm in communal farming areas or on a commercial farm. The main limiting factor relates to whether the farmer has access to the required milling equipment. Harvesting of bush and feed mixing could also be done manually. A mill or chipper of some type is necessary to comminute the feedstock (twigs, smaller branches and leafy material). A limiting factor for communal farmers was identified by perusing the current forestry regulations. This relates to a moratorium which was placed to such areas, and strictly limits the use of bush, regardless of whether such area is in a bush encroached area. Special permissions to utilise the bush must be sought. Alternatively, the communal area should lie within a gazetted conservancy area, which eases the obtaining of a permission to utilise and possibly commercialise the bush to animal feed production.

The cut-off point for optimised bush based feed production is determined by the total capacity of bush harvesting and milling operations. In trial runs conducted on the harvesting speed of front-end loader, a maximum of about 3.5 hectares of bush at a harvesting level of about 10 tonnes per hectare can be bush thinned per day. As only leaves, twigs and branches are suggested to be utilised for animal feed, one inherently harvests more biomass than is required. In addition, the chipping and milling capacity is limited by equipment throughput capacities, i.e. to about 2 tonnes per day. The exact harvest/milling ratios were not determined, but it was found that between 5 and 15% of the bush after harvest is utilisable for animal feed, depending of the size of the bush harvested. The latter scenario is presented for bush that is destined for immediate consumption of feed, with no drying, pre-treatment or storage and/or sales of the bush material at a later stage.

As the freshest possible bush material was required for animal (sheep) feed, no drying or storage took place. However, as the highest quality bush material can only be sourced during the growing season of the bush, it is advisable to consider drying and storage of the material. This would then additionally mean that sufficient drying and storage capacity must be provided. Also, the production could then be directed to harvest bush every second day only, but mill such every day, then dry the excess and store material which is not utilised immediately for animal feeding, for the winter or drier periods of the year. When drying milled bush material, attention should be given to rain. Milled bush does not dry well then and tends to mould, making the feed poisonous for animals.

There are no eminent risks to the business case, if harvesting and bush utilisation licenses are in possession of the farmer/producer.

9.7 Commercialisation of bush based feeds

Bush based animal feed is not a commodity product as yet. Thus, anyone wishing to commercialise production should endeavour to obtain licences from MAWF to do so. For the commercialization of bush based animal feed, the key piece of legislation is the "*Fertilizers, Farm Feeds, Agricultural Remedies and Stock Remedies Act No 36 of 1947*". This is a South African Act that was adopted by Namibia at independence. The Act governs the registration, importation, sale and use of the farm feeds in Namibia. Other legislation relevant for animal feed production, must consider national initiatives and regulations that are aimed to support trade in meat, in particular the export trade. Therefore, the production of animal feeds must consider the prevention of undesirable residues in meat. Feeding of ruminant protein (e.g. bone meal; but fish oil and meal is allowed) to ruminants is banned (Government Notice 199, Government Gazette No 1927 of 15th August 1998). The Namibian Standards Institute currently does not have any standard relating to animal feeds and therefore is not involved in the animal feed industry in any way.

The enforcement agencies are the Ministry of Agriculture, Water and Forestry, represented by the Directorate of Veterinary Services as well as the "*Registrar of Registration of Fertilizers, Farm Feeds, Sterilising Plants and Agricultural Remedies*".

Namibia does not have Good Manufacturing Practice Legislation (GMP) legislation. However, given that the Namibian economy relies heavily on the export of beef, mutton, hides and skins, the livestock industry in general is well managed and controlled to ensure that processes meet European, US-American and Chinese procurement standards.

9.8 Environmental improvements and socio-economic empowerment

The amount of bush extracted to conduct an analysis of the rangeland improvement was too little to warrant an analysis of its impact. However, Farm Langbeen was chosen as the pilot site when bush extraction for animal feed production was already ongoing. As mentioned above, bush thinning was conducted on 150 hectares of land over the period 2011 to 2017. This may seem little and may suggest that bush based animal feed production is not a stand-alone solution to combating bush encroachment. It is however an important additional benefit of the feed production, improving its overall viability. A cost-benefit analysis of bush harvesting (the cost factor) and improved rangeland condition (the benefit) rendered an NPV of NAD 26.6 million and in the areas where bush was thinned after six years the carrying capacity has improved to now stand at an estimated 34.83 kg live body mass per hectare. This represents an improvement of 75% compared to the baselines values of 2011. Furthermore, no persons have lost their jobs, and the condition of livestock did not deteriorate despite the prolonged drought period.

10 Recommendations

It was the first time, to the best knowledge of the authors, that bush based feeding trials for sheep were conducted in Namibia. Due to the limited scope of the project, the recommendations for use of bush based animal feed in sheep are limited to potential future use in an intensive feeding setting. Despite positive results, the trials were not able to fully establish the extent to which sheep could be fed utilising encroacher bush as the main source of fibre. Further research is required.

The Khomas Region is topographically defined by its hilliness and rather large bush (not shrubs as e.g. available in southern Namibia) making it less suitable for extensive sheep rearing. However, the trialled diets provided options to farmers to keep a flock of sheep in a small area, feeding them on bush based feeds. The value of natural supplements like Camelthorn pod meal and Opuntia chunks furthermore makes it interesting for farmers to keep sheep in an enclosed environment. However, it is suggested that this is done on a rather small scale (up to 150 animals). The side effects of intensive feeding of sheep in a confined space were not tested and elaborated upon in these trials.

The research conducted on bush based animal feeds for cattle, largely confirms the available knowledge also held by farmers. The pilot research is considered to have substantially augmented the available knowledge. However, additional know-how and technology transfer is required to fill knowledge gaps.

10.1 Future research requirements

Due to resource constraints, the research could not attend to all objectives that may have been laid out for the trials. But the results obtained to date lay the foundations for important future research that is recommended to be done.

Although the added supplements proved to have boosted the level of nutrients, mainly protein which is required by young animals, the high fibre content maintained in the bush based diets still require further interventions to unlock the potential of utilising milled bush as roughage.

It could be possible that increasing the inclusion levels of supplements in the bush based diets beyond 50% tested in this experiment could dilute the fibre content. However, this may also increase the costs of bush feed production. Therefore, other interventions that directly degrade fibre to release the energy and other nutrients contained in the milled bush e.g. use of NaOH, biological treatment, urea treatment should be considered for future research.

Other anti-nutritional factors such as polyphenols (e.g. tannins) also might play a role in the low ME and OMD. Research should be conducted to determine the presence of these anti-nutritional factors in the bush and devise appropriate interventions to treat them.

Finally, the effects of bush based feed on meat and milk quality were not measured so far. Bush based feed could potentially contain residual phytochemicals such as tannins, saponins and essential oils that are widespread in several native shrubs and trees. These bioactive compounds could influence rumen microbial ecology, potentially decrease methane emission in ruminants, positively modulate ruminal fat bio-hydrogenation and improve meat quality and its shelf life. Thus, it is important to further investigate the consequent impact of bush feed on meat quality of ruminants.

The following research suggestions, presented in order of priority are important to be carried out in the near future. The below mentioned suggestions can also serve as ideal topics for academic research. However, a combination of academic and applied research methods would be necessary to ensure the practicality for Namibia and its livestock production objectives.

10.1.1 Sheep feeding trials

- Nutritive production patterns of sheep due to inter-sheep species variability;
- Keeping of larger flocks of sheep in an enclosed area over several sheep (re-)production cycles using bush based feeds for growth and maintenance
- Effect/impact of excretes on the environment based of certain supplements used in the trials;
- Health and safety testing of certain supplements used; this would mean that e.g. sheep used in trials need to be slaughtered after a feed phase and the intestines be microscopically investigated;
- Long-term effectiveness of bush extraction methods done to cater for the milled bush required for the animal feeding trials;
- Short and long-term rangeland conditions change due to bush extraction; and

- Trialling the commercialisation of animal feed production, including obtaining licenses to sell such as commodity animal feed item in local retail outlets catering for agricultural production systems.

10.1.2 Cattle feeding trials

- Health of the rumen and liver organs, post intensive feeding of the animals with diets containing NaOH;
- The effect of pelleting to improve e.g. digestibility of bush based animal feeds;
- The effect of various NaOH pre-treatment concentrations and durations on the wood fibres (nutritional analysis);
- Tests for cellulose, hemicellulose and lignin and tannin composition of the wood based fibres used in the trials;
- Long-term effectiveness of bush extraction methods done to cater for bush based feeds required for the animal feeding trials, and possible co-production applications like animal feed and charcoal making on the same farm to optimise biomass utilisation;
- Short and long-term rangeland conditions change due to bush extraction;
- The usefulness of various bush encroacher species for animal feed production;
- Nutritive production patterns of cattle due to intra- and inter-cattle species variability (reminder: the animals tested were cross-bred Limousin/Bonsmara), nor female v's male feeding and growth patterns;
- Effect/impact of excretes on the environment based of certain supplements used in the trials; nor on the metabolic effect the various supplements would or could have on the meat of the cattle; and
- Claims on health and safety testing of certain supplements used.

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List of Annexes

Annex 1: Methodology of animal feed matter testing

Dry matter (DM)

The dry matter (DM) content of the collected samples were determined by weighing about 2 g of samples ground to pass a 1 mm sieve into previously weighed crucibles and dried overnight in a force draught oven at 100ºC (AOAC, 2000). The dried samples were removed from the oven and cooled to room temperature in desiccators before being weighed again.

The DM of samples was calculated as follows:

$$DM\ (g/kg) = \frac{\text{Weight of sample (g) after drying}}{\text{Weight of sample (g) before drying}} \times 1000$$

Ash or inorganic matter

The samples used to determine DM were also used to determine the ash or inorganic matter content of each sample. After weighing the dried samples, the crucibles plus dry samples were placed in a muffle furnace and incinerated overnight at 550°C (AOAC, 2000). Finally, crucibles plus ash were cooled to room temperature in desiccators and weighed again.

The ash content of each sample was determined as follows:

$$Ash\ (g/kg\ DM) = \frac{\text{Weight of sample after incineration (g)}}{\text{Weight of dried sample before incineration (g DM)}} \times 1000$$

Organic matter digestibility (OMD) and Metabolisable energy

The Organic Matter Digestibility (OMD) and Metabolisable energy (ME) of the feed were estimated using the In Vitro Gas Test according to the procedure of Menke *et al.,* 1979. A sample of about 230 g grinded to pass through a 1mm sieve was weighed and placed into the glass syringes in duplicates. The 30ml of rumen liquor collected from a rumen fistulated donor ox and prepared into a rumen-buffer mixture was added into the syringes. The syringes were then incubated in an incubation apparatus maintained at 39°C. The gas production readings were recorded after the first 8 hours of incubation, the clip opened and the piston moved back to 30ml position. The final reading was taken at 24 hours after the incubation commenced. Gas production at 24 hours from a standard hay meal (GbH) and a concentrate standard (Gbc) were used as correction factor.

The correction factor for hay meal (FH) is:

FH =44.43/ (Gbc – GbO)

While that of concentrate mixture (FC) is:

FC = 62.6/(Gbc – GbO)

The mean of these factors were then used for correction of sample measurement

OMD was calculated using the following as follow:

OMD % = 14.88 + 0.889 gas production (Gb) + 0.045 Crude protein (XP; g/kgDM) + 0.065 Crude Ash (XA; g/kgDM)

Similarly, Metabolisable Energy (ME) was calsulated as follow:

ME (MJ/kg) = 1.242 + 0.146 gas production (Gb) + 0.045 Crude protein (XP; g/kgDM) + 0.0224 Crude lipids (XL; g/kgDM)

Crude protein (CP)

Crude protein was determined by the combustion method as described by AOAC (2000) and according to the standardized analytical procedures of the Agri Laboratory Association of Southern Africa (AgriLASA, 2007). Nitrogen is determined by total combustion of the sample at 950°C in the presence of oxygen where nitrogen is converted to NOx gas (Dumas Principle). The NOx is reduced to N2 which is measured in a thermal conductivity cell. Percent protein is calculated by multiplying the reported nitrogen by 6.25.

Lipids (Ether extract, EE)

Ether extract (EE) was determined according to the standardized analytical procedures of the Agri Laboratory Association of Southern Africa (AgriLASA, 2007). The ether extract (EE) content of each sample was determined by weighing about 2 g of samples ground to pass a 1 mm sieve into clean dried extraction thimbles. Glass cotton wool was inserted in a thimble to keep the sample in place during extraction and then place the extraction thimbles containing the samples in the extractor. A clean and dried Soxhlet flask was weighed and connected to the extraction apparatus after being filled to about 2/3 of its capacity with petroleum ether. The cooling water supply and heating mantle were turned on and the temperature was adjusted to achieve a condensation rate of ether at 5-6 drops per hours for at least 4 hours. As the cool water condensed the ether vapours, it dropped onto the sample placed into the extraction thimble and the fat extracted by the ether dropped back into the flask.

After the extraction period, the remaining ether was evaporated and the flasks were placed in a drying oven at 100°C to dry overnight. The flasks were then cooled in desiccators and weighed again to determine the extracted residues.

The EE fraction of samples was determined as follows:

$$\text{EE (g/kg DM)} = \frac{[\text{Flask (g)} + \text{Ether extract}] - \text{Flask (g)}}{\text{Sample (g DM)}} \times 1000$$

Neutral-detergent fibre (NDF)

Neutral-detergent fibre (NDF) of samples was determined according to procedures described by Goering and Van Soest (1970) and Robertson and Van Soest (1981). This procedure was used to determine the fibre portion of the analysed samples, consisting of hemicellulose, cellulose, lignin, cutin and silica (cell wall fraction). Respective samples of about 1 g were weighed into sintered glass crucibles and placed in the extraction unit. The machine and cooling system were turned on and 100 ml cold neutral detergent solution (NDS) was added to each crucible, and boiled for 1 hour. The NDS was drained out by suction and the samples were washed with hot water and then rinsed with acetone.

After completing the drying process with vacuum extraction, samples were placed in a drying oven to dry overnight at 100°C. Dry samples were removed from the oven and placed in desiccators to cool and weighed again before being placed in a muffle furnace and incinerated overnight at 550°C. The incinerated samples were taken from the furnace, cooled in a desiccator, and weighed again.

The NDF content was calculated as follows:

$$\text{NDF (g/kg DM)} = \frac{[\text{Sample (g DM)} - \text{Sample after boiling \& drying (g)}] - \text{Ash (g)}}{\text{Sample (g DM)}} \times 1000$$

Acid-detergent fibre (ADF)

Acid-detergent fibre (ADF) was determined according to procedures described by Goering and Van Soest (1970) and Robertson and Van Soest (1981). This procedure was used to determine lignocelluloses and silica of the analysed samples. Respective samples of about 1 g were weighed into sintered glass crucibles and placed in the extraction unit. The machine and cooling system were turned on and 100 ml cold acid detergent solution (ADS) was added to each crucible with the sample residue and then boiled for an hour.

The solution was drained out by suction and the samples were washed three times with boiling water and then rinsed twice with acetone. The remaining residues were dried overnight in a drying oven at 100°C. Dried samples were taken from the oven and transferred in a desiccator to cool before being weighed. The samples were incinerated overnight at 550°C in a muffle furnace. The ash samples were removed from the furnace, allowed to cool in desiccators, and weighed.

The ADF content of samples was calculated as follows:

$$\text{ADF (g/kg DM)} = \frac{[\text{Sample (g DM)} - \text{Sample after boiling (g)}] - \text{Ash (g)}}{\text{Sample (g DM)}} \times 1000$$

Calcium and Phosphorus

Calcium and phosphorus were determined by Atomic Emission Spectroscopy (AES) method using the Inductively Coupled Plasma (ICP) instrument. This analytical method involves isolation of the minerals from the organic matters prior to the analysis by first ashing the samples. The ashed sample is digested consecutively with nitric acid and hydrochloric acid to decompose them. The digested sample is filtered before diluted with de-ionized water. Sample diluents are injected in the in the ICP-MS instrument for analysis to give the concentration of Ca and P.

Annex 2: Health and Safety Sheet for NaOH

ace associated chemical enterprises

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COMPANY DETAILS

Name : Associated Chemical Enterprises (Pty) Ltd.
Address : 10 Amethyst street, Theta, Johannesburg.
Tel : + 27 (0)11 496-3300
Emergency tel. no. : + 27 (0)11 496-3300
Fax : + 27 (0)11 496-3311

1. Product and Company Identification:

Trade name : SODIUM HYDROXIDE pellets
Chemical family :
Chemical name : Sodium Hydroxide pellets
Catalogue no : S2515CC/S2516CC
Synonyms : Caustic soda, Sodium hydrate

Chemical abstract no : 1310-73-2
NIOSH no :
Hazchem code :
UN no : 1823

2. Composition:

Hazardous components :
EEC classification : 215-185-5
R Phrases : R35 = Causes severe burns.
S Phrases : S26-37/39-45 = In case of contact with eyes, rinse immediately with plenty of water and seek medical advice. Wear suitable gloves and eye/face protection. In case of accident or if you feel unwell, seek medical advice immediately.

3. Hazards Identification:

Main hazard :
Flammability :
Chemical hazard :
Biological hazard :
Reproductive hazard :

3. Hazardous Identification (continue):

Eye effects - eyes : Burns. Risk of blindness!!
Health effects - skin : Causes severe burns.
Health effects - ingestion : Risk of perforation in the oesophagus and stomach.
Health effects - inhalation : Burns of mucous membranes.
Carcinogenicity : No evidence of carcinogenic properties.
Mutagenicity : No evidence of mutagenic or teratogenic effects.
Neurotoxicity :

4. First Aid Measures:

Product in eyes : Irrigate thoroughly with water for at least 10 min. If discomfort persists obtain medical attention.
Product on skin : Wash off skin thoroughly with water. Remove contaminated clothing. In severe cases, obtain medical att.
Product ingested : Wash out mouth thoroughly with water. Obtain medical attention.
Product inhaled : Remove from exposure, rest and keep warm. In severe cases, obtain medical attention.

5. Fire Fighting Measures:

Extinguishing media : n/a
Special hazards : n/a
Protective clothing : Plastic apron, boots, gloves, goggles/face shield.

6. Accidental Release Measures:

Personal precautions : Wear appropriate protective clothing.
Environmental precautions : Transfer to container and arrange removal by disposal company.
Small spills : Wash site of spillage thoroughly with detergent and water.
Large spills : Liquids should be contained with sand or earth and transferred to salvage containers.

7. Handling and Storage:

Suitable material :
Handling/storage precautions : Store at room temperature (15-25°C recommended). Keep well closed and protected from direct sunlight and moisture.

8. Exposure Controls/Personal Protection:

Occupational exposure limits :
Engineering control measures : Ventilation: Extraction hood
Personal protection - respiratory : Dust respirator
Personal protection - hand : Gloves: Rubber/plastic
Personal protection - eye : Goggles/face-shield
Personal protection - skin : Sleeves
Other protection : Plastic apron, boots

MATERIAL SAFETY DATA SHEET	**No:** 01 **Date issued:** 10 September 2014 **Page** 2 of 2

9. Physical and Chemical Properties:

Appearance : White solid
Odour : Odourless
pH : 14(50g/l H2O)
Boiling point : 1390℃
Melting point : 318℃
Flash point : n/a
Flammability :
Autoflammability :
Explosive properties :
Oxidising properties :
Vapour pressure : 1mmHg 739℃
Density : 2.12
Solubility - water : very soluble
Solubility - solvent :
Solubility - coefficient :
Neurotoxicity :

10. Stability and Reactivity:

Conditions to avoid : sensitive to air and moisture
Incompatible materials :
Hazardous decomposition products :

11. Toxicological Information:

Acute toxicity :
Skin and eye contact : Burns skin and eyes. Risk of blindness.
Chronic toxicity :
Carcinogenicity : No evidence of carcinogenic properties.
Mutagenicity : No evidence of mutagenic or teratogenic effects.
Reproductive hazards : Hazardous properties cannot be excluded but unlikely when handled appropriately.

12. Ecological Information:

Aquatic toxicity - fish :
Aquatic toxicity - daphnia :
Aquatic toxicity - algae :
Biodegradability :
Bio-accumulation : No environmental hazard is anticipated provided that the material is handled and disposed with care.
Mobility :

13. Disposal Considerations:

Disposal methods : Contact your local waste disposal authority for advice, or pass to a chemical disposal company.
Disposal of packaging : Rinse out empty containers thoroughly before returning for recycling.

14. Transport Information:

UN No : 1823	**IMDG - marine pollutant** :
Substance identity no :	**IMDG -EMS no** :
ADR/RID class : 8,41'(b)	**IMDG - MFAG table no** :
ADR/RID item no :	**IATA - shipping name** :
ADR/RID hazard identity no :	**IATA - class** : 1823
IMDG - shipping name :	**IATA - subsidiary risk(s)** :
IMDG - class : 8	**ADNR - class** :
IMDG - packaging group : II	**Tremcard no** :

15. Regulatory Information:

EEC classification : 215-185-5
R Phrases : R35 = Causes severe burns.
S Phrases : S26-37/39-45 = In case of contact with eyes, rinse immediately with plenty of water and seek medical advice. Wear suitable gloves and eye/face protection. In case of accident or if you feel unwell, seek medical advice immediately.
National legislation :

16. Other Information

Further information
The above information is believed to be correct but does not purport to be all inclusive and shall be used only a guide. The information in this document is based on the present state of our knowledge and is applicable to the product with regard to appropriate safety precautions. It does not represent any guarantee of the properties of the product. Associated Chemical Enterprises Pty Ltd shall not be held liable for any damage resulting from handling or from contact with the above product