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Communal rangelands in northern and central Namibia: The grazing and browsing resources and their users

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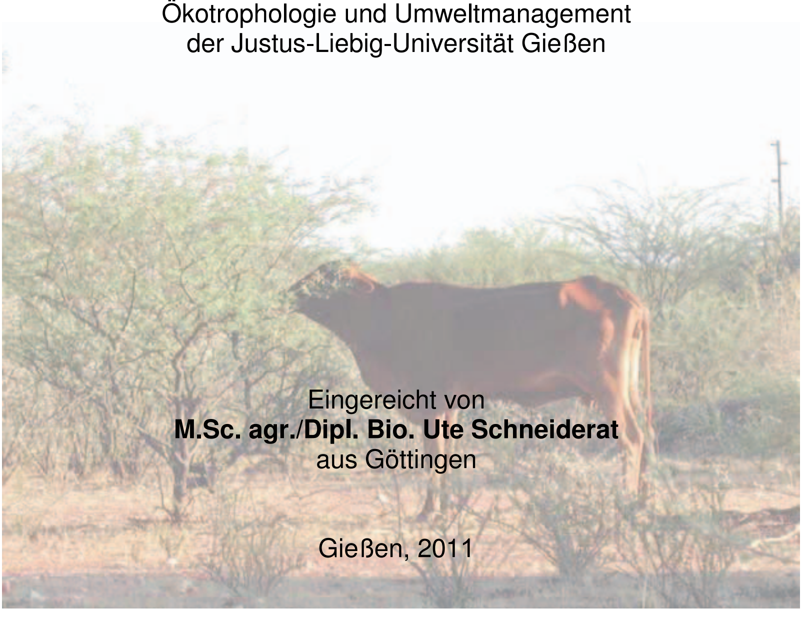

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Abbreviations

AFC	Age of first calving
HIV/AIDS	Human Immuno-Deficiency Virus/ Acquired Immune Deficiency Syndrome
BCS	Body condition score
BecVol	Biomass Estimates from Canopy Volume
BM	biomass (air-dried material)
BW	Bodyweight
CBNRM	Community-based Natural Resource Management
CBPP	Contagious Bovine Pleuropneumonia (lung sickness)
CC	Carrying capacity
CF	Crude fibre
CFA	Configuration frequency analysis
CI	Calving interval
CP	Crude protein
DM	dry matter
DMI	Dry matter intake rate
DoB	Date of birth
DoP	Date of first parturition
DS	Dry season
DVS	Directorate of veterinary services
EC	Electric conductivity
E_H	Evenness index
FAO	Food and Agriculture Organisation of the United Nations
FMD	Food and Mouth Disease
GDP	Gross Domestic Product
GIS	Geographical Information Systems
GP	Growing period
GPS	Geographical Positioning Systems
H	Shannon index
LSU	Large stock unit, 450 kg BW equivalent; (1 small stock = 1/6 LSU)
m.a.s.l.	meters above sea level
MAWRD	Ministry of Agriculture, Water and Rural Development, Namibia
ME	Metabolisable energy
MoHSS	Ministry of Health and Social Services
NAD	Namibian dollar
NOLIDEP	Northern Livestock Development Project
OM	Organic matter
PHT	Progeny history technique
RoN	Republic of Namibia
RUE	Rainfall use efficiency
RUF	Rainfall uncertainty factor
SARDEP	Sustainable Animal and Range Development Programme
SSU	Small stock unit (~1 sheep or goat; 6 sheep or goats = 1 LSU)
TLU	Tropical livestock unit (250 kg BW)
WS	Wet season

1 Introduction

Namibia is the driest country in sub-Saharan Africa with a mean annual rainfall of 270 mm that shows marked regional variations. Due to the environmental factors of low and unpredictable rainfall, high evapotranspiration rates, and partly poor soil fertility, the land in most areas of Namibia is suitable only for natural grassland production. Thus, pastoral livestock production is the predominant agricultural system in Namibia, while a mixed system with mainly millet cropping, is found in the north. Approximately 44% of the total land continues to be held under freehold title, commonly referred to as the commercial farming sector (Werner, 2003), which is dominated by white landowners (RoN, 1991), in (Werner, 2003). The non-freehold areas, referred to today as the communal areas, comprise about 41% of the total land area. The remaining 15% are state land (Sweet & Burke, 2000). The communal sector operates subsistence oriented to a large extent, and directly supports 95% of the nation's farming population (Kruger & Woehl, 1996). Namibia shows a high plant biodiversity (Ashley, 1996; Barnard & Namibian National Biodiversity Task Force, 1998; Maggs et al., 1998), which seems to be endangered by land use, and could eventually result in an irreversible degradation of landscapes.

It is still widely believed that a degradation of the communal rangelands, in terms of reduced primary productivity and irreversible biodiversity losses, has been taking place, due to a combination of high population pressure, high livestock densities and a resulting overgrazing of the fragile environment.Uncertain jurisdiction over communal land, caught up within a slow land reform process (Tapia Garcia, 2004; Werner, 2003), and the breakdown of the traditional, flexible management institutions and practises after Namibia's independence (Byers, 1997) may have increased the tendency to an overexploitation of the communal land in Namibia. New structures supporting the traditional leaders are not sufficiently in place, hence leaving a gap of authority for the allocation and the use of natural resources (Cox et al., 1998).

The people of the communal areas heavily depend on natural resources (Gundy, 2003), and poverty is widespread among the rural farmers of Namibia (Kruger, 1998; Werner, 2003). Livestock production depends on the forage resources from the rangelands. Apart from the discussion on the strong effect of rainfall events on rangelands in arid and semi-arid areas, which probably overrides the impacts of livestock grazing (Ellis & Swift, 1988), intense land use clearly has a negative impact on the rangeland vegetation (Glatzle, 1990; James et al., 1999; Jeltsch et al., 1996). However, there is evidence that the degradation of rangelands is not necessarily an outcome of communal pastoralism in Namibia (Ward et al., 1998), and that communal farming systems are actually economically more efficient than the commercial systems (Binswanger et al., 1995, in Blackie, 1999; and Barret, 1991). On the other hand, the population growth, taken together with the poverty, especially in rural areas, will very likely increase the pressure on communal rangelands (Kruger & Woehl, 1996).

The access to only one water point in communal rangelands can result in zones with a high utilisation pressure, and maybe also in some forms of rangeland degradation. People seem to have used the selected communal grazing areas since the 1950s and 1970s; if these areas were constantly overstocked, the degradation of the past should be detectable. Severe droughts regularly reduced livestock numbers in the past. Nowadays, through drought subsidies, the stocking density has been kept on a high level. However, rangelands in semi-arid areas seem to have a high resilience balancing the impacts from land use and droughts on the vegetation.

Rangeland research and grazing capacity calculations have focused primarily on the commercial sector in which conditions are controlled – the communal livestock sector remains complex and difficult to investigate. Small-scale rangeland evaluation methods and the estimation of grazing capacities are usually adapted to commercial farming, even so the communal grazing management follows very different rationale. The browsing resources, which play an important role for goats and occasionally also for cattle within mixed herds in communal areas, have mostly been neglected in previous calculations of the carrying capacity. Few studies have integrated browsing resources in their resource assessment in Southern Africa, and few authors have especially studied communal areas: Moleele (1998) and Mphinyane (2001), both in Botswana; and Kamupingene & Abate (2004) and Dube et al. (2006), both in Namibia.

Is communal rangeland in Namibia really overgrazed, or in fact degraded? What is the best way to measure it? To which degree do rural livestock farmers depend on communal grazing resources? What function does livestock have in communal areas nowadays? Current comprehensive information for Namibia related to these topics on communal livestock farming is missing.

2 Literature Review

2.1 Land distribution, population and livestock farming in Namibia

The Namibian government has inherited a highly skewed distribution of land. Approximately 36.5 million hectares of land, representing 44% of the total land continue to be held under freehold title, commonly referred to as the commercial farming sector (Werner, 2003). In contrast to this, there are the non-freehold areas, formerly known as native reserves and today called the communal areas. This communal land comprises about 33.4 million hectares and represents 41% of the total land area. The remaining 15% is state land, including the conservational areas (Sweet & Burke, 2000). The communal land accommodates the main ethnic groups of the country, which is mainly based on the former colonial land distribution. Although the tribal names have been replaced with neutral regional names and some boundaries have been changed, these areas remain intact as the present communal areas. These communal areas are situated mainly in contiguous blocks in the north of the country, while the commercial areas occupy most of the centre and south of the country.

For the communal areas, there are user rights, rather than ownership rights. Communal land is mainly State-land, and various forms of custom-based practises define the tenure. Only the cropping areas in the northern areas are usually allocated to individual households, while the grazing areas are meant to be shared by the members of a community (Adams et al., 1990; Vigne & Whiteside, 1997). Unequal access to land and the means of livelihood is a legacy of the colonial system. In pre-colonial times, the land was owned by individuals in Namibia, but was also considered the territory of the different ethnic groups. Today, the frame conditions for communal farming have changed dramatically. Limitations of access to land and water in the now commercial areas, as well as the drilling of boreholes in the communal areas have reduced the space for long-distance livestock movements such it was practiced in the past (Jones, 2003; Krugmann, 2001).

The pattern of poverty in Namibia mirrors the unequal distribution of land. Namibia has the unpleasant reputation of displaying one of the highest income inequalities in the world (Jones, 2003). In 1994, the annual per capita income from farming in the communal sub-sector was approximately NAD[1] 260 (Kruger, 1998). About 70% of the population lives in rural areas and 30% in urban areas. It is estimated that between 50% and 67% of all households (depending on the measure used) are poor. Poverty is particularly

[1] 2001: NAD 10 ≈ € 1. 1994: NAD 4.5 ≈ USD 1.

concentrated among the people living on rural communal land i.e. the majority of the population (Werner, 2003). Poor people have few options, but to depend on primary production for food and energy and can therefore place a tremendous strain on the natural resources (Jones, 2003).

Population growth directly affects the future demand for natural resources. Namibia's population (currently estimated at 1.8 million) has been reckoned to be growing at more than three percent a year (Jones, 2003). There are indications, however, that the impact of HIV/AIDS may actually reduce this rate of annual increase to around two percent (Krugmann 2001) or even less. Even if this is the case, an increase of two percent annually still places stress on Namibia's renewable natural resources. Population growth is driven by factors such as poverty, lack of education, poor health and nutrition, lack of access to fertile land, water and sanitation (Krugmann, 2001). General or historical census data or information, other than the collected data on the demography, population or the specific rainfall data, were not available for the community of Mutompo itself, but indeed for the Kavango region, which can serve as a means of orientation. In 1996, the Kavango[2] (42,771km²), had a population of 110,331 people, which means a population density of 2.6 people per km² (Hochebeb, 2002). Similar values for the population were reported from the Ministry of Health and Social Services (2002) for 1996 (see Table 1).

Table 1: Summary of demographic statistics of the Kavango and Otjozondjupa regions

	Kavango			Otjozondjupa		
	1991	1996	2000	1991	1996	2000
Area (km²)		42,771			108,124	
Total population (no.)	116,830	110,313	180,350[3]	102,536	92,041	148,950[4]
Population growth rate (per annum) 1991-2000		3.91%			3.46%	
Population density (numbers/km²)	2.73	2.58	4.22	0.95	0.85	1.38

Source: Ministry of Health and Social Services, Republic of Namibia (2002) MoHSS health facilities by region[5].

[2] The borders of the Kavango region have changed twice in recent years, as has its name: "Kavango" was used for several decades by the previous government; in 1992, it was changed to "Okavango", and then back to "Kavango" in 1998 (Jones & Cownie, 2001). Kavango region has a size of 48,483 km² today and in the official data of 2000 the cleared areas account for 3.96% (1,920 km²).

[3] The census 2001 reported a total population of 201,093 people in the Kavango region (RoN, 2002).

[4] The census 2001 reported a total population of only 135,723 people in the Otjozondjupa region (RoN, 2002).

[5] www.healthnet.org.na/grnmhss/htm/mhssstrc1.htm. Accessed 04/07/2005; data 2000: www.healthnet.org.na/grnmhss/htm/healthinnam1.htm. Accessed 04/02/2006.

Data from the Kavango census 2000 showed a serious increase of the population by 63.5% between 1996 and 2000. However, the highest number of people is concentrated along the Okavango River, and the population declined by 5.6% between 1991 and 1996 in the Kavango region (Table 1). Demographic data of 1991 and 1996 for the complete political region of Otjozondjupa, where the other community, Okamboro, is situated, shows a decrease in the population of about 10.2%. In 2000, the number heavily increased by nearly 62% (Table 1). And in 2001, the number was reported to be just 135,723 people (Mendelsohn et al., 2002), which was caused mainly by AIDS/HIV.

Because of the increasing population pressure, more and more rangeland is being used for crop production, since alternative sources of income are almost non-existent in the remote rural areas (Kruger & Woehl, 1996). Increased private fencing in and of communal areas has also contributed to a further reduction of communal grazing areas (Bayer et al., 1991; Tapscott & Hangula, 1994; Fuller et al., 1996; Cox et al., 1998; Krugmann, 2001). Hence, some farmers have already started with "defensive fencing", in order to reserve at least some of the land for grazing (Kruger & Woehl, 1996).

Today, the communal areas in Namibia directly support 95% of the nation's farming population (Kruger & Woehl, 1996). Hence, agriculture is the largest employer and it directly or indirectly supports 70% of the population, while accounting for 10% of the GDP and 14% of exports (IFAD (1997), in Kruger, 1998; Sweet, 1998b). However, the agricultural output is dominated by the commercial sub-sector, which contributed to 73% of the total output in 1998 (commercial livestock 69%, commercial crops 4%), while subsistence farming contributed to only 22% (communal livestock 5-6% in 1999). This figure could be misleading, as most of the farming transactions taking place in the subsistence sub-sector are not recorded. Despite adverse climatic conditions and inherently poor farming practises, the sector manages to sustain a large number of both livestock and small-scale crop farmers[6].

In 1998, about 2.2 million cattle, 2.1 million sheep and 1.7 million goats were recorded in the country (in addition to smaller numbers of pigs, poultry and farmed ostriches). However, the numbers of livestock vary because of the fluctuating rainfall patterns. The 1998 census data shows the distribution between the communal and commercial sectors, as presented in Table 2.

[6] www.tradedirectory.com.na

Table 2: National livestock census 1998

	Cattle	Sheep	Goats
Communal	1,368,152	359,224	1,230,260
Commercial	824,207	1,727,210	479,930
Total	2,192,359	2,086,434	1,710,190

Source: Directorate of Planning (1999), in Sweet & Burke (2000).

Livestock farmers in communal areas hold approximately 62% of the total cattle population, 72% of the goats and 17% of the sheep (Table 2), this being mainly confined to the northern part of the country. Herd sizes per households within communities vary considerably between and within regions, and livestock ownership is strongly skewed, with a small number of people owning large herds and a majority owning few animals or none at all (Sweet & Burke, 2000).

Livestock keeping in Namibia is known for its feed quantity and quality problems, especially during the dry seasons. Forages are normally dry and contain very little protein and minerals. This leads to a deterioration of the animal body condition, a higher susceptibility to diseases and the death of large numbers of animals during extended dry seasons, when not providing supplement feeding or moving animals to areas with better grazing opportunities. The reproductive performance becomes impaired because of an excessive loss of condition and weight (Masunda, 2002A). According to official figures the productivity in communal areas is indeed low, when measured against the marketed output. While 42% of the national cattle herd was owned by communal farmers in the 1980s, their contribution to meat production was only 4% - the average yield of cereals produced per hectare at 243 kg can be considered as low. Taken together, the contribution of communal farming to GDP was estimated at 2% in 1983 (in Adams et al., 1990) – yet, informal markets and slaughtering are not integrated within these figures. Although subsistence agriculture in communal areas makes a limited contribution to Namibia’s GDP (2.2% in 1998), its value is underestimated and it is vital for the livelihood of most rural households (Jones, 2003). Distant markets limit the development of farming in the communal areas and agricultural incomes are low and variable. Livestock supplies many non-marketed products and services, the value of which is not fully reflected in the national accounts. These include draught power, milk, hides, meat, manure and a traditional form of savings for rural communities. The success of livestock farming on communal land has depended on mobility, as a strategy for ensuring access to water and pasture, in the past (Jones, 2003). However, the provision of permanent boreholes, an increase in the human population and the development of large permanent settlements have helped to reduce the possibility of maintaining mobility as a range management strategy.

Blackie (1999) noted that many people in Namibia believe that the communal farming is an inherently inefficient way of using land and that the communal land should be subdivided into ranches like the ‘commercial farming areas’. In fact, experience worldwide shows that small family farmers have the potential of being more efficient than large farmers (Binswanger et al. (1995), in Blackie, 1999). Additionally, several studies in southern and eastern Africa compare open pastoral ‘communal’ land areas to ‘commercial’ ranching farmlands (see Scoones, 1995b), finding the pastoral grazing systems to be more economically efficient than sedentary or commercial ranching. Similar other examples on this highly economically efficient form of land use by communal and opportunistically managed rangelands can be found in Behnke & Abel (1996), and Barret (1991). These calculations were based on the use of several products and functions livestock, providing and fulfilling communal areas (e.g. milk, drought power, capital assets, insurance, and social and cultural functions), in contrast to beef production and commercial fattening, and regarding a calculation per area, instead of production per single animal. Some ecologists (e.g. Robertson (1998), in Blackie, 1999) also consider closed freehold ranching systems to be more environmentally destructive than open communal systems. It is interesting to note that it was a justification of the distribution of land under apartheid, that freehold farming was more efficient and less environmentally damaging (Blackie, 1999).

2.2 RANGELAND RESOURCES IN NAMIBIA

High variability of rainfall (inter-annual, intra-seasonal and spatial), and the distinct seasonal changes of the amount of rangeland fodder resources, as well as their quality, are typical characteristics of semi-arid and arid rangelands of Namibia, with which livestock farmers have to cope when applying farming strategies on which the success of the entire livestock production depends. The total annual rainfall varies greatly from year to year, with a coefficient of variation (CV) from 20% up to 80%, following the rainfall gradient from northeast to southwest (Mendelsohn et al., 2002), and in the southwest is a higher risk of droughts than in the northeast. Estimating the forage usage and requirement of livestock in semi-arid areas, and getting an idea of the carrying or grazing capacity is important, especially for the communal areas, in order to prevent the degradation and desertification of rangelands in the uncertain climate conditions of Namibia. A sustainable exploitation seems to be possible to a certain threshold, after that, the danger of irreversible degradation prevails. Rural people’s livelihoods depend to a high degree on natural resources (Flower & von Rooyen, 2001; Gundy, 2003).

The easiest, but very rough and partly imprecise method to estimate or predict the primary productivity of grasses is using a linear regression model of rangelands, expressed as the above-ground dry matter production available for forage at the end of the growing season, based on the amounts of annual or seasonal rainfall (see FAO, 1991). This kind of model has been used by several authors: e.g. by Le Houérou & Hoste (1977), for the Mediterranean, and the Sahelo-Sudanian zone; by Walter (1973), according to Rutherford, (1978) for the Nama Karoo; by Deshmukh & Baig (1983) for East and South Africa; and by Wijngaarden (1985) for semi-arid Kenya (all in FAO, 1991), as well as by Sweet (1998a) for Namibia. Le Houérou (1984) listed more than 100 authors who used or validated this model worldwide. Walter (1970, in Knemeyer, 1985) made a rough estimation of primary production of grass biomass in the arid areas of Namibia, with a linear regression model: 1,000 kg ha^{-1} (= 100 g m^{-2}) of grass biomass in dry matter, per 100 mm mean rainfall. The measured field survey data for dry matter of grass, carried out in Namibia by Knemeyer (1985), added up to much lower values: in WS values of grass DM were between 56.3 g m^{-2} in Outjo, to 86.3 g m^{-2} in Otjiwarongo; with a mean annual rainfall of about 376 mm. This probably occurred due to the very low rainfall amount in December 1979 (23.5 mm) and January 1980 (15.3 mm) in the survey area of northwestern Namibia, during a field study carried out by Knemeyer (1985). An effective amount of rainfall is necessary to initiate the growing process of the vegetation, which has lower values for annual grasses than for deep-rooted perennial species. Du Plessis (2000) indicated the effective rainfall for the Etosha pan in northern Namibia for the rainy season 1994/1995, with values between 35.5% to 57.6% of total annual rainfall, or 29.6 mm for the plains areas, and 44.1 mm for the savanna areas. Maurer (1996) wrote that a growing and germination process cannot start, until at least 20 mm of rainfall are reached within a two weeks period under Namibian conditions, or when the soil is saturated well into the root zone. In Namibia, rain falls during the hot WS, when the evapotranspiration rate is highest. This means the first raindrops of a rainy season do not reach deeper soil horizons, but evaporate immediately, or just wet the soil surface. Therefore, only low rainfall amounts at the beginning of a rainy season are of no relevance for most of the herbaceous species. However, some trees such as *Acacia* species react faster on the first rainfall of a starting WS.

Another explanation for low grass biomass amounts could be low soil fertility or a rangeland degradation having taken place within the sampling area of Knemeyer, which would reduce the primary productivity to less than a tenth, in comparison to the model of Walter (1970). Seasonal and annual rainfall variability, other biotic and abiotic factors, a high regional heterogeneity of different factors in Namibia, as well as the impacts of land use on the vegetation, are not considered within these simple rainfall models. Therefore, these kinds of models can only provide a coarse projection of carrying capacity of the rangelands, and was used as such within this thesis.

Moreover, few studies have integrated browsing resources in their rangeland resource assessments in Southern Africa (du Toit, 1974; Walker, 1980; Huntley, 1982; Rutherford, 1982; Knemeyer, 1985; Dekker & Smit, 1996; Moleele, 1998; Mphinyane, 2001; Kamupingene & Abate, 2004; Dube et al., 2006). Some were applied on communal grazing areas in Botswana. (Moleele, 1998; Mphinyane, 2001) and in Namibia (Kamupingene & Abate, 2004; Dube et al., 2006). This two studies analysed explicit the browsing resources and their value for livestock in communal areas in Namibia. Browse constitutes of leaves and twigs from shrubs and trees available to ruminants as feed and in a broader sense including also flowers, fruits or Acacia-pods. Important information was discussed at the International Conference of Browse in Africa, dealing with various aspects of browse plants. The papers of this conference were published by Le Houerou: 'Browse in Africa: The current state of knowledge` in 1980. The notion of browse is a complex issue, depending on plant species, animal species, forage availability and accessibility and the nutritional state of the animals. Browse is of high importance as fodder resources during dry seasons and droughts, especially for communally managed, mainly free roaming mixed livestock herds, and it is often not integrated in carrying capacity calculations. Multiple uses of woody plants include soil maintenance and protection against erosion, it is a source of energy (fire wood), peole use it as construction material and with the shade trees and bushes reduce water loss from the soil.

The feeding behaviour differs in livestock species. Catte, goats and sheep prefer grass, or leaves and pods from trees and bushes, and feeding behaviour even distiguishs between different type and races of livestock. Cattle, sheep and horses and donkeys are grazer, goats are browser under arid or semi-arid environmental subtropical conditions, but this was found also in other areas of the world (e.g Mediterranean region: Landau et al., 2000). Additionally, livestock feed selective on natural forage resources in rangelands (Sahel: Breman & de Wit, 1983; worldwide rangelands: Glatzle, 1990; Central Somalia: Baas, 1993; Sahel, cattle: Ayantunde et al., 1999; goats, South Africa: Hendricks et al., 2002; and in Namibia, cattle: Rothauge, 2004). Botha (1981 in Brand, 2000) carried out a study about the diet selection of different animal species on mixed Karoo near Middelburg, in Eastern Cape in South Africa. Dorper sheep select in their diet 57% browse and 15% grass, Merinos share their diet in 53% of browsing and 23% grazing resources. The Boer goat, which is the most common breed in southern Africa, feed to 63% on browse and only to 11% on grass. Africaner cattle are caracterized as grazer, they utilze 56% grass and 33.7% shrubs in the study of Botha (1981, in Brand, 2000). Moleele (1998) found, that cattle rely heavily on browse even when grass is plentiful in semi-arid rangelands of Botswana, because at certain times of the year, browse is more nutritious than grasses. In the Sahelin zone in Burkina Faso, Sanon et al. (2007) reported that cattle browsed around the year on leaves and litter for around 4.5% of the time spend on pasture. Sheep and goats shifted their feeding preferences to browse in the dry season, and showed a peak in browsing activity in the DS of 28 and 52% of the time, respectively (Sanon et al., 2007). Landau et al. (2000) found in their review for the dry Mediterranean agro-pastoral system that browsing resources represent 40-60% of goat's diet, but intake rates and the digestibility is inhibited by the high tanniferous phenolic substances in bushes and shrubs. Kaitho et al. (1998) carried out a detailed study with sheep in Ethiopia about the effect of tannin on preference and digestion of different browse species, and found few impacts on preferences and dry matter intake, but more effects on digestibility. Landau et al. (2000) reported that Polyethylene Glycol (PEG), a polymer, can bind tannins irreversibly in the rumen of the animals.

Knemeyer (1985) analysed the browse resources and their quality, additionally to the grazing resources, in order to estimate the possible stocking rates of wildlife on a Namibian farm, as well as the economic feasibility to keep wildlife next to or instead of domestic livestock. In the study of Knemeyer (1985), the vegetation in northwest Namibia is differentiated into the grass as herbs and shrubs (up to 0.5 m height), and the larger bushes and trees (>0.5 m up to 2.5 m height). Grass added up to the largest amount of forage resources for wildlife, followed by the dry matter of herbs and shrubs (with a mean of 47.5% of grass DM in DS and 54.3% in WS) (Table 3). The lowest values regarded as forage resources were the larger bushes and trees, with only around 4 % of the grass dry matter. The mean herbs dry matter on all sampling points in Knemeyer's study was 76 kg ha^{-1}; the means in the DS were approximately 55 kg ha^{-1}, and 127 kg ha^{-1} in the WS. Then, the mean leaf dry matter was around 76 kg ha^{-1} in DS and 273.8 kg ha^{-1} in WS in the northwest region of Namibia (Knemeyer, 1985).

Table 3: Dry matter of different components of vegetation in Namibia in the dry and wet season, (Knemeyer, 1985)

	Mean grass dry matter (DM) (kg ha-1)	Mean herbs and small shrubs DM (kg ha-1)	Mean leaf DM (height 0.5 – 2.5 m) (kg ha-1)	Total mean DM of vegetation (kg ha-1)
DS	255.0	121.0	10.00	387.0
WS	690.0	374.4	26.4	1,090.8

WS = Jan – April; DS = May - Dec. Mix of Mopane savanna in the northern area, and thorn bush-savanna in the southern part. Rainfall around 400 mm.

Recent values of maximum standing above-ground biomass of grassland, measured on several research stations in Namibia, for calibration of NDVI (normalised difference vegetation index) satellite data in the 1999/2000 season, were summarised by du Pisani

(2000) for the Sonop Research station at 2,020 kg ha^{-1}, for Sandveld around 1,420 kg ha^{-1}, for Neudamm (central Namibia) around 2,010 kg ha^{-1}, and for Gellap Ost (south Namibia), the lowest value, with 1,040 kg ha^{-1} (including standing litter). The maximum standing above-ground biomass value for Neudamm exceeded the value found by Knemeyer (1985, see Table 3) for grass, herbs and small shrubs for the WS (1,064 kg ha^{-1}) about twice, despite adding shrubs within this value, which were not added in the maximum standing above-ground biomass. This could have been caused by the differing rainfall amounts or by regionally different soil and rangeland conditions. Biophysical and rainfall data were not integrated in the NDVI-calibration study. The NDVI consists of an index, obtained by calculating the values of the reflectance of all green vegetation in the Red band and the Near infrared band (du Pisani, 2000). Therefore, it is difficult to separate the woody vegetation from the ground vegetation.

Data from a 'veld' survey carried out in Namibia, published by Walter (1954, in Le Houérou, 1984), resulted in a mean annual primary production of 3,120 kg DM ha^{-1} $year^{-1}$, in areas with a rainfall regime of 360 mm of annual rainfall and a rainfall use efficiency (RUE[7]) of 8.7 kg mm^{-1} ha^{-1} $year^{-1}$. These values are very high, in comparison to studies carried out by Walter (1954) in South Africa and Zimbabwe, which report a higher annual rainfall and a mean annual primary production of 900 and 1,380 kg DM ha^{-1} $year^{-1}$, respectively. With a rainfall amount of around 378 mm during the season 1979/1980 and a maximum grass dry matter of 247 kg ha^{-1} in northwest Namibia, the RUE_{grass} is at 1.78 kg mm^{-1} ha^{-1} $year^{-1}$ (Knemeyer, 1985). Considering the total above DM measured in the study by Knemeyer (1985), the RUE_{total} = 2.84 kg mm^{-1} ha^{-1} $year^{-1}$, which is much lower than the data by Walter (1954, in Le Houérou, 1984), still lies in the range of the values for the Sahel. A low value for RUE_{total} could be a sign for a degradation of the rangeland, poor soil conditions, or simply a season with poor rainfall. Applying the RUE exclusively on browse forage resources for consumption, one estimates 1 – 2 kg per hectares per millimetre of rainfall under pristine Sahelian range conditions (Gillet (1986), in Mortimore, 1998). For Namibian conditions, no data for browse – rainfall relation or their production to rainfall variability was available. Although Le Houérou (1984) stated, that the RUE-value includes all aerial primary productivity which also covers the browsing resources, this is not the common standard. RUE focuses on the grass and herb biomass.

Sweet (1998a) took up the RUE (most likely also RUE_{total}) with values between 0.5 and 6 kg mm^{-1} ha^{-1} $year^{-1}$ for use within a rainfall model which estimated Namibian primary productivities and carrying capacities (explanations see p. 113 ff., and Table A 15 in the

[7] RUE = the number of kilograms of aerial dry matter phytomass produced per hectare per millimetre of annual rainfall (Le Houérou, 1984).

appendix). Sweet (1998a), separated communal from commercial farming systems in his model, by using different acceptable utilisation-levels of 70% for communal areas, and 50 % in commercial areas, which resulted in a more conservative stocking rate for the commercial sector. He also integrated a rainfall probability rate of 70%, assuming a minimum rainfall could be expected in 7 years out of 10. However, Sweet (1998a) did not consider the variability of productivity, which is expressed as a production to the rain variability ratio (PRVR-value), as described in Le Houérou et al. (1988). The PRVR-value is, on the average 1.5 for arid semi-arid areas, which means, the variability in production is 1.5 times greater than the variability in rainfall (Le Houérou et al., 1988). Seen together with the different values for effective rainfall in Namibia (described on p. 8), reflects how imprecise these simple rainfall models still are, when the input data is not adapted to the local conditions, such it was in Palmer's Grazing Capacity information system (GCIS), developed for regions in South Africa, and based on satellite imagery, as well as ground-truthing (Palmer, 1999). Palmer (1999) also used a simple production model for the annual rainfall, RUE, and additionally, he integrated the long-term mean annual rainfall, as well as the PRVR (coefficient of variation in production over coefficient of variation in rainfall) in his formula. Moreover, Palmer (1999) considered the initial biomass status on the rangeland, as well as the effective rainfall, in order to calculate the annual primary production. The GCIS was developed primarily for the commercial farms, which are usually divided into camps, and the required detailed input data was not even available for communities in Namibia.

All these biomass values, which show a high variability even within Namibia, point at high regional differences, also on a small scale, considering the rainfall, as well as the biophysical conditions influencing the growth and the desiccation and decomposition of the vegetation biomass. Seasonal rainfall distribution determines the growth and seasonal development of rangeland vegetation and its quality (Breman & de Wit, 1983), and also determines the forage amount and quality. The forage quality of all grasses, and - to a lesser extent - also the quality of browse, depend greatly on the season, being strongest at the beginning of the growing period and then falling steadily by around 0.1 to 0.3 % per day (approximately 1 – 1.5% per week) (Bayer & Waters-Bayer, 1998). An example from grazed farmland in north-western Namibia investigated by Kneymeyer (1985), shows that, within six months, between the peak of dry matter (DM) of herbs with 15.6 g m^{-2} in March and a minimum of only 1.7 g m^{-2} in August, the values for herbs decreased by 89.1% (which means 14.9% per month). The leaf dry matter of small bushes decreased within a six month period by 90.9% (and 15.5% per month). Values for grass dry matter were measured just twice, once in dry season (DS) and once in wet season (WS). The maximum value of grass DM of 69.0 g m^{-2} decreased to a minimum of 25.5 g m^{-2}, which means a decline of 10.5% per month only (and 2.4% per week) (Knemeyer, 1985).

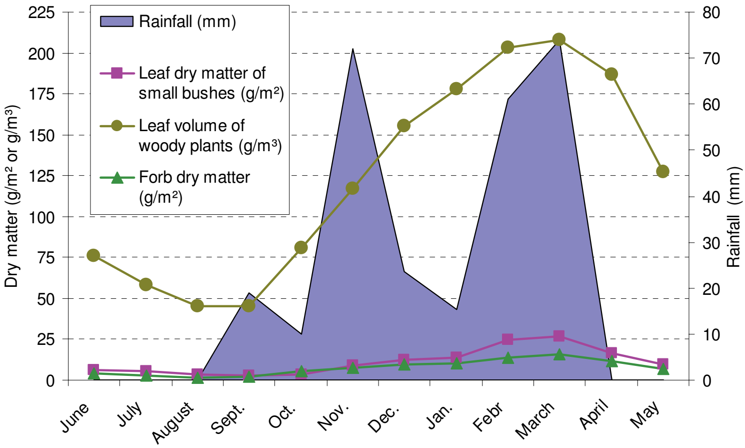


Figure 1: Seasonal development of forb dry matter (with depredation of wildlife), leaf volume and DM in northwest Namibia (after Knemeyer, 1985)

In Knemeyer's study, the amount of browsing resources decreased faster than the grass and the herbs, thus in this area. In contrast, Bayer & Waters-Bayer (1998) stated, that browse was more persevering than the grass, which seems to be valid for a vegetation dominated by annual species, such as most herbs and several grasses, which rapidly react to rainfall, but disappear immediately after seed ripening and distribution. From the ruminants nutrition point of view, browse resources are of paramount importance in arid or semi-arid regions, due to the shrubs and trees species being usually rich in protein and phosphorus throughout most of the dry season (Owen-Smith, 1982), and they are a possible compensation of a deficit caused by the energy-poor dry herbaceous forage during the dry season (Le Houérou, 1989). Browse resources are more stable and less prone to additional over-exploitation (Scholes (1986), in Peel et al., 1999). Browse productivity studies were rather rare before 1980, because the measurement of browse is difficult and time consuming. More appropriate methods of measurement were established from that time onwards (e.g. Bille, 1980; Hiernaux, 1980; Le Houérou, 1980; Pellew, 1980; Walker, 1980; Rutherford, 1982; Knemeyer, 1985; Bayer, 1988; Dekker & Smit, 1996; Smit, 1996; Topps, 1997; Van den Bosch et al., 1997; Aganga et al., 2000). Various studies show that browse production can be predicted from allometric relations, e.g. stem circumferences or crown diameter, and various predictive equations have since been published for the Sahel zone and other areas (see literature above). Allometry is defined as the measure and study of growth or size of a part in relation to a complete organism. Allometric equations represent the most important method for estimating above-ground forest dry matter or carbon used in ecological research as well as for commercial purposes. Knemeyer (1985) applied a very detailed allometric method in order to estimate the browsing fodder resources for wildlife, which serves as an orientation for this study. The software BecVol (Biomass Estimates from Canopy Volume) developed for South Africa by Smit (1996) is considered to be the most appropriate approach to estimate browsing resources for livestock in Namibia as well.

Besides some elaborate socio-economic overviews and valuations of communal areas in Namibia by some authors (e.g. Yaron, 1992; Byers, 1997; Vigne & Whiteside, 1997; Blackie, 1999; Jones, 1998; Jones & Cownie, 2001; Krugmann, 2001 and Mogos et al., 2009), there are some studies, which deal with rangelands, natural resources or livestock in southern Africa, especially on communal land. These are, for instance, those for Namibia by Irving & Janssen (1992), Kressirer & Kruger (1995), Fuller et al. (1996), Ward et al. (1998); Kruger & Rethmann (1999), Sullivan (1999); Kruger (2001, within SARDEP), Zimmermann et al. (2001), Kuiper & Maedows (2002), Masunda (2002a, 2002b), Zimmermann (2002), Imbamba (2003), Jones (2003), Leggett (2003a, 2003b), Burke (2004), Kamupingene & Abate (2004), as well as Dube et al. (2006), making no claim to be a complete list. Occasionally it seems, that much of the scientific work, which was done on communal farming systems in southern Africa in the past, has not been published, neither on a national nor on the international level, or has yet find its way into the so-called grey literature.

2.3 IMPACTS ON NATURAL RESOURCES IN COMMUNAL AREAS

The natural vegetation from a rangeland, both woody and herbaceous, provides rural communities with a wide range of resources. The woody vegetation is used e.g. as fuel wood (deadwood is preferred), as poles for construction, fences or livestock pens, for carving utensils and implements, edible fruits, bark and roots for traditional medicine, and the leaves are partly used as livestock fodder (Gundy, 2003; Shackleton et al., 1999; Twine, 2003). Grasses and herbs are also used as animal forage, and thatch grass is collected to repair traditional roofs, or build new ones[8]. Many rural households in communal areas depend directly or indirectly, but to a high degree on natural resources to sustain their livelihoods, especially poorer households (Flower & von Rooyen, 2001; Gundy, 2003).

[8] In ‘modern’ communities, however, houses are no longer built the traditional way, with wooden poles for the basic wall construction and the roof, and a clay-dung mix for plastering. Other materials, such as old oil barrels are now used as walls, and corrugated iron-sheets for the roof constructions (own observations).

The components of the impacts of utilization on the vegetation and on the environment, which can result in long-term and irreversible degradation, are thought to include (Abel & Blaikie, 1990): soil erosion, changes in soil structure, a decrease in palatable and nutritious plant species, a decrease in perennial grasses and an increase in annuals, a decrease in biodiversity, bush and shrub encroachment, a decline in quality and quantity of forage, a decline in primary and secondary productivity of rangeland; and as a result of this, a decline in the welfare of herd-owners.

The fauna and flora of Namibia are characterised by a high biodiversity and include a high share of endemic species (Maggs et al., 1998; Barnard & Namibian National Biodiversity Task Force, 1998; Mendelsohn et al., 2002; Mendelsohn & el Obeid, 2003; Strohbach & Strohbach, 2004). A general assumption in ecology, the diversity-stability theory, says, that communities rich in species are more resistant to disturbances, and recover better, e.g. from a drought, meaning that they are more stable and resilient (see Blench & Sommer, 1999). The loss of biodiversity disrupts the ecosystem stability and the functions that underpin human survival (e.g. the provision of clean air and water, the control of soil erosion and floods, and the assimilation of wastes) (Jones, 2003).

The intensity of utilization as well as the history (or duration) of land use plays a clear role in the degree of changes and impacts on soils and rangeland vegetation. In addition to this, extreme climate events, such as drought or multi-year-droughts have a strong effect on the vegetation of arid and semi-arid rangelands. Effects of livestock on the rangelands are probably overridden by the variable and unpredictable climate conditions in arid and semi-arid regions (Disequilibrium theory: Behnke & Scoones, 1993; Sandford, 1993; Sullivan & Rhode, 2002; Leggett et al., 2003b).

According to the disequilibrium theory, the impacts of the variable climate conditions on rangelands override the impact caused by livestock, though, there is some evidence that heavy grazing does change the composition of the rangeland vegetation (e.g. Bester et al., 1999; Dougill & Cox, 1995; Bester et al., 2003; Dougill & Trodd, 1999; Zeidler et al., 2002). Mwendera et al. (1997) reported for lightly to moderate grazed areas in the Ethiopian highlands, a greater species diversity of less preferred, unpalatable species by selective feeding behaviour of grazing animals dominating the botanical composition. In addition, light to moderate grazing at the beginning of the dry period enhances plant biomass productivity, while any utilization reduces the productivity during the time of reduced growth (Mwendera et al., 1997). In non-grazed plots, few dominant species suppressed the other species; while in very heavily grazed plots, less grazing or trampling resistant species were eliminated, resulting in total in a lower species number, yet no selective grazing took place (Fusco et al., 1995; Mwendera et al., 1997). On a 4-year-trial of different stocking densities

(15, 25, 35, 45 kg ha^{-1}) in the camel thorn savanna of Namibia (Sandveld Research Station, approximately 60 km north east of Gobabis), Bester et al. (2003) reported, that the annual rainfall amount was the over-riding factor influencing grass production, and the stocking densities had only a slight effect. Two desirable grass species (*Stipagrostis uniplumis* and *Eragrostis rigidior*), as well as *Arisitida stipitata* (which is associated with poor conditions) tended to increase as the stocking rate increased, associated with a drier climatic condition. However, two highly desirable grass species (*Anthephora pubescens* and *Schmidtia pappophoroides*) declined drastically when the stocking rate increased in the camel thorn savanna of Namibia. Also, the management regime at the Sandveld Research Station prior to this study drastically influences the results of this short-term trial (Bester et al., 2003), meaning that the history and intensity of land-use determines the rangeland condition, just as the rainfall of the previous season (e.g. drought year), as well as the seasonal distribution of rainfall during a rainy season (Bester et al., 1999). An analysis of the ground cover of perennial grasses showed no significant differences within different stocking densities (same condition and location as described above) from 1984 to 1991, but the variation in annual rainfalls did lead also to changes in the ground cover in Namibia (Kruger & Rethman, 1999). A study conducted by Sullivan (1999) deals with the impacts of people and livestock (communally managed) on topographically diverse open wood and shrub-lands in north-western Namibia. The findings highlight that abiotic factors, such as topography and substrate category, have a high explanatory strength in relation to woody floristic composition, and that the results indicate only localised impacts of settlements; a resilient, if variable, secondary productivity of the regional livestock population is eminent (Sullivan, 1999). Some of the results of the different studies support the disequilibrium theory, others do not (see Kuiper & Meadows, 2002, for southern Namibia). Regional heavy and intensive grazing seems to influence the vegetation of rangelands of different soil types to different degrees, and the time of grazing seems to be an important factor, also. In addition, the selective feeding preferences of livestock for more palatable grass species could result in changes of the species composition (Kuiper & Meadows, 2002), towards unpalatable and annual grass species. However, high resilience was detected e.g. for the Nabaos communal grazing areas, in southern Namibia, after a good rainfall year, which was analysed by means of aerial photography and expert interviews (Kuiper & Meadows, 2002). Unfortunately, these results were not validated by a quantitative vegetation analysis or by ground truthing methods.

Briske et al. (2003) criticised the current debate about the validity of paradigms, the equilibrium and the disequilibrium theory. They recommended that '...*the rangeland debate should be redirected from the dichotomy between paradigms to one of paradigm integration,* [and that] *equilibrium and non-equilibrium ecosystems are not distinguished on* *the basis of unique processes of functions, but rather by the evaluation of system dynamics at various temporal and spatial scales.'*

A shift from natural forages to species of lower productivity or poorer quality or a mere reduction of forage on areas within the main grazing areas would most likely lead to a reduction in the performance of livestock, in both, growth and reproduction. In cases of heavy deterioration or degradation, when the production capacity of the rangeland is destroyed on a long-term basis, profitable livestock keeping is no longer possible, which strongly influences the welfare of the local livestock farmers.

Artificial water places have been drilled, in order to make dry lands accessible for livestock keeping and to provide permanent water for human consumption, which also makes the establishment of permanent settlements possible. These artificial sources of water indirectly affect the surrounding rangelands, due to a higher concentration of livestock numbers around these water places. Researchers have used the grazing gradient, in order to analyse the impacts of land-use and grazing or browsing on the vegetation and on the nutrient cycle. The impacts of livestock are highest around the water places, decreasing gradually with the distance to the periphery for two reasons:

(1) The area available for grazing increases with the distance from the focal point, resulting in a reduction of impacts by livestock.

(2) Livestock or wildlife have to drink regularly, so they are limited in how far they can travel away from the water (James et al., 1999).

This intensity gradient of grazing, browsing and trampling can be best used as a tool, in order to analyse changes in the vegetation and soil characteristics, as well as the nutrient transport of livestock within the different zones around the water places. Osborn et al., (1932, in Lange, 2003) were the first in Australia to recognise the radial patterns in grazing intensity that developed around watering points, examining the effects of grazing on the vegetation along radial transects starting from watering points. Subsequently, Lange (1969) coined the term 'piosphere', (from the Greek 'pio' = drink) for the description of radial grazing patterns around a watering point in Australia (Landsberg, 2003). Several papers have dealt with the impacts of these artificial water places on the vegetation (e.g. in Australia: Pickup et al., 1994; Pickup et al., 1998; and James et al., 1999). In southern Africa: Glatzle, 1990, Dougill & Cox, 1995; Jeltsch et al., 1996; Moleele & Perkins, 1998; Mphinyane, 2001; Mphinyane & Rethman, 2003; Tolsma et al., 1987; Leggett et al., 2003a and 2003b; and Todd, 2006. In West Africa: Lind et al., 2003; and in New Mexico: Fusco et al., 1995. From the late 1980s, the grazing gradient method has often been combined with remote sensing techniques on a larger scale, especially in Australia (Pickup et al., 1994; Pickup et al., 1998), but also in other parts of the world, where a larger scale investigation seems reasonable (Dube & Pickup, 2001; Lind et al., 2003). The impacts of newly established water points for wildlife on the vegetation were also investigated in game reserves (Makhabu et al., 2002). Other literature deals with the impacts of the utilization on the woody vegetation (browsing, cutting and pollarding of shrubs, bushes and trees) (Twine, 2003), or the patterns of bush encroachment around boreholes, analysed more in detail (Moleele & Perkins, 1998). Analyses of the vegetation composition, examined in concentric cycles around the water sources, reported changes in vegetation as a response to grazing and trampling (Glatzle, 1990; James et al., 1999; Jeltsch et al., 1996). The zone immediately around a water point (of approximately 0.1 to 0.5 km), which is referred to as ‘sacrificed zone’ or ‘high-impact zone’, shows signs of extreme disturbance, such as trampling. These disturbances resulted e.g. in a broken soil crust, and high level of erosion due to the low vegetation cover or even bare soil. The horizontal transfer of dung and urine by livestock accumulates several nutrients (Tolsma et al., 1987; Mphinyane & Rethman, 2003). This sacrifice zone supports short-lived, often unpalatable, trampling-resistant and partly toxic plants, sprouting after rain. During a dry season, this zone can be without any ground vegetation. Leggett et al. (2003b) reported of a 2 km ‘sacrificed zone’ around water places in a communally managed grazing area in north-western Namibia, in which annual herbs dominated, and which tended to be larger during DS, contracting during WS. They found large trees (> 10 m height) in this high-impact zone, large enough not to be knocked over by domestic stock. Nevertheless, a distinct browse line on these trees was observed. In the second zone, beyond the ‘sacrificed zone’ (about 0.5 to 2 km away from water place, or further away), an increase in the number of unpalatable perennial woody shrubs is often observed in semi-arid woodlands and arid shrub-lands. The development of this bush-encroached zone seems to depend on the rainfall regime, as in arid regions, rainfall usually limits the establishment of shrubs and bushes, whereas in wetter areas, the shrub encroachment increases with the intensity and history of the water place in a more complex way (Jeltsch et al., 1996; Jeltsch et al., 1999). However, in the studies applying a transect approach on the communally managed grazing areas (see Leggett et al., 2003a and 2003b), no such bush encroached zones were described beyond the ‘sacrificed zone’, which resulted likely in the keeping of mixed herds, with a high percentage of browsers, such as goats, in contrast to the pure cattle herds kept e.g. in central Namibia on commercial farms. In a third zone, beyond the probably bush-encroached zone (approximately > 2 km of distance from the water place), a decrease in the abundance of palatable native perennial grasses is found probably due to selective grazing. The values for the size of this zone are only approximations because the extension of the zones differ, which in turn seem to depend on the rainfall regimes, soil conditions, vegetation types, as well as the intensity of grazing and history of water sources. Close to the water points, livestock drop urine and dung during resting, grazing and drinking time around the water place. This behaviour of livestock leads not only to an aggregation of nutrients, but also to an increase in nutrients within the plant material (Tolsma et al., 1987; James et al., 1999; Mphinyane, 2001; Mphinyane & Rethman, 2003).

Most of the studies carried out on commercial farmland, where rotational grazing takes place and the farmland is divided into several camps, each is equipped with an artificial water place. Often the browsing resources are not considered, or the bush encroachment is noticed as a negative impact on farmland, which reduces the grass production. In several botanically oriented studies, the stocking density is not known, or only expressed as low, moderate, and heavy on these camps. In the studies in southern Africa, the transect length within the camps is short in comparison to Australia, because the camps are small. Camps and rangelands in Australia are much larger and the analysis took place on a larger scale (Friedel, 1997; James et al., 1999, Landsberg et al., 2003).

A general assumption holds that the overstocking of rangeland causes a 'degradation', or 'desertification'. Behnke & Scoones (1993) equated 'rangeland degradation with the long-lasting or permanent loss of an economic food, in this case an irreversible decline in livestock production.' A formal definition of rangeland degradation was given by Abel & Blaikie (1990): '[Range degradation is] *an effectively permanent decline in the rate at which land yields livestock products under a given system of management. 'Effectively' means that natural processes will not rehabilitate the land within a timescale relevant to human beings, and that capital or labour invested in rehabilitation is not justified. This definition excludes reversible vegetation changes even if these lead to temporary declines in secondary productivity; it includes effectively irreversible changes in both soils and vegetation.'* In his review on degradation and desertification, Dodd (1994) stated, that studies exploring the critical subject of interactive effects of livestock grazing, weather, and fire or fire suppression changes in the vegetation of Sub-Saharan Africa have apparently not yet been performed, neither on short- nor on long-term. In conclusion, Dodd (1994) 'found no scientific evidence that nomadic or even commercial use of domestic livestock causes irreversible changes in range vegetation away from watering points and habitations.' In some studies, the impacts of rainfall and other abiotic factors have more influence on the rangeland vegetation than e.g. grazing by livestock (O'Connor, 1994 for African savanna grassland; for Namibia see Kruger & Rethmann, 1999).

3 Study areas

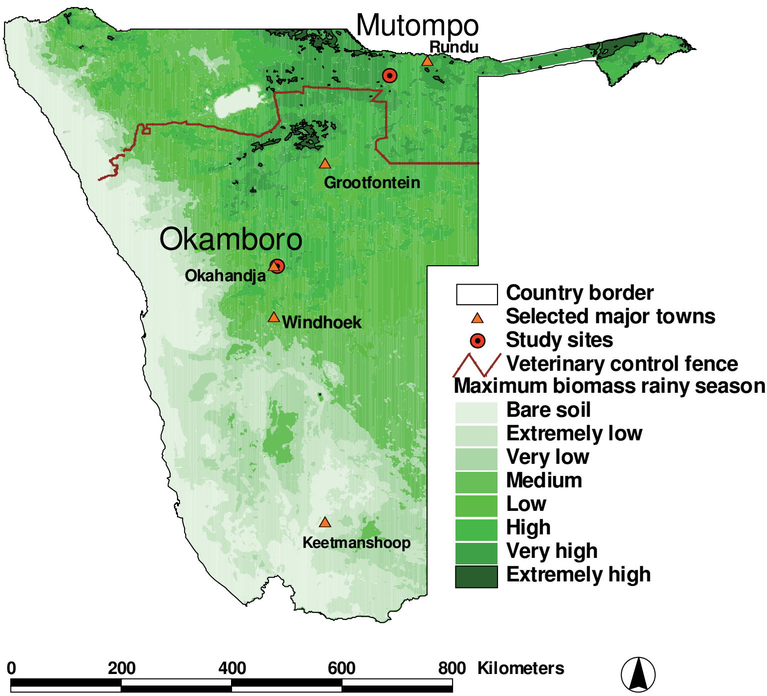
The study was undertaken in two communal areas located in central (Okamboro) and northern (Mutompo) Namibia (Map 1). The study was carried out in the context of the BIOTA Africa research project (Biodiversity Monitoring Transect Analysis in Southern Africa) for biodiversity monitoring and understanding drivers of changes. This study was integrated in first phase (2001-2003) of the BIOTA Southern Africa research project[9], being a part of the Subproject S11: Socio-economic aspects of changes in biodiversity in southern Africa. BIOTA Africa uses 1 km² large, permanently marked research sites, so-called "biodiversity observatories". In 2001, twenty-eight of these BIOTA-observatories were set up along a 2,000 km transect, covering the major vegetation zones along the main rainfall gradients, leading from the summer-rainfall area of northern Namibia to the winter-rainfall Cape Region of South Africa. The position of the study sites was selected by the BIOTA-team in 2000; initially 13 of these areas were located in South Africa and 15 in Namibia. Five of the areas near the observatories in Namibia are communally managed, while the others are under commercial or other land use. The aim of the project was to study the effects of land use on the biosphere.

Only two of the communal areas, the communities Okamboro (Ovitoto reserve) and Mutompo (Kavango area) do not have a camp structure comparable to a commercial farm, but have one main central water pump providing the people and livestock with water. Therefore, those two communities were selected for the rangeland evaluation. Mutompo is located in the inland Kavango[10] region, 60-65 km southwest of Rundu (near the Mile 46 Station), about 15 km west of the national road B8, at an altitude of 1,160 m.a.s.l. The geographic position of this community is about 18° 30' 00'' East and 19° 26' 00'' South (see Table 4, p. 22). The Kavango region belongs to the northern communal area, which comprises the largest communal area of the country, and is separated by the veterinary control fence to the south (see Map 1), and the national border to Angola towards the north (see Map A 1 in appendix, p. 261). Okamboro is an Ovaherero-community, located in Central Namibia, about 30 km east southeast of Okahandja. The Ovitoto-reserve is a small separated area near Okahandja. The geographic position of this community is about 17° 00' 00'' East, and 22° 00' 00'' South, and it is situated at an altitude of about 1,450 m.a.s.l. (see Table 4, p. 22).

[9] See internet: http://biota-africa.org/reg_south_obsmap_ba.php?Page_ID=L800_05

[10] In contrast to along the river in Kavango, those areas to the south and away from the river are called inland Kavango, following the popular and local use of "inland" to characterize the non-riverine areas of the region (Jones & Cownie, 2001).

Public databases and publications were used to gather information about the political regions Kavango and Otjozondjupa (see Map A 1 in appendix), which stand for Mutompo and Okamboro, respectively. For the communities itself only very few information could be found.



Map 1: Locations of the two investigated communities in Namibia, and the maximum biomass during rainy season

(Data sources: Mendelsohn et al., 2002, electronic version. Ministry of Health and Social Services, Republic of Namibia (2002) MoHSS health facilities by region. (www.healthnet.org.na/grnmhss/htm/mhssstrc1.htm. Accessed 3 July 2005.)

3.1 ENVIRONMENTAL CONDITIONS

Both study sites are semi-arid regions with high rainfall variability. The rainfall coefficient of variation shows values between 30 to 40% (see Table 4). In Namibia, about 36% of the measured years were dry years, with rainfall being less than 10% of the corrected mean value of 314 mm annual precipitation. In Table 4, the annual measurements from the

BIOTA weather station are compared to the long-term estimated mean annual rainfall, according to Mendelsohn et al. (2002). The rainfall in central and northern Namibia in the seasons of 2001/2002 and 2002/2003 lay underneath the average long-term mean in Mendelsohn et al. (2002), however, for both communities, these rainfall values lay within the range of the rainfall variation coefficient of 30%. In the rainfall season 2002/2003, when the main field period was conducted, precipitation levels were 50mm less in Mutompo, and about 100mm less than the estimated mean annual rainfall in Okamboro.

Table 4: Climate conditions and growing period of Mutompo and Okamboro

	Mutompo/ Mile 46	Okamboro/ Ovitoto
Geographic position	18° 30‘ 00‘‘ E 19° 26‘ 00‘‘ S	17° 00‘ 00‘‘ E 22° 00‘ 00‘‘ S
Altitude (m.a.s.l.)	1,160	1,450
Mean annual temperature 2002 * (°C)	22.1	22.2
Average annual evaporation ($mm\ year^{-1}$) [2]	1,820 - 1,960	1,960 – 2,100
Mean rainfall in season 2001/2002 *[1] (mm)	428	248
Mean rainfall in season 2002/2003 *[1] (mm)	494[3]	248
Estimated mean annual rainfall [2] (mm)	550	350
Rainfall coefficient of variation [2] (CV %)	30 - 40	30 - 40
Mean relative humidity of the air in 2002 * (%)	47.5	36.0
Mean soil temperature in 2002* (°C)	26.5	26.8
Average growing period (days)	105	58
Main vegetation zone	Dry woodlands	*Acacia* highlands
Main soil type	Dystric-ferralic and eutric Arenosols	Leptosols
Range of average growing period[+] (days)	91 – 120	41 – 60
Agricultural suitability[+]	Livestock grazing, quickly-maturing crops	Livestock grazing
Percentage of years without growing period[+] (%)	4	22

[1] The climate year lasts from 1st July until 30th June of one year, due to southern hemisphere.
[2] Mendelsohn et al. (2002). [3] April to June is missing, data only for 9 months. * Source: BIOTA South Project weather station data[11]. Source: de Pauw et al. (1999).

The average range of the growing-periods (GP) is listed in Table 4; showing that only in the Mutompo-Mile 46 area, they reached the minimum of 90 days, when cropping quickly maturing crops is possible. In the Ovitoto region, and in Okamboro, the period lasted 58 days on average.

[11] Contact: Ute Schmiedel, Institute of General Botany, University of Hamburg; Klaus Berger, Institute of Soil Science, University of Hamburg.

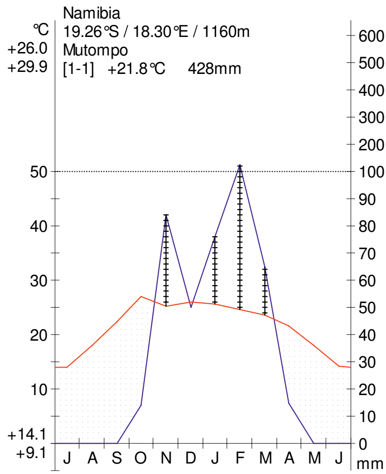


Figure 2: Climate diagram of 2001/2002 near Mutompo

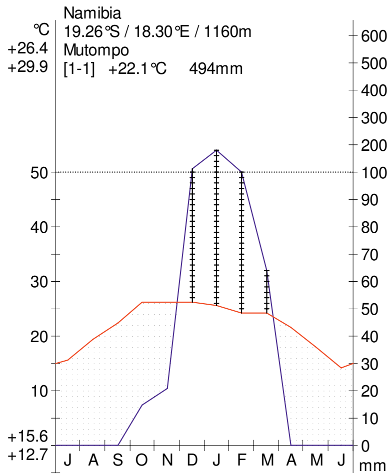


Figure 3: Climate diagram of 2002/2003 near Mutompo
(Rainfall data missing from April to June 2003.)

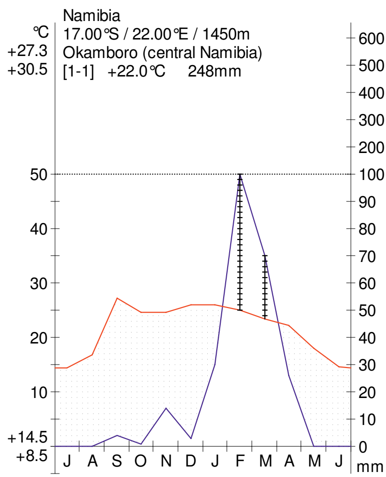


Figure 4: Climate diagram of 2001/2002 near Okamboro

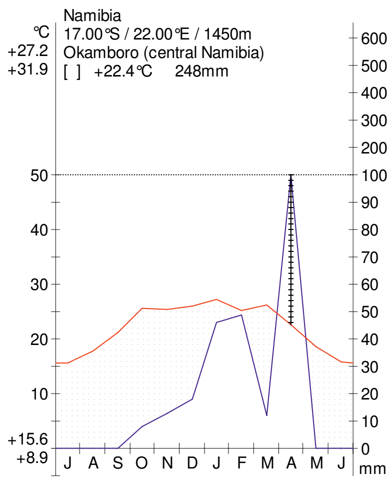
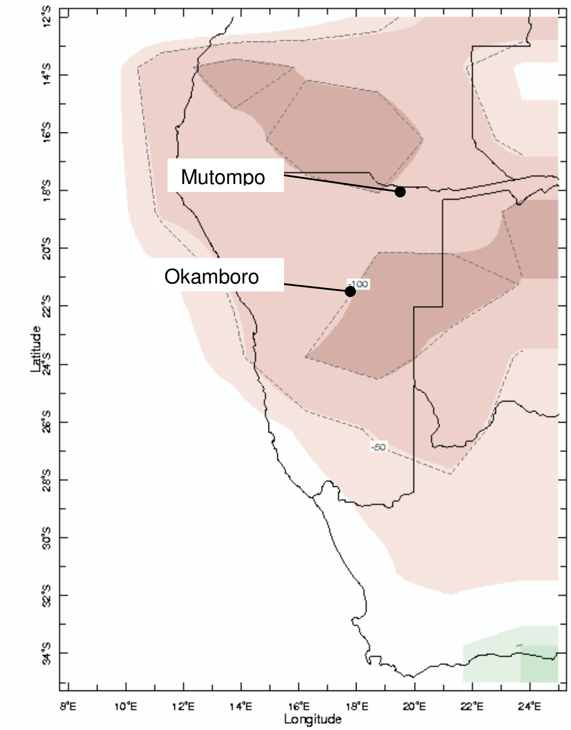


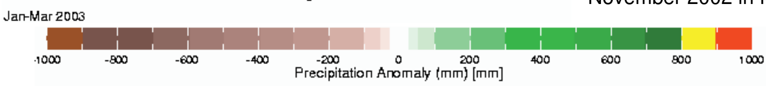
Figure 5: Climate diagram of 2002/2003 near Okamboro

Mainly, the length of the average growing season determines the agricultural suitability of the different regions. The Mutompo region is suitable for livestock keeping and cropping; in the Okamboro region in central Namibia, however, only livestock keeping is appropriate

(Table 4). The risk of years without growing period was 22% for central Namibia, in the Mutompo region only 4% of the years have the risk of a failed growing period.

The climate diagrams of Mutompo[12] (Figure 2 and Figure 3) (as in WALTER and LIETH 1960 convention[13], with a change of scale in the mm-axis at 100 mm) indicate four humid months, with a positive water balance during the seasons 2001/2002 and 2002/2003. Rainfall started in October and ended in April, and the maximum rainfall occurred in February 2001 and in January 2002. In total, the rainfall was 428 mm for the season 2001/2002, and 494 mm for the season 2002/2003, which amounts to around 170mm to 50mm annual rainfall below average (see Map 2). However, for April 2003, no value was available. In April 2002, the monthly rainfall amount added up to 15.2 mm. The minimum mean daily temperature during the investigated period was measured in July 2001 at 9.1℃; the maximum mean daily temperature was 31.3℃, measured in November 2002 in Mutompo.





[(NOAA NCEP CPC CAMS_OPI v0208 anomaly prcp) * dT) * 3. Averaged in T with overlapping interval 3, boxes with less than 0.0% dropped. (Source: http://iridl.ldeo.columbia.edu. Accessed: 15 December 2003.)

Map 2: Precipitation anomaly from January 2003 to March 2003 in Namibia
(in comparison to long-term measurements from Jan. 1979 - to Dec. 2004)

[12] Data collected from a weather station at Mile 46-research station, located in a distance of about 6 km away from the community.

[13] Walter, H. & Lieth, H. 1960. Klimadiagramm - Weltatlas. VEB Gustav Fischer Verlag, Jena. Diagrams compiled with Climate Plot 32 by S. Riediger, 1999, Department of Biology, University of Osnabrück).

In Okamboro, rainfall started early in September 2001, with low rainfall amounts, and monthly figures increasing around 100 mm and 70 mm until January (Figure 4). January and February 2002 were the two only humid months in this season in Okamboro. Two peaks were visible during the rainfall months from October 2002 to April 2003 - with a break in March 2003 (Figure 4). April was the only humid month with a positive water balance in Okamboro. The total rainfall amount in 2001/2002 was 50 mm under the long-term annual average, and 100 mm in 2002/2003 (see Map 2). The minimum mean daily temperature during the investigated period was 8.5℃ in July 2001; the maximum mean daily temperature was 31.9℃, measured in January 2003 in Okamboro. The peak of rainfall was in April, instead of January or February. The rainy seasons of 2001/2002 showed an equal distribution in the Okamboro region (see Figure 4, S. 23), compared to the season of 2002/2003, where a gap in March 2003 was visible (see Figure 5, S. 23). When analysing the daily rainfall amounts of the wet season in 2003, a gap of 38 days with very low daily rainfall amounts and only 8.6 mm in total was recorded between 03/03/03 – 09/04/03 in Okamboro. The rainfall in April 2003 (98 mm) fell between the 10^{th} and 16^{th} of April; afterwards no more rain fell.

In Mutompo in northern Namibia, the soil substrate is sand of the inactive dune system of the Post-Karoo Sequence (Tertiary to Quaternary). From this Kalahari-dune system, deep, but weak-developed red soils build up, which are mainly of poor fertility. Main soil units are strongly leached dystric-ferralitic arenosols (pH 4–5) in the part of the dry forest-vegetation and slightly loamier eutric arenosols, with higher pH values (6-7) in former inter-dune valleys, often covered with thicket vegetation. A comparison of the dune with interdune vegetation reveals a clear difference in vegetation structure and species composition (personal communication, A. Petersen). Petersen assumes, that higher evaporation rates caused by the finer texture, have led to a different water supply and therefore to the differentiation of the vegetation. Eutric arenosols, which occur in elongate small patches in this region of Kavango, are preferred sites for the agricultural purposes of the local community. Although these sites are also in a nutrient-poor environment, they provide a slightly higher nutrient value than most regions in sandier sites around Mutompo. The higher pH value is also more favourable for crop production. Soils in the Ovitoto area, where Okamboro is located, are described as weakly developed soils (Lithic Leptosols; FAO, 1998). The topography of Okamboro can be described as structured and hilly. The beds of two rivers build a valley, which stretches through the community, the altitude in the rangeland area of Okamboro lying in the range between 1,340 meters a.s.l. in the north and 1,780 meters a.s.l. in the southeast's southern mountainous regions.

3.2 POPULATION AND SOCIO-ECONOMIC CONDITIONS

Population and a number of socio-economic characteristics of the two communities, surveyed in 2001/2002, are summarised in Table 5. The average population density in Namibia is 2.1 people km^{-2} (total 1.83 million people), ranging from 5 to 15 km^{-2} in the northern regions bordering Angola, to less than 0.3 km^{-2} in the south. The estimated population density in Mutompo was 2.2 people km^{-2} and 2.8 people km^{-2} in Okamboro.

The investigated communities are located in communal areas, where the people mostly belong to a single Namibian ethnic group, Kwangali Kavango people in Mutompo, and Ovahereros in Okamboro. The Ovambos, which live also in the north of Namibia, account for 49.8% of the Namibian population. The Kavango people account only for around 9.3%; and the Ovahereros for 7.5% of this multi-ethnic state (Malan, 1998).

Table 5: Population characteristics

	Mutompo (North of Namibia)	Okamboro (Central Namibia)
Main ethnic group	Kwangali/partly Mbunza	Ovaherero
Language group	Rukwangali	Otjiherero
Estimated population density (people km^{-2})	2.2	2.8
Main agricultural activity	Cropping (millet) and livestock	Livestock and gardening
Livestock	Cattle, goats, sheep, few horses and donkeys	Cattle, goats, sheep, few donkeys
Available communal grazing area (ha)	3,850[1]	5,800[2]
No. of households (n)	14	29
Population of the community (n)	83	158
Mean household size (n)	6.9 (SE 1.23)	6.2 (SE 0.82)
Non-permanent household heads (%)	8	23
Pensioners in the household (age >60 years, %)	7	8
Children in the household (age < 16 years, %)	58	31
Mean total educational level (years; age ≥ 16)	3.3 (SE 0.54)	3.9 (SE 0.69)

[1] 5.5% used for cropping (about 209 ha); [2] about 10% of the area was fenced. Own data.

These lands are under a communal management, normally without fences within the area. The administration of land in communal areas has been carried out since June 2003, by established Communal Land Boards (RoN: Communal Land Reform Act, 2002. Act 5 of 2002), although the ownership lies with the government, and the grazing rights, as well as the rights to use the land are in the hands of the local people. The utilization of land and other resources cannot be described as an open access system, because traditional regulations and local institutions, such as the community councillor or headman/headwoman and other traditional authorities, decide e.g. about new settlements of households (the right to exclude), or about the establishment of new fields for cropping.

3.3 Production systems and market access

An extensive small-scale agro-pastoral system can be found in Mutompo. Crops, such as millet, sorghum, groundnuts, beans, pumpkins, and melons, grown on a subsistence level, but with low yields. Extensive small-scale pastoral systems with a focus on large stock occur in Okamboro, in the Ovaherero-community, which is constituted by traditional cattle farmers. Small-scale gardening in central Namibia is very limited, due to the low and variable precipitation. Table 6 shows the characteristics of the production systems of the investigated communities. The recent values for the human population density, the cattle population per square kilometre and the cattle/human ratio (suggested values by Otte & Chilonda (2002), in parenthesis) give first evidences for overstocking and overpopulation respectively on Okamboro, regarding the agro-ecological zones with their low potentiality of biomass productivity as well as the high rainfall variability. However, this has to be evaluated after more than one rainy season, and is related to the degree of degradation of natural resources, and the resilience potential of the vegetation, which is often unknown, but seems to be high when an appropriate seed bank is available.

Table 6: Production system

	Mutompo (North of Namibia)	Okamboro (Central Namibia)
Production system	Agro-pastoral system; mixed rain fed system	Pastoral system
Human population density (people km^{-2})	2.2 (suggested: 9.8)	2.8 (suggested: 1.5)
Species of livestock	cattle, goats	cattle, goats, sheep
Breeds	Indigenous	Indigenous and crossbreds
Cattle population per square kilometre[1] (LSU km^{-2})	3.3 (suggested: 5.1 cattle km^{-2})	9.3 (suggested: 1.9 cattle km^{-2})
Cattle/human ratio[1] (LSU/human ratio)	5.18 (suggested: 0.52)	5.96 (suggested: 1.27)
Livestock mobility status	Sedentary	Semi-sedentary
Output from livestock	Draught, milk and meat	Milk and meat
Major crops	Millet/sorghum	None
Cultivation intensity	Low	Minimal (gardening)

[1]Classification according to indicators (suggested values in parenthesis) adapted from Otte & Chilonda, 2002. (Simplified in this table: 1 cattle = 1 large stock unit = 6 small stocks.)

The human population density in Mutompo is moderate, and the stocking density is low, which is typical for an agro-pastoral system. Based on the output function of livestock and on the degree of economic dependence on them, mixed systems have been defined as those which derive between 10 and 50% of gross profits from livestock, or about 50% or more from e.g. rain fed cropping (Wilson (1986), in Otte & Chilonda, 2002). Draught power of oxen is essential in the northern Namibian community of Mutompo for ploughing and transport purposes.

In the Okamboro region, where the biophysical condition and climate are much harsher and dryer, pastoral systems have been established. All settlements are sedentary. Only in Okamboro, a part-time mobility of cattle herds in order to cope with a drought situation in 2003 was observed.

Often, poor infrastructure, no information on prices, and difficulties in market access impede a more market-oriented production and the marketing itself in Namibian communal areas. The typical environmental conditions, with erratic and low rainfalls of arid and semi-arid regions force production to an extensive level, due to few and seasonal biomass production on rangelands. Additionally, the high risks of droughts require strategies to cope with these unpredictable situations.

For the people of Mutompo marketing of livestock or surplus crops is difficult, due to missing infrastructure, missing means of transport, and the long distances to market places. Livestock marketing is better organised in the Ovitoto-Reserve, where a farmers association organises a regular permit market (many sellers – one buyer) in Okanjira (in a distance of 15 km, gravel road), where livestock are categorised according to age and condition, and official prices are paid per kg live bodyweight. Farmers in Okamboro mentioned that people who are interested in buying animals sometimes come to visit the village. That seems to be the easiest way of marketing. However, often information on actual livestock prices and the missing knowledge about the exact bodyweights of their livestock makes selling this way an insecure method.

3.4 RECENT AND HISTORICAL LIVESTOCK NUMBERS

Current estimates of livestock numbers in the Kavango regions for 1996 and the year 2000 were compared with other historical data for livestock, according to the Directorate of Veterinarian Services (DSV) in 1996 (see Table A 1 in the appendix and Figure 6 for small stock and large stock). This data represents a high increase in comparison to the population estimates of 1987/88. The most commonly owned livestock are cattle and goats, and these account for more than 95 % of the total livestock population (Hengua & Bovell, 1997). The development of livestock numbers in the Kavango region, was kept on a low level until the 1995/1996 drought year (Figure 6), and was dominated by cattle. The stocking density in the entire Kavango region increased from 5.3 kg ha^{-1}, in 1996, to approximately 11.3 kg ha^{-1}, in 2001. In the investigated inland community of Mutompo, the stocking density was found to be around 15 kg ha^{-1} in 2001 (own data). The Okavango Native Territory, to which Mutompo belongs, was established in 1937 (Yaron et al., 1992), but only in the 1970s the first permanent settlements around the Mutompo area emerged. An old aerial photograph from the year 1972 shows no fields in Mutompo (Mendelsohn et al., 2002). Mutompo was established around the beginning of the 1970s, when the water hole was drilled. First, only a hand pump was installed. During this time, people started moving from areas near the Okavango River to the inland areas, where the population pressure was still low, and resources were left unused. Then, only wildlife grazed and browsed on the resources of the dry forest and few mobile herders or San people may have used this area. Since the 1930s, colonial power exploited the forests of northern Namibia.

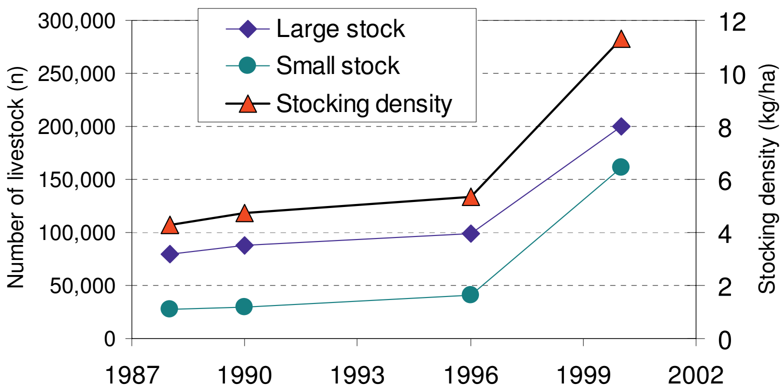


Figure 6: Development of livestock number and stocking density in the Kavango (1988-2000)
(Sources: Adams et al., 1990; Yaron et al., 1992; Hengua & Bovell, 1997; DVS 2000, personal communication. Detailed data see Table A1 in the appendix; Kavango covers and area of 42,771 km²). For the period between 1991 and 1996, no livestock data were available.

In spite of this exploitation, the Namibian forest resources were in much better condition than those of the neighbouring countries, where large scale logging of high quality wood was stopped after independence (Hailwa, 1998; Mendelsohn et al., 2002). Water supply was the main problem, before the well was drilled in the 1970s. Temporary water places, so-called ‘ndombe’ (or ‘endombe’) in the local language ‘Rukwangali’, provided first settlers and their oxen with water. Small depressions of soil, with higher clay content, prevented water from draining into the soil and small ponds arose. First clearing of forests and cultivation commenced in this period. In 1989, the water supply improved with the installation of a diesel pump and a round concrete water basin (Falk, 2007). This attracted more people to settle in Mutompo and the community grew fast, towards the end of the 1980s.

Okamboro is located in the Ovitoto Native Reserve, which was proclaimed in 1923 and its boundaries defined by Government Notice No. 122 of 1923, with an initial size of 47,791 ha (Adams et al., 1990). The size of the Ovitoto Native Reserve was declared as about 61,194 ha in the 50s of the 20th century (Wagner, 1957), which is also the size of it today[14]. Grazing and browsing of livestock is the main form of agriculture in Ovitoto. The historical development of livestock numbers of Ovitoto, from 1943 to 2000, is shown in Table A 2 in the appendix, and in Figure 7. At least since the second half of the 20th century, the area has had a history of high grazing pressure. In 1943, the estimated stocking density in the Ovitoto area was around 33 kg ha^{-1} (Wagner, 1957, see Figure 7). Until 1954, the pressure decreased significantly. By then, stocking densities approached about 62 kg ha^{-1} (Wagner, 1957). The stocking density dropped to a level of 45 kg ha^{-1} in 1989, and notably declined to a minimum level of 29 kg ha^{-1} in 1997, after the drought years of 1995/1996. Obviously, the number of small stock decreased dramatically, in comparison to the large stock numbers during this post-drought period.

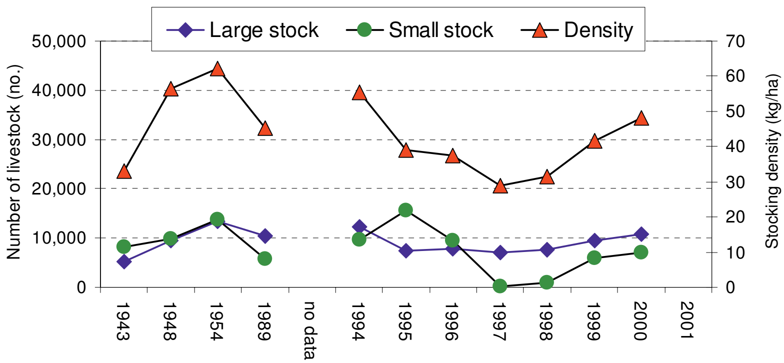


Figure 7: Development of the numbers of livestock and stocking densities of Ovitoto (1943-2000)

(Sources: 1943 – 1954: Wagner, 1957; 1989: Adams et al., 1990; 1994-2000: Veterinarian Office Okahandja. Data see Table A 2 in the appendix; the Ovitoto Reserve covers and area of 61,194 ha ~ 612 km²)

The stocking of cattle recovered after 1997 in the Ovitoto Reserve, pushing the value of total stocking density to 48 kg ha^{-1} (41.9 kg ha^{-1} were found for Mutompo in 2001; own

[14] Source: Administration of Ovaherero, report, 19/01/1990, (in Adams *et al.*, 1990).

data), which was above the recommended value, within the range of 30 to 40 kg ha^{-1}. The numbers of small stock declined from the peak in 1995 to less than 100 animals in 1997 due to a heavy drought. During this two years period the numbers of large stock, which was mainly composed of cattle, only slowly decreased. Cattle numbers hardly decreased. Since 1997, the number of small stock has concisely approached to the levels of 1943. An increase of livestock number is expected within the communal areas of Ovitoto in the future, due to a higher number of absentee households, or family members who earn wages in the near urban centres, investing this money into the livestock of the communal areas.

In 2001, in Okamboro, which was classified as a pastoral system, the livestock-keeping households kept 1,740 heads of livestock in total - around 3.4 times the number of heads of livestock owned by farmers in Mutompo, with 437 heads (see Table 7). Referring to total bodyweight, Okamboro had 4.2 times the bodyweight of that in Mutompo. Cattle had the highest share of around 88%, referring to bodyweight in both communities; small stock shared around 11%, and donkeys and horses made only 0.5% and 2% of the total in Mutompo and Okamboro, correspondingly (see also Table 7). In Okamboro, there were generally more sheep in a flock than in Mutompo. Surprisingly, in both communities, the cattle share around 88% of the total herd, and small ruminants constitute about 10% of the stock, both referred to the body weight, even tough Mutompo had a mixed farming system with cropping and livestock, and Okamboro was a pure livestock keeping community. In Mutompo the livestock number kept per livestock-keeping household (n = 12) were 34 (SE 9.5), and 67 heads (SE 16.7) in Okamboro (n = 25) (for more details see Table 27, p. 122 and Ch. 5.3.1, p. 121 ff.).

Table 7: Livestock numbers and their composition of species

Livestock species	Mutompo (n = 12)			Okamboro (n = 25)		
	No. (n)	Total BW (t)	Share of total BW (%)	No. (n)	Total BW (t)	Share of total BW (%)
Cattle	197	50.96	88.1	941	212.97	87.5
Goats	226	6.22	10.8	623	20.38	8.4
Sheep	12	0.37	0.6	157	5.27	2.1
Donkey/horses	2	0.28	0.5	19	4.75	2.0
Total	437	57.83	100	1,740	243.37	100

In both communities, the livestock herds were clearly dominated by cattle. Cattle are supposedly most important to people in both communities, though oxen are of first priority in Mutompo, used for transport purposes and for ploughing, cows take up extremely high importance in Okamboro, aiming to enlargen the herd sizes, and increasing milk production.

Animal numbers reported for Mutompo, by the Department of Veterinarian Service (DVS 2000, personal communication) were 193 cattle, 153 goats, and 2 donkeys. In 2001, (DVS 2001, personal communication), the livestock numbers accounted for 198 cattle, and 121 goats, but no donkeys. These numbers correspond with the counted livestock numbers in Mutompo in 2001, except all twelve sheep are missing, as well as over 70 goats.

3.5 MUTOMPO, KAVANGO REGION - IN DETAIL

The region of Mutompo is classified as tree savanna and dry woodland (see Photo 1 and 2, p. 232 in the appendix), which is dominated by open broad-leafed woodland on eroded dune structure with deep sands of the Kalahari Plateau. These dry woodlands merge with the tree savanna of the north-central area. On the remains of old dunes, the vegetation varies considerably between that on the sandy dunes and the more clayey soils in the inter-dune valleys. Thus, tall teak (e.g. *Baikiaea plurijuga*), false mopane (*Guibourtia coleosperma)*, burkea (*Burkea africana*), kiaat (*Pterocarpus angolensis*), and mangetti trees (*Schinziophyton rautanenii*) often dominate the deeper sands, tending to an open tree-savanna. The most common shrubs in these dry forest regions are *Glewia flava, Croton gratissimus, Commiphora glandulosa, Combretum collinum, Bauhinia peterisana, Lonchocarpus nelsii, Terminalia sericea, Ochna pulchra* and *Baphia massaiensis*. *Combretum-Commiphora* associations grow on deep reddish to yellow sands, which are inter-dune areas. Whilst lying lower, the more clayey soils are characterised by a shrubby vegetation of silver terminalia (*Terminalia sericea*), camelthorn (*Acacia erioloba*), *Combretum hereroense*, *Acacia fleckii* or other *Acacia* species, with patches of grassland, tending to an open thorny-tree savanna (Mendelsohn & el Obeid, 2003). The grasses tend to be coarse and unpalatable including *Eragrostis pallens, Sporobolus* spp., *Aristida* spp. and *Pogonarthria* spp., however also more palatable species occur, including various species of *Brachiaria, Digitaria* and *Eragrostis* (Sweet & Burke, 2000; Strohbach & Strohbach, 2004).

The vegetation near Mutompo and on the Mile 46 Research station have a high degree of phyto-biodiversity with 335 annotated plant species, investigated on the squarekilometer plots 'Observatory Mutompo' and 'Observatory Mile 46' (see Map 3, p. 35) within the dry forest region (Strohbach & Strohbach, 2004). Based on this number of plant species, it is estimated that, in total, approximately 380 species occur in this area (Strohbach & Strohbach, 2004). However, these observatories were located in areas of dense woody layers, which provides protection against grazing and fire (Strohbach & Luther-Mosebach, 2010), and are in some kilometre distance to the huts and the community Mutompo, where almost no land use effects vegetation biodiversity.

Infrastructure in the Kavango is poorly developed and distances to the market or shop are far. A distance of approximately 15 kilometres of sand path needs to be managed in Mutompo until reaching the tar road in the direction to Rundu or Grootfontein. Along this road, villages with better infrastructures are located. Rundu, the Kavango district town, is around 70 km away from Mutompo. The next shop or small market is located in Katjinakatji, which is also a place for livestock marketing, which is approximately 15 km away from Mutompo. For buying clothes or for selling cereals people have to go to Rundu. Transport facilities were observed to be a general problem; due to only one household having access to a car. Oxen and wooden sledges are the only means of transport, and the roads are very sandy. To reach Rundu people have to go first on foot to the tar road, then people usually hitchhike. Hitchhiking is not free in Namibia; it costs about NAD[15] 10 to 15 for a ride from the tar road near Epingiro (see Map 3, p. 35) to Rundu one-way.

Temporary water places provided first settlers and their livestock with water. After establishing a community near a newly drilled borehole in the 1970s (see Figure 8, p. 36), people from the south bank of the Okavango River moved to this area and cleared the forest to start with rain-fed cropping. The average annual rainfall permits the growing of quickly maturing crops without irrigation on dry land fields (see Table 4, p. 22). Mixed production systems exist in the North of Namibia. Farmers grow millet (Mahangu), sorghum, some maize, beans, groundnuts, pumpkins, melons and vegetables, such as spinach on a subsistence level, with oxen for draught power. Most of the mahangu and maize harvested is consumed domestically, while sorghum is used to produce beer. In drought years or when the rainy season starts late or is very short, the harvest does not suffice until the next harvest. In 2001, fourteen households lived in Mutompo. About 44% of the households have come in during the last 10 years, another 33% settled there from 1981 to 1990. Then, there seems to be a long gap, because the two oldest households settled in the area 30 and 31 years ago. Maybe during that time, these two households were mobile, moving with their livestock between the available water access points. In 1989, the water supply improved with the installation of a diesel pump and a round concrete water basin. This attracted people to settle in Mutompo and the community grew fast, towards the end of the 1980s. Village life was affected by the liberation war between the SWAPO (South West African People Organisation) and the SADF (South African Defence Force) then, too. Villagers reported that the army even attacked the settlement in 1982 because it was suspected to be a guerrilla hideout. After this, all of the people of Mutompo left with their livestock and went back to the areas near the Okavango River. Despite their fear, the residents returned to Mutompo in 1986, due to land scarcity in the

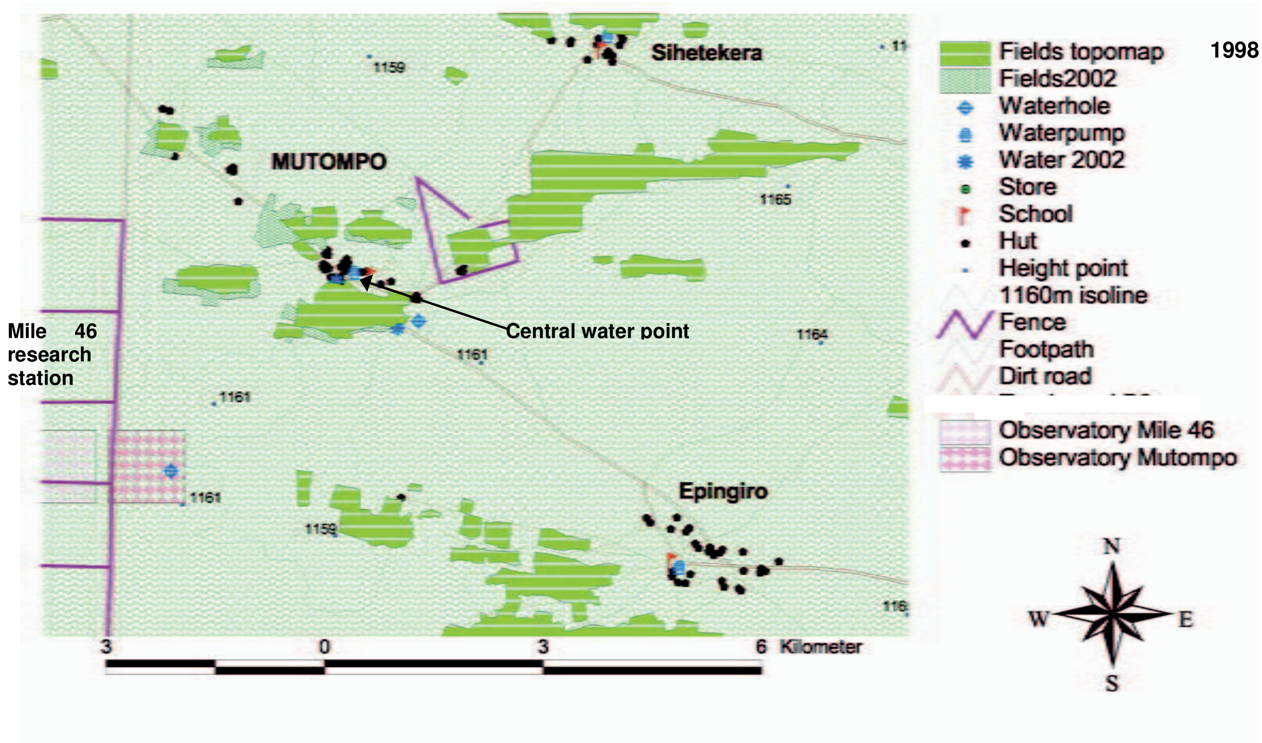
[15] NAD (Namibian Dollar) 10 ≈ € 1

river regions (Falk, 2007). The mean of years, which households were in Mutompo in 2001, was calculated to be 14.2 years (SE of mean: 3.4; median: 14 years).

In Map 3, the areas of settlement, and the surrounding areas for grazing and the fields, as well as the infrastructure are shown. To get a better overview, Figure 8 (p. 36) shows an aerial photograph of the area of Mutompo. In Mutompo, huts are spread along the only dirt road, with the permanent water point and the basic school hut situated in the centre. Most of the huts cluster in this area near the water pump, where next to the water point for livestock also a tap from a round water reservoir is found. Temporary water places could be found after rainy season, on plots where the soil contains more clay and silt, and has a higher water holding capacity. Two of them were found near the dirt road southeast the large field, which is devided by the road coming from the direction of Epingiro.

The land is flat (1,159 – 1,165 m a.s.l.), which indicates the light green colour in Map 3 (p. 35), and only slight hills can be found, which might reflect the former dune structure. The vegetation of the area is classified as closed woodland, open bush land, thickets and open savannas (or cleared areas or fallow ground). Fields (light green: topographic map 1998; darker green: own GPS measurements in 2002) are more widely distributed around the settlements, mainly in the darker soil with more clay and silt content. The area of the fields including the fallow land, measured in 2002, constitutes around 5.5% of the total communal area of Mutompo of estimated 3,848 hectares. In 2002, the field sizes lie between 2.7 and 56.5 ha. Bigger fields were observed to be managed together by related households. Larger cropping areas in western direction belong to the community Sihetekera, not to Mutompo. Fields located south of Mutompo, stretching northeast from Epingiro, belong to the community Epingiro. Open bush lands as well as thickets were found near the community, stretching into an area of some kilometres around Mutompo (see Figure 8). Open woodlands lay westerly and southerly of the open bush lands and fields, and were used for grazing by the livestock. The cattle trails, leading from the central water point to the grazing areas and to the open bush- and woodland, are well visible in the small aerial photograph of Figure 8.

During the study periods, it was observed that parts of the fields lay fallow. In other areas, through the extending of old fields, new cropping areas were established. On some fields, small shrubs and bushes were observed, on others only fallow grass (*Tricholaena monachne*) grew, but in huge amounts. If the areas with small shrubs and bushes were not former and deserted old fields of removed households, the fallow periods may last several years. Maybe fields are cropped every year, when rainfall allows a successful cropping.



Map 3: Map of Mutompo (Kavango region, northern Namibia)

Figure 8: Ariel photographs of the community Mutompo

The entire area around Mutompo is used for grazing the cattle, the goats, and few sheep, nearly without fences. Along the border to the Mile 46 research station, their fenced camp structure is visible (Map 3). Moreover, an old fence around a small area with a field blocks the way of livestock in easterly direction towards the community Sihetekera. Most of the time, livestock depends on the public water point in the centre of the community, and the animals have to go there for drinking at least once a day. In all communities, usually the livestock is penned up over night; cows or goats are milked in the morning, respectively in times when milk is available. In Mutompo, during the cropping period of the rainy season, cattle and goats are herded in order to protect the fields and crops from grazing and trampling. Around some of the fields, there exists a natural fence, which is made from thorny bushes, to keep the animals out. In some cases, the livestock was able to trespass this natural fence. During the non-cropping season, the harvest residues usually remain on the fields, this serving as additional feed for cattle during the dry season. Livestock is not herded during this period, but sent off in specific directions in order to walk to the preferred grazing areas. The animals seem to know the region, the paths to the grazing areas, as well as the watering places quite well. In the early evenings, most of the cattle and goats eventually gather at the central watering place. Household members or the herders then collect the animals and bring them into the kraals. In the mornings, the oxen are sometimes separated from the rest of the herd in order to use them for transport of water or other means of transportation, or for ploughing the fields. Bulls are not separated from the herds, thus, there is practically no breeding control.

Contagious Bovine Pleuropneumonia (CBPP or lung sickness) and Foot-and-Mouth Disease (FMD) are reported to be the economically most important livestock diseases in the region. Other diseases, such as Lumpy skin disease, Three-day sickness (ephemeral fever), Black quarter, Botulism and poisoning through poisonous plants (e.g. poison leave of *Dichapetulum cymosis*; Afrikaans: Gifblaar, in Hengua & Bovell, 1997) also occur. Governmental veterinary services vaccinated cattle in the Mutompo region against CBPP and FMD without any costs for the first time in 2003.

The neighbouring governmental cattle research station 'Mile 46' (see Map 3), which is going to offer training for local communal farmers in breeding control, health care and general livestock management, also supporting the conservation and improvement of local Sanga-cattle breed, holds about 300 cattle on a camped area of 5,770 ha. In 1993, the livestock numbers were declared as 120 (Ministry of Agriculture & International Service for National Agricultural Research (ISNAR), 1993), which means a stocking density of about 5 kg ha^{-1}. In 2002, during the field survey, the stocking density was about 12.4 kg ha^{-1} (or 300 cattle), due to new research activities starting on the station.

3.6 OKAMBORO, OVITOTO - IN DETAIL

The Okamboro region is a thornbush savanna, which is the dominant vegetation type in the central part of the country (see Photo 2 and 3, p. 233 in the appendix). Bush encroachment by *Acacia mellifera* and *Dichrostachys cinerea* is partly observed. Other characteristic species include *Acacia reficiens, A. erubescens* and *A. fleckii*. Common grasses include *Antephora pubescens, Brachiaria nigropedata, Digitaria* spp.*, Stipagrostis uniplumis* and *Schmidtia pappophoroides* (Sweet & Burke, 2000). In the Okamboro region and in the Ovitoto area, some characteristics of vegetation apply also to the Camelthorn savanna (300-400 mm rainfall) of the central Kalahari, which is an open savanna. *Acacia erioloba* (Camelthorn) is not widely distributed, but common shrubs include *Acacia hebeclada*, *Ziziphus mucronata, Tarconanthus camphoratus*, and *Grewia flava* occur. In normal rainfall years there is a good grass cover, but of mainly coarse, unpalatable grasses such as *Eragrostis pallens* and *Aristida stipitata.*

Today, about 10 communities are located in the Ovitoto Reserve, 'Okanjira' in the centre being one of its largest. The Ovitoto Reserve is surrounded mainly by commercial farms. Okamboro is located in the north of the Ovitoto area, bordering west on the Osona base and east on a military area, so-called 'Swakophöhe', which was formerly a commercial farm. North of the Okamboro area run the borders of a nature reserve, the Van-Bach-Recreation area (Map 4, p. 40). In the community Okamboro, the huts are concentrated in two clusters (Map 4), north and south of the large dry riverbed (see the aerial photograph Figure 9, p. 41). Steep slopes are visible through partly high differences in altitudes. Fourteen fenced camps were found within this community. Single farmers use their camps for sick animals, for pregnant cows, or sometimes to control and protect breeding bulls. The huge camp in the south is shared with a farmer in Ombupoori, a community in the south. The area of the entire fenced camps constitutes around 10 % of the total estimated communal grazing area of Okamboro, which is around 5,800 hectares.

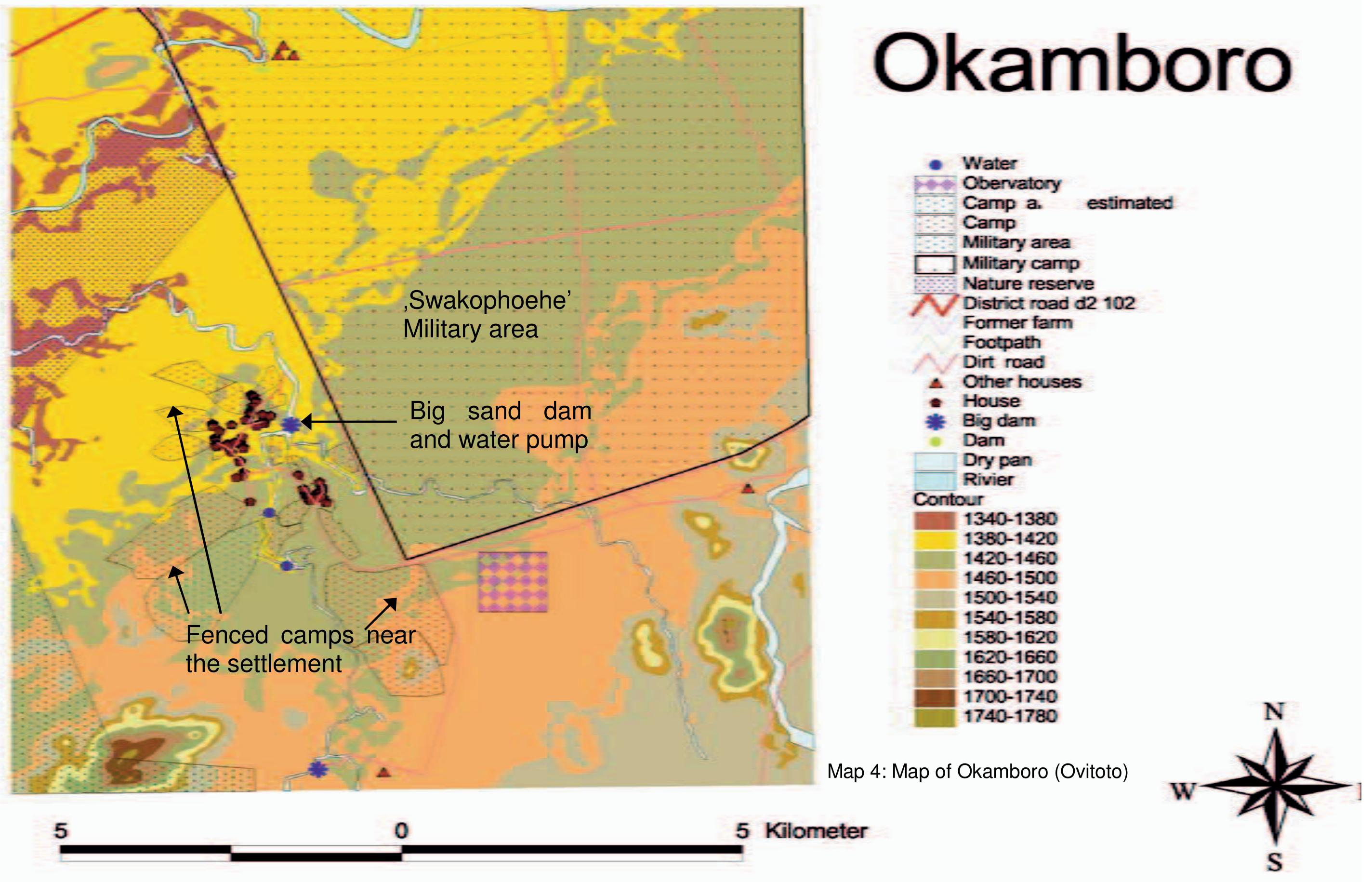
Infrastructure is reasonable; most communities within the Ovitoto-Reserve and the next town, Okahandja, (about 25 km distance from Okamboro), are connected by gravel roads. Shops, a boarding school, a petrol station, the livestock market and most of the Ovitoto administrational offices are located in Okanjira, which is approximately 15 km away from Okamboro. In Okamboro itself, few households run a small shop, and a mobile trader regularly comes to the community.

The settlement of Okamboro, which could be found in official maps (Wagner, 1957) some kilometres south of the actual place, had a population of 73 people (20 men, 31 women, 8 boys, 14 girls) in 1954. Thus, it was then one of the larger villages (mean size 61 inhabitants, median 37 inhabitants; Wagner, 1957). Unfortunately, there is little information and data available about the Ovitoto Reserve of more recent dates. The main problems with the Ovitoto Reserve (already in 1923) were a lack of water, coupled with inadequate pastures (Adams et al., 1990). In 1954 the stocking density was approximately 62 kg/ha in the Ovitoto Reserve (Wagner, 1957). However, the estimated carrying capacity was eight ha LSU^{-1} (approximately 56 kg ha^{-1}) (Adams et al., 1990). The number of boreholes in 1989 was reported at 24; however, two of them were in poor condition or not working properly. Then the average number of hectares per water point was 2,551, and the average cattle and small stock numbers per water point were 430 and 237, respectively.

The main cattle are an Afrikaner-breed type, or crossbreds of Brahman x Afrikaner. Boer crossbred goats and few Damara sheep are kept. In the Ovitoto-reserve, the veterinarian office of Okahandja vaccinates cattle against anthrax, botulism and black quarter (3 in 1 vaccination), as well as brucellosis for young heifers once a year, free of charge.

The main permanent water place for livestock is the big pond behind the sand-dam, which results from water trickling through the dam wall (see Map 4, p. 40 and Figure 9, p. 41). additionally, people use a water place, equipped with a diesel pump, for fetching water from a tap for human use; sometimes sheep and goats were observed to be watered on a concrete watering place next to the pump. A second water place, equipped with a hand pump, provides people with drinking water. After rainy season, people wash their clothes in deep holes dug into the dry revier[16]. In 2002, the government provided a third modern borehole for animal and human water supply, located further upstream of the sand dam near the dry river. People reported shortly after construction of this new water place, that the diesel pump was broken, and it did not work up to May 2003. Temporary natural ponds were created in the riverbed by water, which flooded the revier in rainy season. One natural temporary water place between sandbanks is located further south, and some smaller ones were found downstream. Another permanent water dam is located near Ombupoori, about five kilometres from the sand dam. Sometimes cattle walk in the direction of this place for watering, when grazing in the south or southeast regions of Okamboro, the livestock owners or employed herders, guide the livestock to the local watering point, normally in the mornings.

[16] Afrikaans for river, means a dry riverbed, which is only flooded during rainy season.



Map 4: Map of Okamboro (Ovitoto)

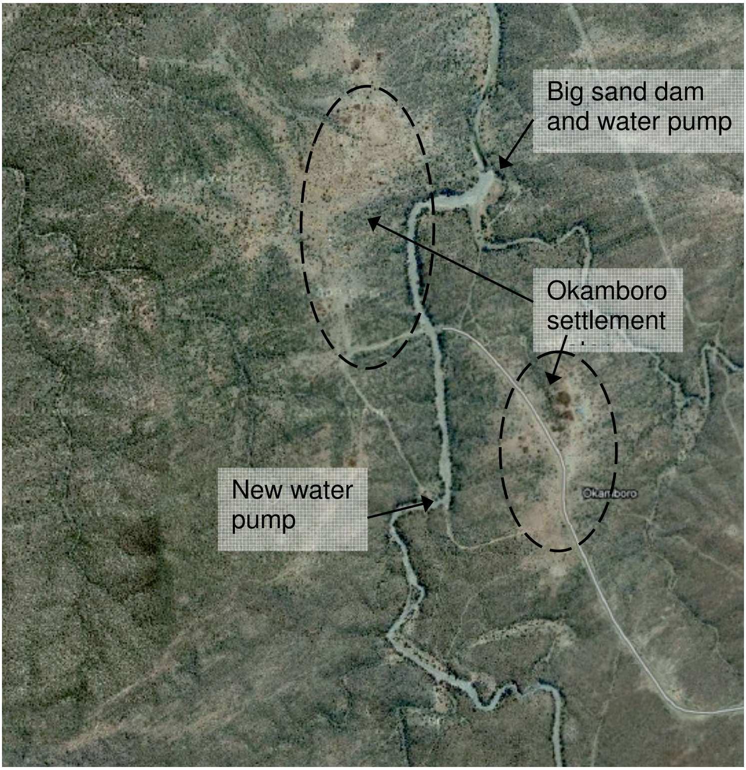


Figure 9: Ariel photographs of the community Okamboro and the surrounding areas

Flocks and herds are separated normally into species (goats and cattle) and age classes (e.g. adults and calves), only lambs are not separated from the adults in Okamboro. The animals are sent off into specific directions for grazing after watering. They normally come back to the kraals every evening. Only farmers who own homogenous small stock flocks, usually made up of goats, herd their stock every day. Cows are milked in the mornings inside or near the kraal, with the calves drinking on the other side of the udder, in order to elicit the milk ejection reflex. Calves and goat kids are separated from adults, because they cannot walk as fast and over long distances as the adults.

Some special breeding bulls e.g. Brahman, are kept in fenced areas and controlled breeding can thus take place. These fenced-in camps are also used for pregnant cows or sick animals; sometimes they serve as grazing reserves. A goat flock protected by two goat-dogs and without a herder was observed in the grazing area during fieldwork, yet dogs were not used as helpers during other herding activities.

In April/May 2003, when rain was very scarce, some changes in the management in Okamboro could be observed. During the end of the dry season or beginning drought, cows were not milked, because the milk production decreases and this practice ensured at least the calves' survival. Most of the younger cattle came back to the kraal every second day, probably in order to prolong their feeding times during the day and night, grazing in more remote areas, or just to save energy by not walking much. The daily walking distances seem to lie within a radius of around 2 to 3 km in normal rainfall years. There is another permanent water place, an artificial dam, located in the neighbouring community Ombupoori, which lies within just the daily walking distance. The cattle of Okamboro sometimes use this watering place. Some of the private fenced areas block a direct path towards this village.

Since Mai 2002, Okamboro has been connected to the power supply system. From then on most of the households have used electricity only for lighting in the evening, because they could not and cannot afford to pay more for electricity or for buying electronic equipment.
Two households have a garden near the riverbed, where the soil fertility is good and the soil moisture is better than anywhere else is; one woman does gardening on a bit larger scale near her house but not near the river, to generate some income. People have to irrigate the vegetables to ensure the harvest. They do not start seeding and planting before they are not sure about appropriate amounts of rainfall. During the season 2002/2003, nobody planted anything in his or her garden, due to the poor and unequal distributed rainfall.

The community of Okamboro had 29 households in 2001. The history of settlement and land use goes back to the 1920s, when Ovaherero people settled in the Ovitoto area because they were needed to work on the neighbouring farms as farm workers (see also Werner, 2003). In Okamboro, 35% of the households settled before the 1970s. Thirty-five percent of the households of today have settled or were established between 1981 and 1990, and 25% of the households have settled or been established during the last 10 years The mean of years, which households had been in the village in 2001, was calculated to be 28.7 years (SE of mean: 5.6 years, median: 16 years). The number of the population for the Ovitoto Reserve added up to 1,419 people in 1951 and 1,542 people in 1954, which settled in 25 existing villages (Wagner, 1957). For Ovitoto this means, that one household (assumed to consist of 6 persons) could use a grazing area of 238 ha in 1951; in 1954 one household could use only 188 ha of the total Ovitoto area (61,194 ha) on average. Today, when considering only the estimated grazing area available around Okamboro, the 29 households use an area of approximately 200 ha each (see Map 4, p. 40).

4 Evaluation of range resources

4.1 SPECIFIC OBJECTIVES AND WORKING HYPOTHESIS

It was assumed that around the settlements and the central watering points, the land use and utilization of natural resources, as well as other impacts, such as trampling from livestock and the collection of fuel wood, occur in higher intensity than in distances further away. Farmers in communal areas depend on the central water places for drinking water and for watering their animals, because only during a short period in the wet season, natural water places are available for livestock. Additionally, livestock depends merely on the natural forage resources, which grow on the communal grazing areas, where space is limited. In the late dry season, the access to natural grazing and browsing resources may become insufficient.

This study aims to

- analyse the quantity and quality of available grazing and browsing resources within communal grazing areas during dry and wet season;
- to investigate the spatial distribution of rangeland resources within the communities' grazing areas, starting from the central water point, moving to the periphery, in order to examine the impacts of livestock and human beings

The following working hypothesis is put forward:

Land use of the communal farmers has a harmful impact on the communal rangeland resources. This is reflected in spatial utilisation gradients of rangeland resources.

Grass and browse biomass, and plant species diversity, which occur in a clear gradient from the water points, are apparent signs of land use. Such grazing gradients stand for a potential opportunity for differentiating the long-term effects of livestock activities from other environmental patterns. When these symptoms are negative or destructive, such as bare soil patches, signs of soil erosion, as well as a low net primary production, it can be interpreted as an over-utilization or overstocking of these communal grazing areas, if these signs persist during a normal or good wet season.

4.2 METHODS OF EVALUATION OF RANGELAND RESOURCES

4.2.1 Design of transects

A rangeland assessment along transects was to be carried out in the two communities (north and central Namibia) in a dry and in a wet season, in order to investigate the short-term quantity and quality of the grazing and browsing resources on communal grazing areas (this chapter). The design of the rangeland assessments comprised taking a sampling every 200 m along five transects, starting from the central water point, and covering the main grazing areas within the community (Figure 10). Near the well, the sampling design going up to the one kilometre point was different. Samples were set every 100 m along transects, in order to identify a possible sacrificed zone. In Okamboro, this sampling design was carried out for all transects. But in Mutompo, due to time constraints and a higher biomass of grass species, as well as the much higher numbers of small shrubs, the 100 m sampling within the first kilometre could not be applied to all 5 transects, but only to two.

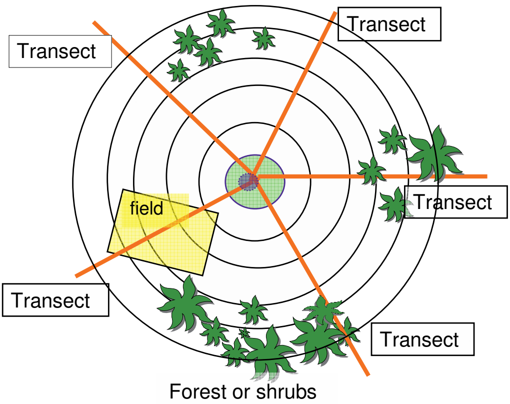


Figure 10: Design of transects

Next to the sampling point and within this area a square meter plot was randomly selected (with a stone's throw backwards). Due to time constraints and the large number of sampling points within large distances, which could be reached only on foot, a replicated sampling on the plots was impossible. Each position was determined with a GPS-device (Garmin III Plus, UTM system, WGS 84). A modified report sheet of BIOTA botanists was used as an instrument for rangeland assessment (see Qu 1 in the appendix).

Community maps of the two communities were produced and designed based on the official national topographic maps of Namibia. Houses and other important points such as fences, streets etc. were marked with a GPS to get information about the size of the grazing areas, the infrastructure, and the BIOTA observatories, as well as the distances between important locations. The size of the fields and grazing areas were estimated with the GIS-software ArcView using XTools.

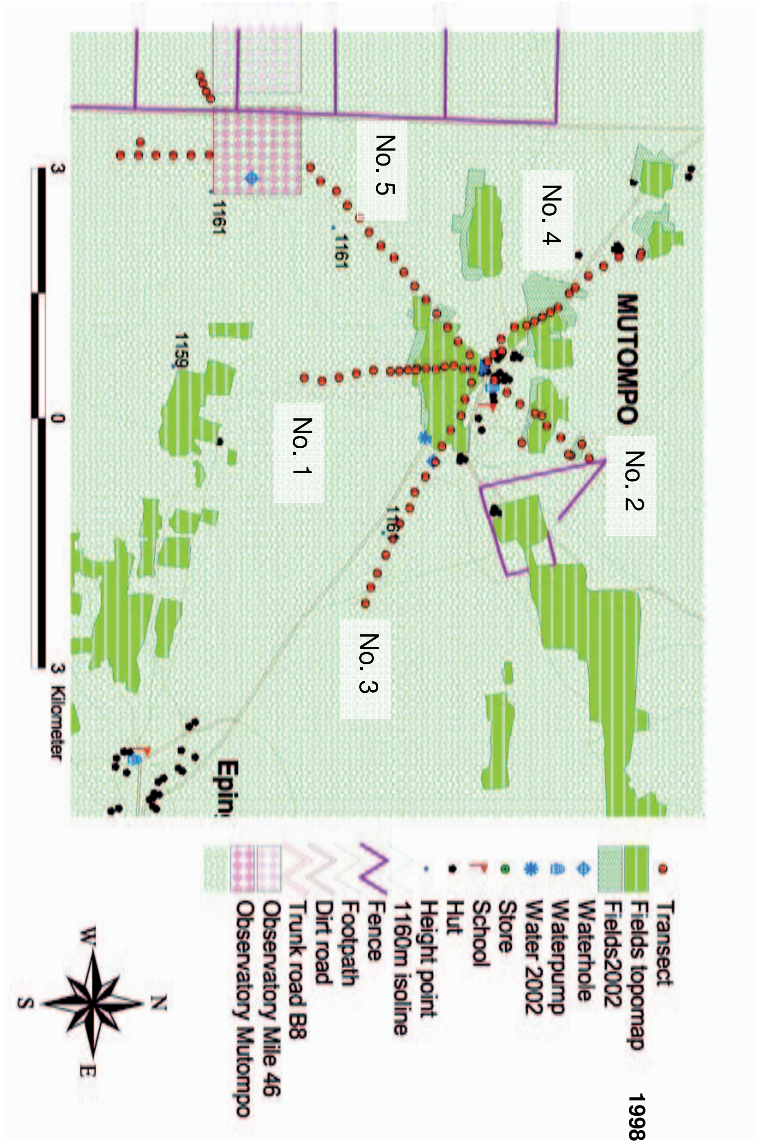
In Map 5, the locations of the transect-sampling-points in Mutompo are shown in red dots. Five transects cover the surrounding, starting from the central water point to the peripheral areas in the directions of south (transect no.1), northeast (transect no. 2), southeast (transect no. 3), northwest (transect no. 4) and southwest (transect no. 5). Five transects covering the surrounding grazing areas of Okamboro (Map 6), started from the central water point behind the big sand dam, and stretched to the peripheral areas in the directions of north (transect no. 1), west (transect no. 2), southeast (transect no. 3), east (transect no. 4) and south (transect no. 5).

In Mutompo, the transect 4, which is the transect heading in northwestern direction, is not in line, due to the intended further distance to the road and the location of the households within this area. The south-western transect 5 is not in a straight line because of the location of the BIOTA-observatory and the fenced border to the Mile 46 research station, where only some samplings were carried out, not contributing to the Mutompo sampling area, but which are illustrated in Map 5. In Okamboro, some transect lines crossed fenced areas (see Map 6), and only when the farmers allowed the taking of grass samples, these areas could be sampled. A fraction of transect 3, which is directed to southeast, is located across the road, focused more on the area next to the BIOTA-observatory, because this large fenced-in camp is shared with farmers of Ombupoori, the neighbouring community.

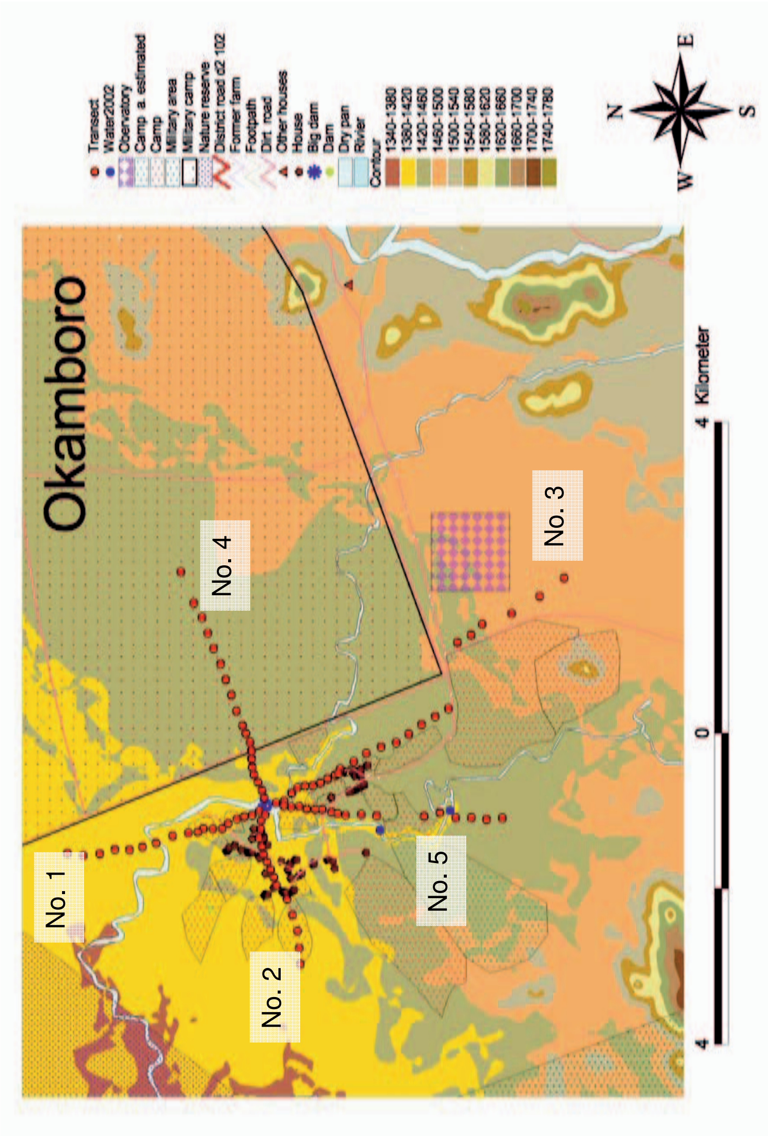
4.2.2 Rangeland evaluation

The total available grazing area (estimated on maps and satellite images), covered an area of about 3,848 ha in Mutompo (see Map 5), and 5,808 ha in Okamboro, and (whereas parts of the military area located in the east of the community Okamboro were included, see Map 6 of Okamboro). The definite numbers for the sizes of areas resulted from the calculation based on an estimated radius of the total area of 3,500 m in Mutompo and 4,300 m in Okamboro.

Surface soil samples (0-10 cm depth; 16 samples of Mutompo; 12 samples of Okamboro) were taken mostly in one-km-intervals to the watering points or from cropping fields in Mutompo nearby the transect vegetation sampling points. These samples were analysed in the Agricultural Laboratory of the MAWRD in Windhoek for the pH-value and the electrical conductivity (EC; µS/cm), the content of organic matter, phosphorus, potassium, calcium, magnesium, sodium, and carbonate. Additionally, the texture of the soils, as well as the sand, silt and clay content were assessed.



Map 5: Map of Mutompo with the transect sampling points



Map 6: Map of Okamboro with the transect sampling points

First sampling of grass and bush and tree biomass took place in October 2002, the end of the dry season, reflecting the remaining vegetation after the rainy season in 2001/2002. The second field sampling was conducted in April/May 2003, after a relatively poor rainy season. Main characteristics of the plots e.g. soil and vegetation type, brief habitat description (e.g. slopes), signs of erosion or disturbances e.g. fire, were registered (see Qu 1 in the appendix). The number of samples is shown in the following table (Table 8).

Table 8: Transect sampling in 2002 and 2003

	Okamboro DS 2002	Okamboro WS 2002/3	Mutompo DS 2002	Mutompo WS 2002/3
Sampling periods	9-11/2002	05/03	10/2002	04/03
No. of transects	5	5	5	5
Range of length (km)	2.6 - 5.0	2.6 - 5.0	2.4 - 5.0	2.4 - 5.0
Grass sampling points (n)	107	82	72	60
Grass samples < 3 gm^{-2} (% of total sampling points)	13 (12%)	23 (28%)	-	0 (0%)
Plots without vegetation (n) (% of total sampling points)	43 (40%)	49 (60%)	16^{+} (22%)	0 (0%)
Mixed grass samples for nutrient analysis (n)	12	(6 grass species)	25	59
Sampling plots for leaf biomass (10x20 m), (n)	55		93	
No. of analysed trees and bushes	3,992		3,071	
Leaf samples of single species for nutrient analysis (n)	-	-	-	5

DS –dry season, WS- wet season. + Mainly burned areas.

The grass cover of the plots was estimated, and grass biomass was clipped by hand about 2 cm above ground level on a square meter. Other herbaceous material was ignored, due to the insignificant biomass. The total weight of the samples was taken after air-drying, which is applicable to the standard for dry matter (DM), due to the very low air humidity in Namibia during the time of sampling. Whilst fieldwork it was not practicable to meet the standard of dry matter material, as drying until the constant weight of the material. Most of the harvested grass material was already dry during the sampling. Different grass species were sorted, if possible identified, and the biomasses were weighed separately. During the DS is was very difficult to identify the grass species due to biological degradation and decomposition processes, therefore some data regarding the grass biodiversity are missing. Species richness is expressed simply as the number of species (taxa) present (S). From the grass species numbers of the plots and their abundances concerning the weight, the grass-Shannon diversity index (H) and the grass-Evenness index (E_H) were calculated. The Shannon index (H) is commonly used to characterise species diversity in a community, taking into account the number of individuals as well as number of taxa (Shannon &

Weaver, 1949). It accounts for both abundance and evenness of the species present (Peet, 1974). The proportion of species in relative to the total number of species (p_i) is calculated, and then multiplied by the natural logarithm of this proportion (ln p_i). The resulting product is summed across species, and multiplied by -1:

$$H_s = -\sum_{i=1}^{S} p_i \log p_i$$

The Shannon diversity index value varies from 0 for communities with only a single taxon to high values for communities with many taxa, each with few individuals.

The Evennes-index (E_H) can be calculated by dividing H by H_{max} (here H_{max} = ln S). This index of equitability assumes a value between 0 and 1 with 1 being complete evenness (Peet, 1974):

$$E_H = H / H_{max} = H / \ln S$$

It should be noted that when equitability or Evenness (E_H) equals 1, then each species is present in the same proportions, while lower values indicate that fewer species are present in larger proportions.

After the wet season (WS) 2002/03, the problem of small sampling amounts arose in Okamboro. Sixty percent of the sampling points were without vegetation, and on 28% of the plots with vegetation, the yield was less than 3 g per square meter (see Table 8). In Okamboro, on 52% of the sampling plots in the DS 2002, and on 88% of the plots in the WS 2002/3, the grass samples taken from a square meter were not sufficient for a complete nutrient analysis. In Mutompo, this problem occurred on 22 % of the plots only during the DS 2002 samplings, because some areas had burnt down before sampling. In these burned areas, no grass biomass was left for sufficient sampling.

Additionally to the grass sampling plots, a 10 by 20 m plot nearby was marked by a 50 m-measuring-tape in order to investigate trees and bushes as forage resources (Table 8). In Mutompo on 55 plots 3,992 trees or bushes, and in Okamboro on 93 plots 3,071 trees and bushes were counted, when possible identified, and the canopy were measured. Available browse was determined by measuring spatial dimensions of tree and bush canopies. For the calculation of the leaf volume (m^3 ha^{-1}) as well as leaf and browse dry biomass (kg ha^{-1}), the computer software BecVol 2 (**B**iomass **E**stimates from **C**anopy **VOL**ume, version 2) was applied, compiled by Smit (1996) for the southern Africa region. The spatial volume of the canopies is calculated by the software from the dimensional measurements of the trees and bushes, regardless of its height by using the volume formulas of an ellipsoid, a right circular cone, a frustum right circular cone or a right circular cylinder. These shapes correspond well with varying shapes of different trees or parts of a tree (Smit, 1996). The estimated leaf volume and leaf dry matter from the spatial canopy volume were calculated for each tree individually by substituting the trees spatial volume into a regression equation obtained from harvested leaves in BecVol (Smit, 1996; and Table A 6 in the appendix). The regression equation simulates the relationship between the spatial tree or bush volume and the actual leaf mass. If bush or tree species could be identified in the field survey, and were listed in the tree list of BecVol, the models for the species were used. If not, a general equation for microphyllous or broad-leaved types of normal or coppiced plants was used (Table A 6 in the appendix). Trees and bushes of the same species and same size were grouped during counting and measurement; otherwise, each single tree would have had to be entered in the datasheets of BecVol and would have been calculated as a single dataset. Due to the grouping of trees and bushes, only the primary step of calculation in BecVol could be applied. The results from the first step calculations were transferred to Excel data-sheets, and the second step of the BecVol- calculations were then applied using the Excel software. For a calculation of the density of trees and bushes per hectare, the size of the sampling plots for browsing resources (10 m x 20 m = 200 m^2) was used. The estimated leaf dry mass below 1.5 m, regarded as the maximum browse height of a goat (Oba & Post, 1999), was defined in this study as the browsing resources of measured bushes and trees. The browse biomass was seasonally corrected. The DS-browse biomass amounts were assumed to be 39.7% of the WS (according to Knemeyer, 1985), (see Table A 22 in the appendix).

The analysis of the nutrients from selected grass samples and some leaf samples were conducted by professional laboratories (see Table 8, p. 48). The nutrient quality of the air-dried mixed grass vegetation was measured after dry season and after rainy season. Crude protein, fibre content, metabolisable energy (ME), and phosphorus were examined, and calculations of energy content were partly completed from literature data (Knemeyer, 1985). The content of calcium was analysed with some selected samples only.

Five leaf samples of different bushes from Mutompo, six single grass species samples, and 59 mixed grass samples for the April/May 2003 period were analysed by the Agricultural Laboratory of the MAWRD in Windhoek. Thirty-seven mixed grass samples, taken in September/October 2002, were analysed by the AGROLAB, Rodenbach, Germany. Additional the ash content were measured, and ME was calculated according to the DLG[17-] equation. During the sampling period of April/May 2003 after only few, efficient rainfalls in

[17] DLG- Deutsche Landwirtschaftliche Gesellschaft (German Agricultural Society)

Okamboro, the sampling amount per square meter was too small for analysis; hence, some grass biomass from different sampling points were pooled and then analysed.

The metabolisable energy (ME I) of the grass samples were calculated by using the equation of Kirchgessner (1997) for reasons of better comparison between the values of the two laboratories (Namibia and Germany):

Metabolisable energy I:

ME I = 12.47 – 0.00686*crude fibre + 0.00388* crude protein - 0.01335 * ash.

The formula used for the calculation of metabolisable energy of leaf material required the crude fibre content only:

Metabolisable energy II:

ME II = 14.05 – 0.01784* crude fibre

(According to Kirchgessner (1997); normally used for hay from second cut.)

A Spearman-rank-correlation relating to other vegetation parameters tested the strength and directions of the relations. For reasons of clarity in the analysis of parameters along the transects, the distance intervals (100 and 200 m) were split up in four kilometre-classes. The sampling points within the distance of up to 1 km are called distance class 1, the plots located between 1 and 2 km are referred to as class 2, the 2 ≤ 3 km distance is class 3, and plots farer than 3 km are summarized in class 4, due to less sampling points in this remoteness. The different possible types of transects were analysed according to Pickup et al. (1994, 1998) and Landsberg et al. (2003).

According to the international standard, 450 kg body weight equivalent was used for LSU (large stock unit) and to convert the unit LSU to other livestock units (Chilonda & Otte, 2006). The small stock unit (SSU), if converted in LSU, uses the equation 6 SSU= 1 LSU, which is commonly used in agricultural literature and governmental datasets in Namibia. That means, that one SSU is equivalent to 75 kg, which reflects not the reality, as different sheep and goat breeds differ in body weight, and breeds in communal areas may be lighter. In Chilonda, 2005 (FAO Livestock Sector Brief: Namibia) and in Mendelsohn (2006) one LU (livestock unit) is defined as 360 kg in Namibia. The LU conversion factors for Africa South of the Sahara is as follow (Chilonda & Otte, 2006): cattle (0.50), sheep and goats (0.10), pigs (0.20) and poultry (0.01). Thus, a cattle body weight is 180 kg, goats and sheep 36 kg for Africa South of the Sahara.

The typically applied unit for the stocking density is hectare per LSU (ha LSU^{-1}), which decreases in magnitude with increasing livestock numbers, and which is contrary to the International System of Units (SI) nomenclature (see Peel et al. 1999). Therefore, stocking densities were expressed in animal weight per hectare (kg ha^{-1}), thus the stocking density of a mixed herd of small stock and large stock can be compared with a cattle herd, and should become an international standard (Burke, 2004). For practical reasons and for better comparison, the stocking densities and grazing- or carrying capacities were expressed in kilogram per hectare (kg ha^{-1}) in this study.

4.2.3 Data analysis

Data entry and graphical design was done in Microsoft ® Excel and Microsoft ® Access. Calculations and statistical analyses were performed with both Microsoft ® Excel and with the SPSS-software package, (Version 11.5), selecting mainly the procedures PROC FREC, PROC DESCRIPTIVE, NPAR TESTS, PROC NPAR CORR, PROC REGRESSION, PROC UNIANOVA.

Descriptive and explorative statistic methods (e.g. mean, median, standard error of means (SE), standard deviation (SD) and frequencies), and nonparametric correlations were applied. The differences between the communities and seasons were tested, by applying the Median test or the Wilcoxon test. UNIANOVA was used to test any differences of data (distance, transects and their interaction), when certain conditions, such as normal distribution, (Kolmogorov-Smirnov test and Shapiro-Wilk test) and homogeneity of variances (Levene-test) were fulfilled. When necessary, the data were transformed before an analysis. Analysis of variance was performed with the least squares, using the MIXED procedure (SPSS). Rank-ANOVA analysis for datasets with non-homogenous variances was calculated in SAS. Data with additional, not normally distributed data were tested with a special procedure (according to Akritas et al., 1997; M. Hollenhorst, personal communication) in SAS (see Table A 10, A 11 and A 14 in the appendix), separated by communities. The Median test was used when ANOVA or the two other analysis methods with SAS could not be used. Few datasets were detected as outliers, were delaminated and where appropriate deleted before the statistic calculation, except for the box-and-whisker-plots.

The levels of statistical significance for the ANOVA-tests, the Wilcoxon- or the Median-tests, or the correlation and regression analysis were conventionally defined and marked, when no other significance levels were mentioned in the legend of the table, as

$p \leq 0.001$ = high significance (***);
$p \leq 0.01$ = distinct significance (**);
$p \leq 0.05$ = weak significance (*);
$p > 0.05$= no significance (ns).

The results of the spatial distribution of grass, browse and nutrient parameter were visualised as box-and-whisker-plots (Figure 11) (Chambers et al., 1983; sometimes called simply a box plot), which is a histogram-like method used to display data. SPSS has a two stage flagging process for outliers and extreme values within the figures. Values which are more than three box lengths from either end of the box are denoted by asterisks and recorded in the box-plot figure as extreme values. Values which are between one and a half and three box lengths from either end of the box are recorded in the figures as outliers and are denoted as non-filled dots.

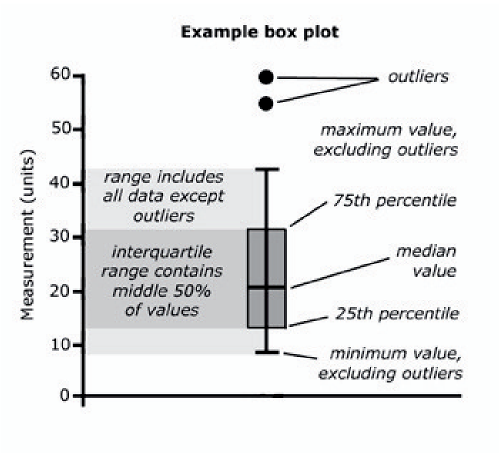


Figure 11: Example of a box-and-whisker-plot

Scatter plots of vegetation parameters, illustrated with a line of local curve fitting (lowess-function in the statistical software package SPSS 11.5) per transect, were used to find and separate trends in grazing and browsing parameters, according to the distance along the set transects for both communities. Additionally, the statistically significant effects of transects or the interaction (transects * distance; (t * d), which were tested in chapter 4.3.2.2 (p. 66) for grass parameters (see Table 16, p. 66), and in chapter 4.3.3.2 for the tree and bush parameters (see Table 20, p. 89), were analysed graphically by means of box-and-whisker-plots or the curves on the transect-distance-scatterplots. Only those parameters were shown, which were directly related to livestock nutrition, such as the standing grass biomass and the browse leaf biomass. The scatter plots of the grass cover and the tree density are shown in the appendix, because this parameter resulted in significant effects, for either the transects or the interaction (t * d) in both communities.

The lowess-function, which is part of the curve fitting of scatter plots (SPSS 11.5), is an iterative local-weighted least squares method, used in order to fit a curve on data points. The applied lowess-methods used 75% of the points of the curve, and 3 iterations. Actually, at least 13 data points are necessary to create an informative lowess-curve with this method, but in order to compare the characteristics of the different transects, which have different lengths and numbers of data points, also datasets with less than 13 sampling points are displayed in this case. SPSS 15 was used to create most of the diagrams in chapter 4.

4.3 RESULTS AND DISCUSSION OF RANGELAND EVALUATION

4.3.1 Soil quality

Table 9 shows the results of the analyses of the Mutompo and Okamboro soil-samples. In Okamboro, the surface soil contained a higher level of organic matter (OM), as well as more silt. It also had a higher electric conductivity, which means more salt, minerals and elements in total. Percentages of the macro elements phosphorus (P), potassium (K), and nitrogen (N) were significantly higher in Okamboro than in Mutompo, only for calcium (Ca), magnesium (Mg) and sodium (Na) the difference was not significant.

Mutompo has a deep, very sandy soil (100% sand in the texture analysis), classified as Kalahari sands (ferralic Arenosols), and containing little organic material (mean of 0.7% organic matter; see Table 9), which resulted in a low water holding capacity, a low ion exchange capacity, as well as a high infiltration rate. These characteristics are signs of low fertility, which occur in most of the areas around the Mutompo village. Sandy soils are prone to wind erosion on bare soil patches. The run-off rate is low, due to the properties of sandy soil and the flatness of the area.

In Okamboro, the soil contains less sand (Table 9) and more silt than in Mutompo, but it is very shallow and partly rocky. The soil in Okamboro contains nearly 5 times more phosphorus than in the sandy soil of Mutompo. In addition, the nitrogen level is around 3 times higher in Okamboro than in Mutompo, whereas the pH-value is similar. Since a pH-value of less than 6.6 is considered as acid (Mphinyane, 2001), the soils in Okamboro and Mutompo can be described as slightly acid. A higher content of organic matter and clay prevents nutrients from leaching, because some nutrients stick to the negative charges of clay complexes, and organic matter binds nutrients. The partly steep slopes in Okamboro are prone to rainwater run-off and soil erosion, which results in shallow soil covering the rocky parent material. More fertile soils, enriched with organic matter, can only be found in depressions or flat areas. Pedogenesis runs very slowly in semi-arid areas, due to a lack of sufficient moisture, and intense frost, which is also important in the process of the weathering of rocky substrate. In Okamboro, the rocky parent material is the source of better and nutrient richer soil, except for Mg, in contrast to the pure sandy soils in the Kavango, but only electric conductivity, organic matter, P, K and N as well as sand and silt content were significant different.

Table 9: Means of surface-soil parameters of Mutompo and Okamboro

Community	Mutompo (n=16)		Okamboro (n=12)	
	Mean	SE	Mean	SE
pH	6.06 [a]	1.18	6.29 [a]	0.13
Electric Conductivity (µS/cm)	41.25 [a]	4.32	78.92 [b]	11.35
Organic matter (%)	0.70 [a]	0.04	1.54 [b]	0.24
P (mg/kg)	2.62 [a]	0.43	13.01 [b]	1.24
K (mg/kg)	38.06 [a]	9.40	106.75 [b]	10.08
Ca (mg/kg)	453.0 [a]	155.0	601.8 [a]	147.2
Mg (mg/kg)	122.4 [a]	27.3	58.60 [a]	6.42
Na (mg/kg)	8.75 [a]	1.33	6.83 [a]	1.38
Nitrogen (%)	0.033 [a]	0.002	0.092 [b]	0.02
Carbonate (estimated) (%)	0.16 [a]	0.63	0.00 [a]	0.00
Sand (%)	96.3 [a]	0.5	84.4 [b]	0.9
Silt (%)	1.7 [a]	0.2	13.3 [b]	0.8
Clay (%)	2.0 [a]	0.4	2.3 [a]	0.2
Texture	100% sand		42% sand, 58% loamy sand	

[a, b] means in rows followed by different superscripts are significantly different at $p< 0.05$, SE = standard error of means.

One soil sampling collected in a cropping area of Mutompo, at a distance of 500 m from the water point, showed the highest values for clay content (5.9%), higher pH values (8.3) and carbonates (2.5%), as well as more organic matter (1.1%) and higher values of macro-elements potassium, calcium, sodium and nitrogen. These soil parameters indicate a much better soil quality for this cropping area than for the other subsoil sampling points. The soil on this sampling point was of much darker colour than in most other areas. This emphasises firstly, that fields are established purposefully by farmers on areas of better soil quality within the old inter-dune areas (compare also p. 25). Secondly, that the range of soil quality is broad and patchily distributed within the community area of Mutompo. It may also mean that free-roaming livestock changes the distribution pattern of nutrients within the community area. Many of the plant nutrients consumed by grazing or browsing animals return to the soil through urine or dung, but not necessarily at the place where they were grazed. In Mutompo, around the central water places, which are areas with larger trees, the livestock were observed gathering in order to wait for water, which is not freely and readily available. Livestock starts its daily trip after drinking in the morning, and is herded or only guided to the surrounding grazing areas, where it spends its time grazing and browsing. In the afternoon, the livestock comes back to the water place to rest and ruminate. Livestock is not fenced in purposely on harvested fields in order to concentrate their dung, but they feed on crop residues on the fields.

4.3.2 Seasonal and spatial effects on grazing resources

4.3.2.1 Local differences and seasonal effects on grazing resources

The dry season value of 8.6, 2.9, and 0 – 68 g m^{-2} dry grass biomass for the mean, median and range, respectively, in Okamboro reflects the rest of grass vegetation at the end of the dry season (standing hay) (Table 10), but grass biomass was very unevenly distributed within in Okamboro, as it is pointed out in further subchapters. The high grass biomasses probably grow on more fertile and good soil, in niches, small basins or valleys, because livestock cannot reach them. Maybe this is the case in the periphery of the community grazing areas, where stocking densities and grazing pressure are very low.

Table 10: Effect of season and site on grass dry biomass

Season/Community	Mutompo	Okamboro	Mean	X^2
Dry season 2002	57.8 g m^{-2}	8.6 g m^{-2}	25.8	91.27***
Wet season 2002/03	91.5 g m^{-2}	1.3 g m^{-2}	37.1	60.30***
Mean	75.3 g m^{-2}	5.2 g m^{-2}		
z-value	2.07*	5.80***		

On areas near the water point or within the settlement area of the community, the grazing pressure, but also the trampling, are very high, and the mainly prevalent annual grasses were grazed and had disappeared just after ripening and seed production - which in turn resulted in bare or nearly bare soil patches.

In Mutompo, the grass biomass was significantly higher than in Okamboro in both seasons, as well as the ground cover (WS Mutompo: 25%, WS Okamboro: 11.1%; DS Mutompo: 17.7%, DS Okamboro: 7.3%), due to the generally higher rainfall regime in the north of Namibia, and in spite of the lower soil nutrients in sandy soils. Significant differences between the seasons were detected for the grass biomass during DS and WS in both communities. Mean grass biomass, however, was expectedly lower during dry season in Mutompo (57.8 g m^{-2}), compared to the WS (91.5 g m^{-2}), but the difference was only of weak significance. With a value of 8.6 g m^{-2}, the mean grass biomass in Okamboro was significantly higher in the DS than in the WS (mean 1.3 g m^{-2}), which is a result of the drought situation. The grass yield was notably low in Okamboro, in both seasons.

The number of grass species did not differ much between the communities, but the mean grass biodiversity Shannon index (H), as well as the mean grass Evenness index (E_H) was significantly lower in Okamboro than in Mutompo during WS (Table 11). This means fewer species in larger proportions were present in Okamboro, and some species arose in very high abundance, in comparison to other species with only one or two individuals.

Table 11: Effect of site on grass parameters

Community	Mutompo	Okamboro	n	Chi²-value, significance
Dry season (DS) 2002				
Mean ground cover (%)	17.7	7.3	116	24.47***
Mean number of grass species (no.)	2.70	2.75	102	ns
Mean grass Shannon index (H) [1]	no data	0.64		-
Mean grass Evenness index (E_H) [1]	no data	0.54		-
Wet season (WS) 2003				
Mean ground cover (%)	25.0	11.1	116	26.30***
Mean number of grass species (no.)	3.1	2.7	94	ns
Mean grass Shannon index (H)	0.63	0.12	134	44.79***
Mean grass Evenness index (E_H)	0.60	0.42	70	5.04*

[1]Biodiversity grass Shannon index (H) and Evenness index (E_H) in DS 2002 in Mutompo the grass species could not be properly differentiated.

The values for both of these indices were similar in Okamboro in DS (E_H=0.54) and Mutompo in WS (H = 0.63, E_H = 0.60), which points at a relative high and well-balanced grass biodiversity in Okamboro during a WS in a normal rainfall year. The biodiversity values and the evenness were strongly affected by the drought, which struck Okamboro in the WS 2002/3. In DS in Mutompo, precise single grass species could not be identified due to grazing impacts, decomposition processes or fire, which had destroyed the dry ground vegetation, therefore values for H and E_H are missing. However, the number of grass species were counted only on 39 sampling points of 72 in total, (total n = 72 DS Mutompo, 16 plots without vegetation, mainly burned).

The other DS values of grass parameters were compared with WS values (Wilcoxon-test, Table 12). Significant differences between the seasons were detected for the ground cover in Mutompo only (WS 25%, DS 17.7%), which is an expected result. The number of grass species differed not much between the seasons. In Okamboro, the means for grass biodiversity (H) show significantly lower values (H = 0.12) in the drought-effected wet season 2003 (Table 11), in comparison to the DS 2002 (H = 0.63). In the DS 2002, more taxa were found, each with only few individuals less than in the WS 2002/3.

Table 12: Significant seasonal differences of grass parameters by community

	DS value	WS value	n	Z-value, significance
Mutompo DS 2002 vs. WS 2002/3				
Ground cover (%)	17.7	25.0	42	2.97**
Okamboro DS 2002 vs. WS 2002/3				
Grass biodiversity index (H)	0.64	0.12	24	3.66***

In Mutompo, no data were available for the grass biodiversity Shannon index (H) and the Evenness index (E_H) during DS.

The mean grass biomass of 91.5 g m^{-2} (915 kg ha^{-1}) in the WS in Mutompo, meant a relatively high yield, compared e.g. to values further west of 560 kg ha^{-1} in a protected area, and 148 kg ha^{-1} in a grazed area near Okongo (Ohangwena district, Namibia), measured in April 1999 by Masunda (2002b). The exact amount of rainfall of this season and the grazing pressure in the area near Okongo was not known. In a study conducted by Bester (1999), the standing grass dry matter in a Camelthorn Savanna at the end of the growing season with different stocking rate treatments was analysed for 1996/97 (706 mm rainfall), 1997/98 (316 mm rainfall) and 1998/99 (331 mm rainfall) at Sandveld Research Station (approximately 60 km north east of Gobabis; central Namibia). Standing dry matter was measured at 276 kg ha^{-1} (range 195 – 335 kg ha^{-1}), 436 kg ha^{-1} (range 353 – 542 kg ha^{-1}), and 655 kg ha^{-1} (range 400 – 1.048 kg ha^{-1}), respectively (Bester et al., 1999). The comparatively large amount of rainfall during 1996/97 resulted in a high grass production two years later. Bester et al. (1999) stated that the amount of precipitation alone does not necessarily encourage the grass production and that the rainfall of a previous season (drought year), as well as the present distribution of rain, plays an important role in promoting the vegetative production. During the 1996/97 growing season, 46.5% of seasonal rainfall fell in January of 1996, but only 7.6% (53.7 mm) and 1.6% (or 11 mm) of the total seasonal rainfall fell in February 1997 and in April 1997, respectively (Bester et al., 1999). In an ensuing study by Bester et al. (2003) the average standing grass dry matter towards the end of the growing season was found to be much higher at Sandveld Research Station: 2000/01: 422 mm, 728 kg ha^{-1}; and in 2001/02: 324 mm, 718 kg ha^{-1}, however, the rainfall amounts were not much higher.

Values measured for the standing grass biomass towards the end of the growing season of 2003 in the Mutompo region (mean: 915 kg ha^{-1}), are comparable with the values from the Sandveld Research station measured by Bester et al. (2003). However, the values for Okamboro, which is ecologically more similar to the Camelthorn Savanna, were much lower after the rainfall of 248 mm in 2003. Grass biomass of only 13 kg ha^{-1} during WS (see Table 10, p. 56) reflects the uneven distribution of rainfall within that drought-like situation in 2002/2003. The rainy seasons of 2001/2002 showed an equal distribution in the

Okamboro region (see Figure 4, p. 23), compared to the season of 2002/2003, where a gap in March 2003 was visible (see Figure 5, p. 23). Furthermore, a rainfall event in 2003, which was concentrated only on the central Namibia region, was most intense in the Khomas area (Windhoek), experiencing 116.2 mm of rainfall within 5 days, which accounts for 41% of the total seasonal rainfall since October 2002 (Mwangala, 2003). The uneven temporal distribution caused a very low standing biomass in the WS 2002/3 in Okamboro. The total rainfall amount was 248 mm, which puts it 50 to 100 mm under the long-term annual average. However, the rainy season one year earlier had the same rainfall amount; yet more standing vegetation biomass was produced, considering the dry standing biomass of 8.6 g m^{-2} (86 kg ha^{-1}) in the DS 2002 (Table 10, p. 56), which represents the rest of the forage resources of the wet season 2001/2002. Based on this dry season value the maximum forage resources in Okamboro in the WS would have been higher than measured in 2002/2003. It has to be considered, that measured grass biomass during the WS, sampled in April and May 2003 (see Table 8, p. 48), is not 100% of the biomass of the grass produced any more. Grazing by livestock or by wild animals (antelopes or small mammals) (Brits et al., 2002; Knemeyer, 1985; Schmidt et al., 1995; Topps, 1997) has taken place during the growing period, and insects, especially termites, have also used the grass as a forage source (Bayer et al., 1991). It is very difficult or may even be impossible to measure the portion of the parts which were removed and which may have re-grown. Light to moderate grazing can stimulate the growth of grass and browse (Mwendera et al., 1997), which makes an estimation of the removed share even more difficult. Grazing exclosure experiments carried out in Okamboro (chapter 5.3.4, see Table 39, p. 159) aim at an estimation of the grazed part of the vegetation.

In Mutompo, the rainfall during the investigated seasons was more equally distributed. During the 2001/2002 season, a high early rainfall occurred in November 2001, and the maximum rainfall was measured in February 2002 (see Figure 2, p. 23). The season 2002/2003 had a clear maximum in January with an almost normal distribution curve (see Figure 3, p. 23). The precipitation anomaly from January 2003 to March 2003 is illustrated for Namibia in Map 2 (p. 24). A darker brown segment, stretching from the north-eastern direction into the Namibian territory and ending in an area tapering off west of Windhoek, marks a deficit between 100 and 200 mm precipitation, compared to the long-term mean values. The Kavango area shows a deficit of about 50 mm during this period.

In the Sandveld region in the Eastern Kalahari in Botswana, much higher grass dry matter values of 472.4 g m^{-2} (4.72 kg ha^{-1}; within a good rainfall year with 553 mm) and 406 g m^{-2} (4.06 kg ha^{-1}; within a poor rainfall year with only 284 mm rainfall) were found in the WS, and 252 g m^{-2} and 204 g m^{-2} in the respective DS (Mphinyane, 2001). The areas of investigation in Botswana were under communal management with uncontrolled grazing which means free roaming livestock. Stocking densities were approximately 11.7 ha LU^{-1} and 16.0 ha LU^{-1} [18], (which corresponds to 30.8 kg ha^{-1} and 22.5 kg ha^{-1}, respectively, when 1 LU = 360 kg BW) (Mphinyane, 2001). Mean stocking densities of livestock grazing on the communal area in Mutompo, was 15 kg ha^{-1} and 42 kg ha^{-1} in Okamboro (see Table 33, p. 140), which does not explain the much higher quantities of grass biomass in the Eastern Kalahari regarding similar rainfall amounts. Grazing pressure was admittedly 26.5% lower than in Okamboro, but much higher in comparison to Mutompo. A higher fertility of the sandy Kalahari soil (the P-content in the soil was 16 mg kg^{-1} in comparison to similar soil condition of Mutompo with 2.6 mg kg^{-1}) is one reason. It could also be higher rainfall amounts in the preceding years or low former land use which leads to such large values of grass biomass.

During the wet season of a drought situation in Okamboro, no grass or herbs at all were found at 60% of the sampling points (see Table 8, p. 48). The mean value of grass biomass for the end of the DS 2002 was 6.6 times higher than in the drought-stricken WS. The primary production of fresh green biomass of grass was very low, even after the late high rainfall amount of around 100 mm in April 2003 in Okamboro (Figure 4, p. 23). It was observed, that the stems of most grass species only grew short and the plants produced seeds as early and as fast as possible. This strategy ensures the reproduction and utilises the low moisture level within the root-zone of soil during the short growing periods completely and most efficiently. A possible reason for the low biomass production in Okamboro was the uneven distribution of rainfall in the season of 2002/2003. However, the total rainfall amount of this season was comparable to the season before, showing a value of 248 mm, which was also approximately 100 mm underneath the normal estimated average in this region (see Map 2, p. 24).

The shallow soil and the partly steep slopes of the area around and within Okamboro, together with the trampling of many livestock hoofs on bare soil patches, encourage the danger of soil erosion, which occur when huge amounts of rain fall within a short period, such as during heavy thunderstorms, as probably occurred in April 2003. Also important for the vegetation, is the high run-off rate, which leads to massive water and nutrient losses, due to low infiltration rates. Soil particles wash away, and the water cannot penetrate deeper into the soil, because the soil quickly reaches its water saturation at the surface level. The water transports the sand and soil particles into the dry river and sand dam in Okamboro, as well as further along into the riverbeds, which stretch through this community (see Map 4, p. 40). The result of this being shallow, unfertile and rocky soil on

[18] LU = livestock unit = 360 kg BW according to Mendelsohn, 2006.

the slopes, in which more fertile soil, enriched with organic matter can only be developed and established in crevices and shallow depressions, which are not a part of the riverbeds. Plants prefer these niches for germination and establishment.

In Table 13**,** the results from the nutrient analysis of grass samples of both communities and different seasons are illustrated. Because of the drought situation in May 2003 in Okamboro, caused by the rainfall gap of 6 weeks in between the WS and in spite of the 100 mm precipitation in April 2003, the mixed grass biomass amounts from the square-meter sampling plots were with a mean value of 1.3 g/m² not sufficient for analysis. As a substitute, six grass species with high abundance were collected in Okamboro and analysed (Table 15, p. 63).

In Mutompo crude protein contents ranged from values between 2.1 to 5.0% (mean 3.4%) and 1.5 to 8.3% (mean 4.0%) during dry and wet season (Table 13), respectively.

Table 13: Site means of grass nutrient values and their differences between the communities

Community	Mutompo (mean)	Okamboro (mean)	Median	Chi-square (n = 37 in DS).
Crude protein DS 2002 (%)	3.4	2.6	2.9	ns
Crude fibre DS 2002 (%)	36.9	37.6	37.0	ns
Phosphorus DS 2002 (%)	0.026	0.112	0.036	18.75***
ME DS 2002 (MJ kg^{-1})	11.9	11.6	11.9	8.53**
ME I DS 2002 (MJ kg^{-1})	12.2	12.1	12.2	13.53***
Ash DS 2002 (%)	3.9	6.24	4.2	13.16***
Crude protein WS 2002/3 (%)	4.0	no data⁺	-	-
Crude fibre WS 2002/3 (%)	42.3	no data⁺	-	-
Phosphorus WS 2002/3 (%)	0.028	no data⁺	-	-
ME WS 2002/3 (MJ kg^{-1})	6.7	no data⁺	-	-
ME I WS 2002/3 (MJ kg^{-1})	12.1	no data⁺	-	-
Ash WS 2002/3 (%)	4.4	no data⁺	-	-

WS-samples were analysed in a Windhoek laboratory, DS-samples in a German laboratory. Means on transect level and SE see appendix Table A 4 and Table A 5. ⁺ No data of nutrients in the WS in Okamboro, because of insufficient grass biomass due to the rainfall gap of 6 weeks during WS .

Values for crude protein ranged from 1.4 to 3.3% (mean 2.6%) in Okamboro in the dry season of 2002. During WS the colletcted grass contained at least 4% crude protein on average. The protein content of forage should be at least 6-7%, in order to keep livestock in good condition. However, for growth and milk production, it must be even higher (Bayer & Waters-Bayer, 1998; Breman & de Wit, 1983; Van den Bosch et al., 1997).

In contrast to crude fibre (CF), the P content and the energy content (ME) of the mixed grass samples, all in the DS, showed significant differences between the communities. The ash content resulted in highly significant differences between the communities, with much higher values in Okamboro than in Mutompo. It may well be that grasses of low quality and high fibre content dominated the mixed grass samples during the wet season of 2003 in Mutompo. A further reason for these differences could be that the time of the collection proceeded too far after the end of the rainy season to find still green and young grass material, which was instead already dry and leached out, and may not have been representative for green and fresh grass in that respective period of time for both communities. Another explanation for this could be the dilution effect of the nutrients; plants take up a large part of nutrients at an early stage of growth, while further plant growth leads to a dilution of the nutrients (Bayer & Waters-Bayer, 1998), and during the peak of standing biomass, the vegetation is already of lower forage value (Le Houérou, 1989). Additionally, in Okamboro, the rainy season did not represent a normal rainfall year, but rather a drought situation, due to the 6 weeks without any rain during WS. In Mutompo, the rainfall amount during the season 2002/2003 was about 50 mm less than the long-term average of the annual rainfall (see Map 2, p. 24). A further reason for the unexpectedly low quality values (especially for ME) could be differences within the methods of the chemical analyses of the two laboratories. Phosphorus values of grass material measured for Mutompo averaged 0.026% in DS and 0.028% in WS. In Okamboro, the values e.g. for phosphorus content of the mixed grass samples were around 4.3 times higher, with a mean value of 0.112 % P for grass in the DS and about the same value for the WS. This reflects the values from the soil-samples, where the values for P in Okamboro were nearly five times higher than in Mutompo (see Table 9, p. 55). According to the regional veterinarians of the Ovitoto region, the supply of livestock with phosphorus and calcium did not pose a problem in Okamboro (Veterinarian Office, Okahandja; personal communication); in Mutompo, a deficit is more likely (see also chapter 5.3 4, p. 146).

Seasonal differences of nutrients could be analysed only for Mutompo, because the nutrients of the grass samples in the WS were not sampled in a comparable way to the DS-sampling in Okamboro, due to the drought like situation. Grass quality differed much between seasons in Mutompo (Table 14), with expected significantly higher values for the crude protein. Nevertheless, the higher values of crude fibre in the WS and low values of ME also in the WS were not expected (see Table 13). Explanations, as mentioned on the previous page, such as the late sampling after the WS, the dilution effect, or the differences between the laboratories could have led to these results.

Table 14: Seasonal differences of nutrients of grasses for Mutompo

Grass parameter	n	Z-value, significance DS 2002 vs. WS 2002/3
Crude protein (%)	20	-2.80**
Crude fibre (%)	20	-3.73***
Phosphorus (%)	15	ns
ME (MJ kg^{-1})	15	-3.41***
ME I (MJ kg^{-1})	16	-3.48***
Ash (%)	15	ns

These analyses in Table 15 concentrated on six young grass species, collected in a fresh green state in the middle of May 2003, which where found in relative high abundance in the rangeland of Okamboro. Values for these six selected grass species showed much better nutrient values in comparison to the WS value of Mutompo of 4% CP content (see Table 13). This reflects the much better quality of grass sampled in a newly grown and fresh state, only a couple of weeks after the rainfall of nearly 100 mm during six days in the middle of April 2003 (see Figure 5 p. 23). Sampling in Mutompo took place in the second half of April 2003, but the maximum rainfall occurred in December 2002 and January 2003 (see Figure 2, p. 23), which are, together with the February, the month of the main rainfall in Namibia. Best month for sampling should be February or March, to get the maximum of vegetation biomass during rainy season.

Crude protein was highest in *Eragrostis poros, Stipagrostis kalahariensis*, and in *Aristida adscensionis.* The grasses were probably in the state of second germination, which followed efficient rainfall after a rainfall gap of five weeks in March 2003. The seeds of grasses at this phase were nearly fully matured, but the stems were always very short, which explain the lower crude fibre content and the much higher protein content.

Table 15: Nutrient values of six grass species from May 2003 in Okamboro

Grass species	CP (%)	CF (%)	ME (MJ kg^{-1})	ME I (MJ kg^{-1})	P (%)	Ash (%)
Eragrostis porosa	11.8	30.8	n.a.	12.19	0.16	8.5
Stipagrostis kalahariensis	10.5	27.3	9.5	12.10	0.14	16.7
Aristida adscensionis	10.4	40.6	n.a.	12.15	0.09	6.5
Stipagrostis uniplumis	9.2	40.4	8.9	12.12	0.08	8.1
Eragrostis cenchroides	8.7	31.0	9.6	12.11	0.11	13.6
Melinis repens	4.8	32.9	9.5	12.14	0.14	9.6
Mean	9.2	33.8	9.4	12.13	0.12	10.5
SD	2.4	5.5	0.3	0.03	0.03	3.9

Grass samples analysed by Agricultural Laboratory Windhoek. CP - crude protein; CF – crude fibre; P – phosphorus.

Stipagrostis kalahariensis had the lowest crude fibre content, but livestock prefers this grass only in its young and fresh status, as well as *Eragrostis*-grass species are also preferred by cattle in their young and fresh status. The most preferred grass species, as mentioned by local farmers in Okamboro, is *Stipagrostis uniplumis*, (Otjiherero: Ongumba, a perennial grass) which stays soft and can still be consumed by livestock in late dry season. However, farmers declared that either the abundance of this grass species has decreased or it has nearly disappeared in the Okamboro village region. Both *Eragrostis cenchroides* and *Melinis repens* contain lower values of crude protein, compared to the other investigated grass species in this analysis. *Melinis repens,* a very small grass species, produces a relatively low biomass per single plant, which is not very useful for livestock feeding on natural pastures, relating to biomass production.

The mean values of metabolisable energy (ME) from the Windhoek laboratory accounted only to 6.7 MJ kg^{-1} for Mutompo during WS (Table 13, p. 61), and 9.4 MJ kg^{-1}, as a mean for the six selected grass species sampled in Okamboro during WS (Table 15). The values for ME of the Windhoek laboratory were much lower, in comparison to the calculated ME I - values[19]. These ME-values differ just at the second decimal place in Table 15 for Mutompo fresh grasses, or at the first decimal place in comparision between Okamboro and Mutompo (see Table 13, p. 61). However, they show highly significant differences between both communities. Literature values for metabolisable energy of forage were reported to lie between 10 and 12 MJ kg^{-1} for grass material, with little variability. The gross energy of tropical pastures is relatively constant at 17.2 to 18.7 MJ kg^{-1} DM, resulting in a mean of 18 MJ kg^{-1}, which is about 0.5 MJ kg^{-1} less then the mean for temperate pastures (Minson (1981), in King, 1983). However, portions of this energy are lost whilst animal metabolism by faeces, urine, methane and fermentation heat during the conversion to metabolisable energy (ME). Analysed values of mixed grass samples, from both sites were already converted to ME I, and resulted in values around 12.0 MJ kg^{-1}, which lie within the range of the values from literature. The results from two different laboratories make it difficult to find possible explanations for such large differences in values, particularly, when the values were low in Mutompo and in Okamboro, both during the WS, in comparison to the calculated ME I - values, and in comparison to the values of the DS in Mutompo, measured in the German laboratory.

The energy content of grasses reached its peak, and diluted after the rainy season. The grass was already dry, during the sampling period in the second half of April in Mutompo, and the middle of May in Okamboro. The decay and decomposition process starts just after the peak of biomass and after the distribution of seeds. In addition, insects, such as termites harvest seeds of grass to an unknown but estimated high percentage. The loss of vegetation through insects, especially termites, and by trampling and desiccation is difficult

[19] Metabolisable energy: ME = direct values from laboratories. ME I is calculated according to Kirchgessner (1997): ME I = 12.47 – 0.00686*CF + 0.00388* CP - 0.01335*ash.

to estimate. Chandler (1983, in Baars, 2002) suggests that 70 to 80% of the total available fodder is lost due to trampling, termites and desiccation, and in certain areas, also to wildlife. These aspects could explain one cause of this decrease in energy content. Other relevant aspects could be differences within the process of analysis, the preparation of the samples, the storage conditions, or the moisture of the samples and the methods of analysis themselves. Windhoek lies in an altitude of 1,500 m a.s.l., and the laboratory rooms were without air condition, which means that the storage conditions (relatively hot, without protection from sunshine) were not optimal. Some weeks elapsed between the grinding of samples and the analysis for both samplings in DS and WS, and directly after sampling, the samples were only air-dried, because there were no other opportunities. The samples put up for analysis in the German laboratory were already grinded in the Windhoek laboratory after the sampling, and then stored in the cool and dark. All of these factors could be reasons for the significant differences and the low values for ME of the grass samples.

Results from the Spearman-rank-correlations of surface soil nutrients (Mutompo in total n = 16, Okamboro in total n = 12) and grass nutrients show mainly weak correlations at the lower level of significance (° = $p \leq 0.1$) between the potassium (K) content of the soil and the grass biomass in the DS (R = -0.685°, n = 7), and the ground cover in the DS (R = -0.613°, n = 10), both in Mutompo. In Okamboro, correlations were found between the P content of the soil and the grass biomass in the WS (R = -0.685°, n = 8), as well as the Evenness index during WS (R = 0.949°, n = 4). Additionally, the ground cover in the DS shows a negative correlation with the phosphorus content of the soil (R = -0.659°, n = 8). Due to the small number of appropriate soil data points, which are directly associated with transect sampling points for correlation, these results show only a trend. Mostly negative correlations suggest that correlations are influenced by land use and the gradients. High values of soil nutrients, associated with and caused by high livestock accumulations, do not seem to support the growth of the vegetation due to the dominating trampling and grazing impacts. Only the P content in the soil seems to boost the Evenness index in Okamboro, which results in an equal distribution of more grass species and not one or two predominating species.

The much lower fertility of the sandy soil seems not to hamper the vegetation growth in Mutompo (see Table 9, p. 55), because grass dry biomass values are much higher in Mutompo than in Okamboro (see Table 10, p. 56). Okamboro has a more structured topography, a shallow soil, as well as rocky areas, which can reduce or hinder the development of vegetation. But, apart from these aspects, next to the impacts of grazing and of other land use, the rainfall amounts seem to be the main factor influencing grass production, particularly in season with rainfall gaps and rainfall below the average. Nevertheless, Okamboro has conditions that are more arid, Mutompo is rather semi-arid.

4.3.2.2 Spatial effects on grazing resources

The results of ANOVA for grass parameters influenced by distances, transects and/or by their interaction (transect * distance-classes) are shown in Table A 8, and Table A 9 (both in the appendix), Table 16 shows the effect of the distance classes on the grass biomass. In Mutompo, high F-values of ANOVA were found for the transect effects for grass BM and ground cover during DS, and also for the number of grass species and the Shannon index during the WS (see Table A 8 in the appendix). Only for the ground cover in the WS, high F-values were detected for the distance class effect, as well as for their interaction with the transects. At first, these results pointed at grazing impacts only in special areas of the community, which becomes obvious for the biomass component near the end of the DS, and for the biodiversity parameters in the WS. An impact of the biophysical heterogeneity, such as the soil fertility, may need to be considered as well. The distance impact on the ground cover, during the WS, could have been caused from grazing impacts around the water point. In Okamboro, high F-values of ANOVA for the effects of the distance were discovered for grass BM in the DS and the Shannon index in the WS (see Table A 8).

Table 16: Differences of distance class for the grass biomass yield (g m^{-2})

Season	Site	Distance class (mean)					
		1	2	3	4	Mean	Significance
DS 2002	Mutompo	49	63	69	65	61.5	°
	Okamboro	3	6	12	42	18.5	***
	Mean DS	26	35	41	53	38.7	
WS 2002/3	Mutompo	67	112	103	65	86.7	ns
	Okamboro	0	0	4	2	1.5	*
	Mean WS	33	56	54	33	44	
	Total Mean	29	45	47	43	41.4	

Significance level: *** = p ≤ 0.001; ** = p ≤ 0.01; * = p ≤ 0.05; ° p < 0.1; not significant p> 0.1.

The parameters of the grass biomass in the DS (Table 16), the ground cover in the WS, the number of grass species in both seasons, the Shannon index (H), as well as the Evenness index (E_H), both for the WS, showed significant impacts relating to the distance classes in Mutompo (see also Table A 8 and A 9 in the appendix). For Okamboro, the grass biomass in both seasons (Table 16), the number of grass species in the DS, as well as the Shannon index (H) in WS, resulted in mostly significant findings (see Table A 8 and A 9 in the appendix). All significant parameters related to the distance classes are graphically analysed in box-and-whisker-plots on the following pages. Highly significant effects related to the transects in Mutompo were found for the parameters of grass biomass and ground cover in the DS, as well as for the number of grass species and the Shannon index (H) in the WS. In Okamboro, the effects related to the transects were weakly significant concerning the parameters of grass biomass in DS, the ground cover in WS and the Shannon index (H) in WS. Some significant parameters relating to the transects and their interaction with distance classes, were analysed on scatter plots, with a line of curve fitting, in chapter 4.3.4 (p. 92 ff.).

Regarding the box-plots figures: in this design of box-and-whisker-plots, the width of the boxes reflect the number of data points, whereas 7 and more data points are shown in broad boxes, and with less than 7 datasets they are very slim. In most of this diagrams is valid, the farther from the water point, the fewer sampling points were taken. One value is exposed as a dash for the ‘median’ only and no percentiles or minimum and maximum lines could be shown. The boxes with a dotted line in different box-plot figures are shown merely for comparision reasons; they show no significance results of the statistical test among the distance classes.

For the grass BM in Mutompo, ANOVA results showed only significant effects at the lower level ($p \leq 0.10$) of the DS, referred to the distance classes (see Figure 12). The mean of grass BM was 56 g m^{-2} in the DS 2002 (Figure 12). The highest median (75 g m^{-2}) was found in class 3 (2 ≤ 3 km from the well), the lowest value (42 g m^{-2}) in class 1 (≤ 1 km) (see Table A 7 in the appendix), which is located closest to the homesteads. While the values of grass biomass in the DS reflects the effects of grazing livestock, the formation of the box-and-whisker-plots points to a higher grazing pressure near and within the community, with a decreasing trend towards the periphery. The WS values for grass biomass, though not significantly related with the distance classes, reflect actually the response to rainfall and represent the grass productivity. Due to the late sampling (in April) after the biomass peak, these values reflect also the impact of grazing pressure and trampling within the first kilometre from the water point.

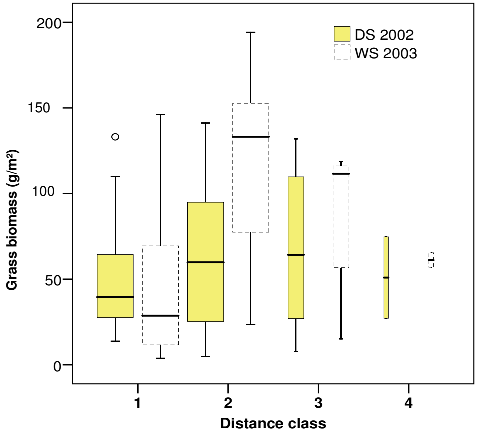


Figure 12: Standing grass biomass for distance classes in Mutompo
(o = outlier value; WS white boxes with dotted line show no significance among distance classes)

The medians of standing grass biomass show a very different picture for Okamboro (Figure 13). Firstly, the values were much lower, compared to the community in the North (see Figure 12:). Secondly, during the DS, a clear exponential curve, such as a

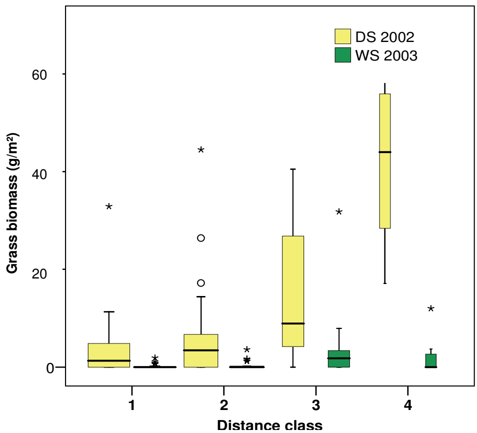


Figure 13: Standing grass biomass for distance classes in two seasons in Okamboro (o = outlier value; * = extreme value)

gradient of grass biomass from the vicinity of the settlement to the periphery was noticed. This was reflected also by the highly significant effects of the distance classes on the grass biomass in the DS of 2002 (Table 16, p. 66), and by the weakly significant effects related to the distance classes in the WS of 2003, despite the drought situation. The DS grass biomass clearly shows the impact of trampling and grazing at up to 3 kilometres distance to the water point. Beyond this 3-kilometre distance, the utilization of grazing resources was much lower, however only seven data points of total 93 supports this result. The means were 9 and 1 g grass BM m^{-2} for the dry and wet season, respectively. The grass BM showed an increase from near zero near the water point to 44 g m^{-2} in the distance class 4 (≥ 3 km) during the DS. This increase was much smaller during the drought-stricken wet season, from the median value zero in the distance class 1, to 1.8 g m^{-2} in distance class 3 (Figure 13). However, due to the drought situation, the productivity is not comparable with a normal rainfall year, and does not give a representative result.

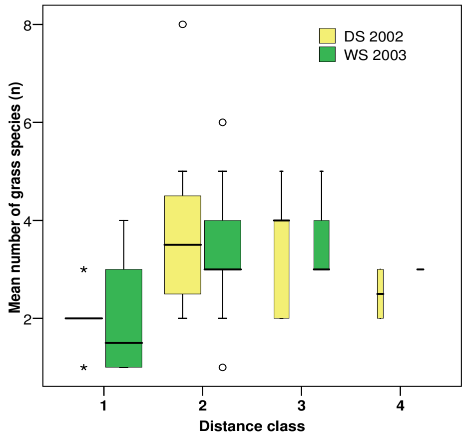


Figure 14: Number of grass species for distance classes in Mutompo (o = outlier value; * = extreme value)

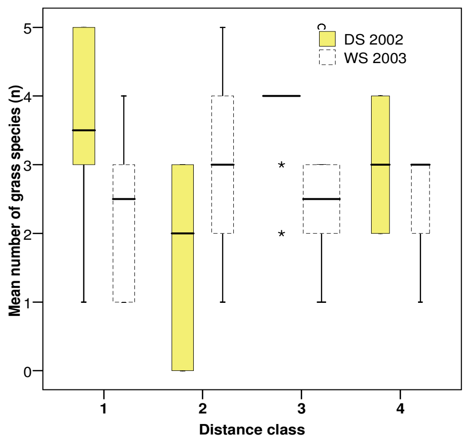


Figure 15: Number of grass species for distance classes in Okamboro (* = extreme value; WS- white boxes with dotted line showed no significance among distance classes)

In Mutompo, the numbers of grass species were highest in class 2 and 3 (Figure 14). The statistical test resulted in a weak significant impact on the distance classes for both seasons, also with a convex course of the medians. During the WS, the results of the lower values of the ground cover (see Figure 16), as well as the low number of grass species (Figure 14) in the vicinity of the settlement point at a distinct impact of grazing and other land use, within the first kilometre zone. The medians of the number of grass species from Mutompo (Figure 14) are comparable to the values from Okamboro (Figure 15). There is no clear trend relating to the distance classes in Okamboro (Figure 15), although the statistical tests (rank-ANOVA, see Table 16, p. 64, and Table A 8 and Table A 9, both in the appendix) resulted in highly significant effects of distance on the number of grass species in the DS 2002. The expectation to find more species in the wet season could not be proven in Mutompo or Okamboro.

The ground cover in Mutompo was significantly higher in the WS of 2003, with a mean of 25% compared to the DS 2002 (mean 17.4%), except in the 4 km-class (Figure 16). Low percentages for ground cover were found in the distance class 1 (median: 15%), and 4 (median: 10%) during the WS 2002/3, and an imaginary course of the medians can be described as convex. Low values in the distance class 1 and 4 partly reflect the low response to rainfall during the growing period. The removal of grass biomass by livestock within the first two kilometres zone around the water point, between the initial start of growing or germination and the time of sampling, could have lead to this alignment. This pattern follows the grass biomass medians of Mutompo in the WS, presented in Figure 12, p. 68, which is not significantly related to the distance classes.

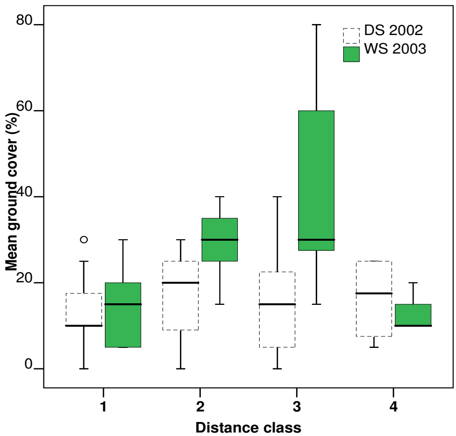


Figure 16: Ground cover for distance classes in Mutompo (o = outlier value; DS white boxes with dotted line show no significance among distance classes)

A weak significant effect, referred to the distance classes is the result of the variance analysis of the Evenness index for Mutompo in the WS (Figure 17 and Table A 9 in the appendix). The lowest values emerged in class 1 (median: 0.44); there were higher values in class 2 and 3 (Figure 17). The value of class 4 (> 3 km) (median: 0.65) was a bit lower than in the two previous classes. The lower the Evenness index, the fewer species were present in increasingly larger proportions. Land use effects on this index occurred within the first km distance from the water point in Mutompo.

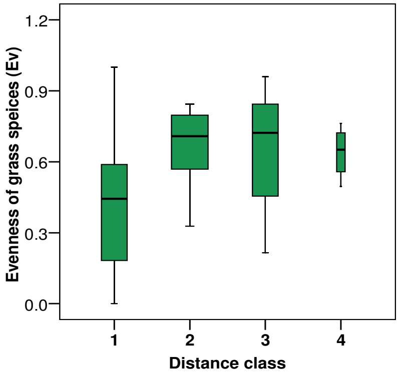


Figure 17: Evenness of grass species for distance classes in WS 2003 in Mutompo

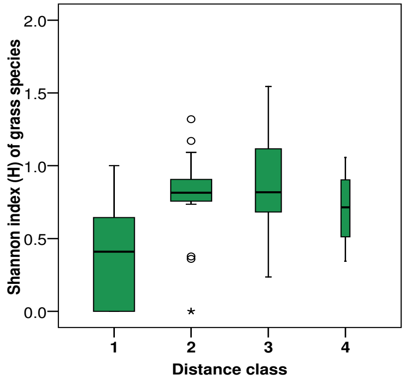


Figure 18: Shannon index (H) of grass species for distance classes in WS 2002/3 in Mutompo (o = outlier value; * = extreme value)

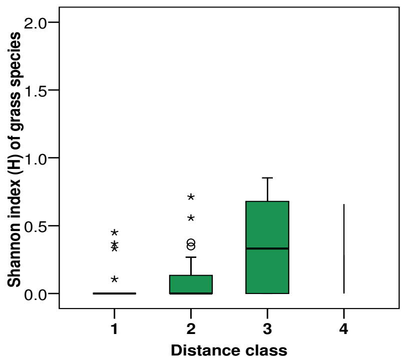


Figure 19: Shannon index (H) of grass species for distance classes in WS 2002/3 in Okamboro (o = outlier value; * = extreme value)

The diversity parameter Shannon index (H) is an index, which incorporates not only the number of species, but also their abundance in relation to the total number of species. The highest grass diversity was found in Mutompo in the distance classes 2 and 3 during the WS 2002/3 (Figure 18). The lowest value (median: 0.41) shows in class 1, the distance from the watering point up to 1 km, which reflects the grazing and trampling impact. Slightly lower values for H (median: 0.72) were detected also in class 4, which resulted again in a convex imaginary course of the medians (Figure 18). In Okamboro, H in the WS 2002/3 (Figure 19) shows a highly significant effect related to the distance classes, with a clear maximum (median: 0.33) found in distance class 3 (2 ≤ 3 km; see Table A 8 and Table A 9 in the appendix). The drought situation in 2003 was reflected by very low H-values, which were probably mainly produced by the annual grass species. Only few species survive and grow under water scarcity, or were already growing there during the sampling time in May 2003. In Okamboro, the H-values also show a convex shape, but the medians are zero in the distance classes 1, 2, and 4 (Figure 19).

The significant effects of measured nutritional values of grass samples referring to the distance classes and the transects with a coefficient of determination (R) higher than 50% for both communities are shown in Table 17. More details of the statistical analysis of the grass nutrients are found in the appendix in Table A 10.

Table 17: Significant effects of distance classes, transects and their interaction on nutritional values of grass parameters

	Distance classes (d)	Transect (t)	t * d	Test type	R
Mutompo					
Crude protein (%) WS 2002/3	**	***	/	Median	0.545
Crude fibre (%) WS 2002/3	**	**		ANOVA	0.550
Phosphorus total (%) WS 2002/3		**	/	Median	0.779
ME (MJ/ kg) WS 2002/3		**		ANOVA	0.471
ME I (MJ/ kg) DS 2002	*		/	Median	0.500
ME I (MJ/ kg) WS 2002/3	***		/	Median	0.356
Okamboro					
Ash (%) DS 2002	*	**		ANOVA	0.918
ME (MJ/ kg) DS 2002	*	*	/	Median	0.878

t – Transect; d – distance classes; significance level of empty cells p > 0.1. Model: y = d + t + d * t. / - the interaction (t * d) could not be calculated with the median test. Detailed results of statistical tests see Table A 10 in the appendix. No data of nutrients in the WS in Okamboro, because of insufficient grass biomass due to the rainfall gap of 6 weeks during WS.

The transects had impacts on the following values: crude protein, the crude fibre content, the phosphorus content, as well as the metabolisable energy, all in WS and in Mutompo. Nutrient-values for the wet season in Okamboro were not available, as mentioned earlier, due to the drought situation. Only the ash content and the ME of mixed grass samples of DS 2002 showed a weakly significant relation to the transects in Okamboro. In Mutompo, high values for the χ^2-values of the median tests were found for ME I, related to the effects by the distance classes in both seasons (see Table A 10 in the appendix). For the CP and the P content, both in the WS, also high χ^2-values were discovered in Mutompo. In

Okamboro, high F-values in ANOVA were found only for the ash content and for the ME both in DS 2002, referred to effects by the distance and the transects (Table 17).

The distinct significant effect for Mutompo during the WS of the distance classes on the mean crude protein of the grass samples are illustrated in Figure 20. Highest CP-values were found in class 1, lowest in class 4 during the WS, with an almost linear decreasing trend in increasing distance classes. This pattern of the newly grown grass during the WS probably results from the nutrient enrichment of the soil, due to increased amounts of dung and urine near the water point, in contrast to a poor soil fertility in general.

Higher values of crude fibre in wet season were not expected (Figure 21), because the higher the fibre content is, the lower the forage value. In Mutompo, the crude fibre contents in the WS (Figure 21) show an increasing trend within the first 2 kilometres of distance, and about constant values onwards. An explanation for these results could be the shorter stems of the annual grasses, which were abundant around the water points. In greater distance, the mixed grass samples included also the thatch grass (mainly *Eragrostis pallens*) and other grasses, which grow larger and contain more fibre components

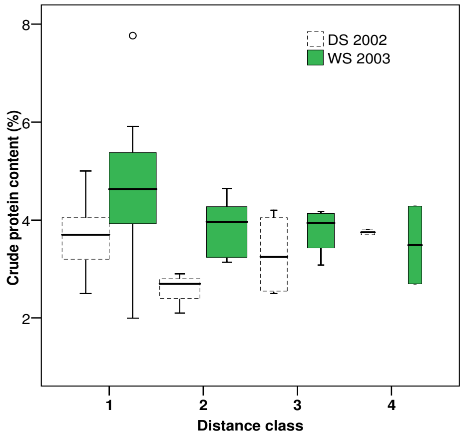


Figure 20: Crude protein-content of grass samples for distance classes in Mutompo (o = outlier value)

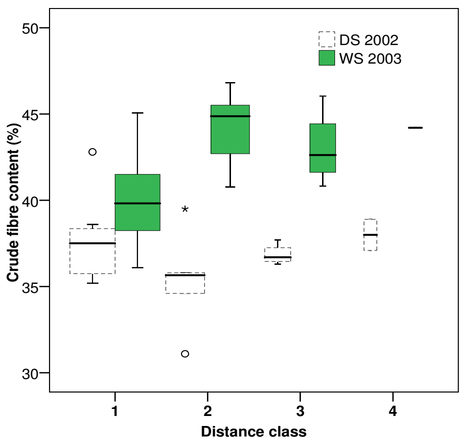


Figure 21: Crude fibre-content of grass samples for distance classes in Mutompo (o = outlier value; * = extreme value)

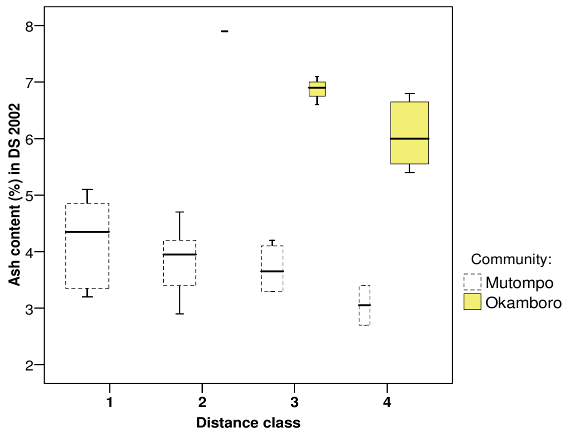


Figure 22: Ash-content of grass samples for distance classes in DS 2002

stabilizing the longer stems. Moreover, livestock grazed preferably on the inflorescences of the grass and left over the stems.

In the DS of 2002, ash content of grasses in Okamboro was on a much higher level than the values in Mutompo (Figure 22), which was also found for some nutrients and minerals of the soil samples (Table 9, p. 55). In both Mutompo and Okamboro, the ash content values decreased with increased distance to the central watering point. The impact of distance on the ash content showed a weak significant level for Okamboro, but a high value for R (see Table 17, p. 72, and Table A 10 in the appendix).

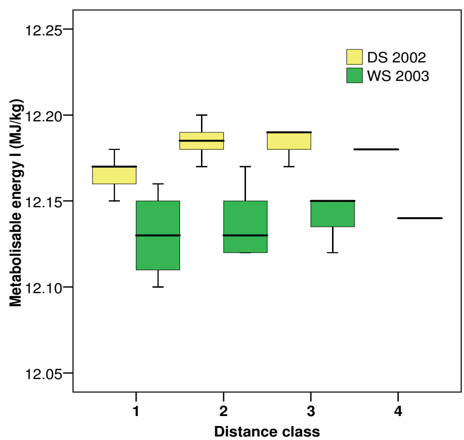


Figure 23: Metabolisable energy I (ME I) for distance classes in Mutompo

The ME I- values (calculated according to Kirchgessner, 1997) in Mutompo showed significant effects for the distance classes in both seasons (Figure 23), and were even of high significance for the WS 2002/3. The median values in the DS 2002 have a nearly convex form; the values of the WS 2002/3 roughly increase with increasing distance class, up to the class 3. However, the differences between ME I-means lie only within the range of a decimal place (see Table A 4 in the appendix). The lower energy content during the WS in comparison to the DS was not expected. The ME values for Mutompo results as well in a much higher mean value in the DS (ME DS mean: 11.92 MJ kg $^{-1}$) in comparison to the WS (ME WS mean: 6.74 MJ kg $^{-1}$).

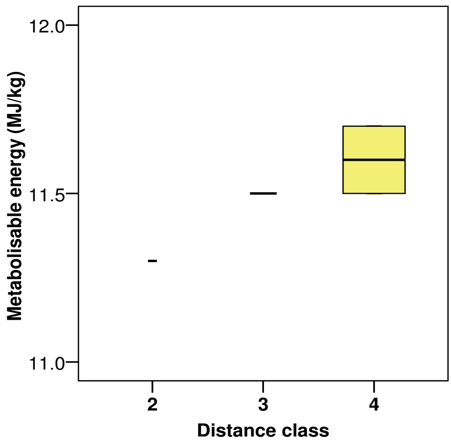


Figure 24: Metabolisable energy (ME) for distance classes in DS 2002 in Okamboro

In Okamboro, the ME-values show a clear increasing trend with an increase of the distance classes in the DS 2002, (Figure 24). However, there are only few values available which support this result, and within distance class 1, no data points exist for the DS. One reason for this pattern could be the selective feeding behaviour of livestock, which prefers nutrient rich grass species to grasses with lower energy content, which indicates a high grazing pressure around the water point in Okamboro. This could also be an explanation for the low ME I-values in the km-class 1 in Mutompo (see Figure 23).

The type and course of the spatial distribution or patterns give information on the impacts of land use, but primary production is additionally influenced by abiotic factors, such as spatial uneven rainfall distributions, heterogeneous soil patterns or inner- and intra-plant species competition for light, soil moisture or nutrients within the soil. The main reason for the higher mineral and ash contents of the mixed grass samples was probably the accumulation of dung and urine through a horizontal transport from the grazing areas into the periphery of the areas around the water points, or to the kraals near the houses, where livestock was kept during the night. As long as the farmers use no manure for fertilizing the fields in Mutompo, this accumulation of nutrients means a waste of fertilizer, and a lack of transport and labour seem to be the reason for not applying these originally traditional practices.

In Okamboro, no cropping takes place which the manure could be used for, and the accumulation of livestock around the water dam is a reason for this pattern as well. Livestock was observed to linger under larger trees near the water place during the day, often dropping dung and urine near the dam. In Okamboro, the sand dam provides livestock with water all year round, except of some weeks in very dry years. Water trickles permanently through the wall of the sand dam, and fills the riverbed behind the dam with water of more or less good quality. A diesel pump on a concrete watering place has to be operated by people for providing the livestock, especially herded goats and sheep, with water; this water source is also used for human consumption.

In Mutompo, the course of the medians of the grass parameters shows a mainly convex course, with low values in the 0-1 km zone, as well as in the > 3 km- zone. In Okamboro, the picture differs more, with an exponential increasing trend with increasing distance from the water point for the grass BM during DS, a convex course for the grass Shannon diversity index (H) during WS, and unclear trends for the number of grass species during the DS, as well as of the grass BM during the drought-stricken WS. For the grass' nutritional values, a linear decreasing trend of the ash content was found, in contrast to the increasing linear trend of the ME, both during the DS. In Mutompo, a gradient was found for the crude protein content in the WS, which seems to be a result of the higher fertility near the water point, due to the high dung concentration from the livestock.

In Mutompo, the grass parameters for the distance classes (d) and for the transects (t) show a higher number of significant results in comparison to Okamboro (Table A 8 and A9 in the appendix), but the significance levels for the distance classes are higher in Okamboro. At least, e.g. for the grass BM in the DS in Okamboro, the differences between distance classes 1 and 4 were much higher (around 40 g m^{-2}; mean: 9 g m^{-2}) than the differences between the maximum and the minimum value in Mutompo (around 20 g m^{-2}; mean: 58 g m^{-2}) during the DS. As mentioned earlier, the drought-like situation after the WS 2002/3 in Okamboro, caused low values for most of the grass parameters (grass BM, ground cover), as well as for the number of the grass species and the two biodiversity indices. This fact, resulting in mostly highly significant differences between the communities (see Table 10, Table 11, Table 13, p. 56-58), and makes a direct comparison between the communities meaningless.

Referred to the hypothesis, a high impact zone caused by the utilization of the rangeland resources can be detected in both communities, whereas this impact zone is more distinct and of greater extent (up to 2 – 2.5 km from the water dam) in Okamboro, compared to Mutompo (around 1 km from the water point). The patterns registered near the water point, were mainly a result of the manner of utilization of the communal grazing areas by the farmers in both communities and their keeping of livestock. A zone of bare soil patches was observed, which is located only in direct proximity to the water place (50 to 150 m), where livestock lingers, waiting for water provision or using this area for resting and ruminating. This zone is heavily trampled and grazed on by livestock, and only few larger trees grow there providing shade. This zone, which shows signs of heavy impact and bare soil, is called the sacrificed zone (Glatzle, 1990; James et al., 1999; Jeltsch et al., 1996)

Mphinyane & Rethman, 2003; Tolsma et al., 1987), and is found in both communities. In this study, the sacrificed zone is integrated in the first distance class (0-1 km from the water point). Unfortunately, the drought situation, which occurred in the Okamboro area during the 2002/2003 rainy season, makes the interpretation of gradients and patterns of the grass and herb biomass, as well as other parameters for the WS difficult, and the results are not representative or transferable to average rainfall years. The large numbers of bare soil patches in Okamboro (see Table 8, p. 48), could either be a result of the drought, or the heavy grazing and trampling, which in turn impedes the primary production. However, rainfall variability is very high in Namibia, and the risks of a drought occurring is also high. Due to the low biomass of grasses in the drought-stricken WS in Okamboro, data on grass nutrients were only available for the DS. It was observed, that the perennial grass *Stipagrostis uniplumis* (Silky Bushman grass; or Ongumba in Otjiherero), which is regarded as a good fodder grass by local farmers, grows only in greater distance from the water dam, and has basically disappeared within the village region, in which mainly annual grasses were found. This can be a sign of long-term heavy grazing impacts around the water dam and on the community area. Herbs were not evaluated in this study, but there fodder values should not be underestimated. If these signs of heavy grazing, especially in Okamboro, are called "degradation", which is specified as irreversible, it could not be clearly supported by the results of this study**.** A long-term monitoring programme of the rangeland resources, the climate conditions and the type and intensity of land use, which would at least cover a timeframe of 10 to 15 years, is the only way to detect degradation and desertification. A long-term monitoring approach is also the only means to detect the threshold beneath a regeneration of disturbances, either caused by droughts or intensive land use. However, higher stocking densities (see Figure 7, p. 30) and a higher population density (29 households, 158 inhabitants), and a longer period of land use and livestock grazing (the Ovitoto Native Reserved was founded in 1923), with a higher intensity have occurred in Okamboro, (see Ch. 3.4 Recent and historical livestock numbers, p. 28). Whereas in Mutompo, apart from the impact of the clearing of the dry forest, fewer people (14 households, 83 inhabitants), and a smaller number of livestock utilised the natural resources, and this settlement was founded not till the 1970s (see also chapter 3.4, p. 28).

Higher values for most grass parameters were found in the distance classes 2 and 3 (1 – 3 km from the water point) in Mutompo, which can be attributed to more biomass of unpalatable species, which were not grazed by livestock. The transects tangented the edge of the dry forest area, in a distance of more than 1 km (distance class 2), continuing further, directly into the dry forest. Values for the crude protein content in WS and the ash content in DS decreased nearly linear with higher distance classes. Competition for light and available soil water between the woody vegetation and grass and herbs, may explain these low values of e.g. the standing dry grass biomass in both seasons, the ground cover in WS, the number of grass species, or the Shannon index in WS for a distance beyond 3 kilometres. Grazing took place in all areas of dry forests, but not in such density as around the water point. Also, in Mutompo, the effect of the transects showed highly significant differences for the four tested grass parameters (Table 16, p. 66). This can be interpreted as either spatially different impacts of grazing within the different grazing regimes, or it reflects the broad spatial distribution and differences of rangeland resources along the transects, referred to the soil fertility and conditions, the area of cropping, the fallow fields, the dry forest zones in the periphery and the open grassland.

Livestock management aspects may further determine the spatial availability of grazing resources. Firstly, the stocking density in Mutompo was 15.0 kg ha^{-1}, and 41.9 kg ha^{-1} (see Table 33, p. 140) in Okamboro. Secondly, in Okamboro, the livestock is guided daily from the settlement area to the water dam in the morning, and then sent in the direction of a grazing area, where the animals graze freely during the whole day. In Mutompo, the livestock is herded during the wet season, in order to prevent losses of crops on the fields, and to control the use of grazing areas. During the dry season, the livestock roams free on the communal grazing areas, just as it is done year round in Okamboro. Cattle paths and other infrastructure, such as roads or the topography and e.g. barriers through fenced camps, lead the livestock through these areas. For the fenced camps in Okamboro, statistical tests demonstrate no significant differences among vegetation parameters of rangeland, being inside or outside the camps (see Table A 3 in the appendix). In addition, the daily grazing orbits of the different livestock species determine the extension of grazing impacts on the different grazing areas, which can differ during the seasons, varying the availability of natural fodder. In comparison to other African countries, where the grazing radius of cattle was over 30 km from the nearest water point (e.g. in Mali, see King, 1983); in contrast to this, the largest grazing orbit of cattle around water points quoted in Namibia was only 5 km (Bayer et al., 1991).

Thirdly, the distribution of huts in the settlement of Mutompo is not directly centred around the water point. There are homesteads located far away from each other, dispersed more alongside the road. This results in a broader distribution of livestock within the communal grazing areas of Mutompo. In Okamboro, the huts align two centres opposite to each other, separated by the dry riverbed (see Map 4, p. 40 and Figure 9, p. 41). Most farmers use the areas behind their homesteads, which leads to a concentration of livestock around the two settlement clusters in Okamboro. Routes are partly disrupted by fenced camps, or rough topography, and livestock grazing does not aim at using the remote periphery. Fourthly, heterogeneity in abiotic conditions results in a heterogeneous distribution of natural resources, which can also lead to heterogeneous utilization patterns on communal grazing areas. Additionally, a suitable rangeland management could preserve key resource areas, located e.g. near a riverbed, in more remote areas, e.g. with better soil, or it could induce the emerging vegetation on fallow fields. Key resources can serve as grazing reserves during times of fodder scarcity (Scoones, 1995a), such as droughts, or simply until the end of the dry season. Within these areas, seed banks are protected and can regenerate. It is also argued, that such key resources in communal areas can maintain the livestock densities on a very high level, above the recommended carrying capacity, but on a low productivity level.

Because of the forage quantity and quality of grass resources, livestock - especially cattle - have to walk to remote areas in late WS and certainly also during DS, in order to get enough grazing intake in Okamboro. The quality of the collected mixed grass samples declines very soon after seed production, and was found to be rather poor already shortly after the end of the WS, in both communities. In Mutompo, grass biomass is sufficiently available, also on fallow fields, and considering the crop residues after the millet harvest. The nutrient status of the grass resources causes no deficit in the nutrient supply of livestock. Compare also chapter 5.3.4 (p. 146 ff.) on the nutrient forage balance and for the discussion of this topic see chapter 6.2 (p. 182 ff.).

Possible consequences of these findings for the livestock and grazing area management in Okamboro could be a reduction of grazing pressure, or a better use of the periphery for grazing resources, in order to lower the livestock impact on the areas near the water point and within the settled areas. The herding of cattle, not only small stock, clearly enhances the control of the herds and flocks, and grazing areas could be grazed and changed more purposefully every day. Group herding techniques, where two herders take care of animals of more than one household, and also the use of cattle dogs, could help reduce the workload as well as the costs. A goat flock protected by two goat-dogs and without a herder was observed in the grazing area during fieldwork in Okamboro, yet dogs were not used as helpers during other herding activities. The establishment of new water places located further upstream would reduce the pressure around the old water dam, and then the temporary ponds lined along the riverbed could also be used more effectively in the WS. A general destocking is not urgently necessary in Okamboro, but a more homogenous use of rangeland resources would reduce the grazing pressure within the settlement area significantly. Destocking only during periods of drought is recommended, but then also taking provisions for the feeding supply of livestock before a DS could help reduce bodyweight losses. Applying an opportunistic drought management in communally managed livestock systems, with e.g. a fast destocking within a drought and restocking after a drought, definitely requires the development of the infrastructure and transport facilities, as well as a good market access and market price information for communal

livestock farmers. Perhaps, governmental price subsidies could be introduced as well, instead of the drought relief programme that has lead to an increase of livestock numbers, due to the support in additional forage supply. A general destocking of livestock would be difficult and not feasible in this community, if this meant a reduction of livestock numbers per household, because livestock remains the main economic activity of the farmers in central Namibia (thereto see chapter 5.3.2, p. 134 ff.), and it also serves a multipurpose function. The capital and insurance function of livestock seems to be crucial for rural households, as long as no effective public or private banking system or a health and pension insurance scheme has been developed (see also the discussion in chapter 6.2.3, p. 190 ff.). Mogos (2009) found in his study with communal and commercial farmers in central Namibia that livestock farmers prefer to diversify their enterprices as a risk management tool, rather than buying insurance.
One promising way to reduce grazing pressure from the communal land is the Affirmative Action Loan Scheme (Agricultural Bank of Namibia. 2000; Agricultural Bank of Namibia. 2001; Garcia, 2004), a resettlement programme, initiated by the Agricultural Bank of Namibia in 1992. The wealthier farmers, with more than 150 large stock units (cattle), or 800 small stock units can qualify to get a loan and farmland, in order to establish a freehold commercial farm, and then move out of the communal land, in order to release pressure on communal grazing resources. Few wealthy farmers keep most of the livestock of Okamboro, which causes the highest pressure on communal rangeland (see Figure 33, p. 123). In 2001, in Okamboro at least two farmers met the requirement of owning more than 150 cattle. In Namibia, the total number of granted affirmative action loans increased from 207 in 1999 to 357 in 2002 (Agricultural Bank of Namibia, 2000; Agricultural Bank of Namibia, 2002; Tapia Garcia, 2004). Even though the target of the Affirmative Action Loan Scheme is to reduce the pressure on communally managed resources, it actually creates incentives to maximise herd sizes, at least on a short term basis. Only communal farmers owning large herds of livestock can qualify for the programme, which is an encouragement and justification to increase livestock numbers, and which could eventually result in negative impacts on rangeland resources and plant biodiversity. Additionally, especially absentee owners, who live and work in the urban centres, invest some of their wages in their livestock, which grazes on the communal land.

A grazing fee per head of livestock paid by farmers into a community fund (Kruger, 2001), or a taxation of livestock would be another means to give incentives to not simply accumulate livestock, but also to sell or slaughter it. For the communal areas in Zimbabwe, Ranvig & Hansen (1999) suggested to introduce a nominal grazing fee, in order to reduce the stocking densities, or give incentives to sell some of the livestock. They remarked that the collection and use of a generated income from these fees could become a conflict in the community. They suggested solutions which would keep the income derived from grazing fees within the village, and thus be used to create goods and services for the users, e.g. by investing in supplement feed during shortages. A water fee, linked with the number of livestock per household - cattle and small stock considered separately - would be a good option for communal areas in Namibia to implement a fair consumption-dependent payment system. The water fees (about NAD 10 per household), which recently have to be paid per household, irrespective of the number of livestock kept, cannot be justified with regard to the poorer households without livestock. Albeit, the wealthier farmers normally raise the payments for repairs when the water pump breaks, and they provide the transport for the diesel. A water-livestock-fee could be charged in rates, with a gradual stepwise increase, whereas the first 15 cattle could be free of charge, the 16th to 50th cattle could cost one NAD per month per animal, the 51st to 100th animals three NAD, and every cattle exceeding the 100 five NAD. A farmer owning for example 100 cattle would then have to pay 185 NAD per month, a farmer with 50 cattle only 35 NAD. Goats could be free of charge, as long as they feed mainly on browse, and as long these fodder niches are sufficient available. Sheep compete with cattle for grass biomass, but are only held in small numbers, and could therefore also be free of charge. This money could and should then be used by the community, to firstly, maintain the water facilities, and secondly, improve its infrastructure, investing in health care (vaccination, deworming, or dipping against parasites), or buying protein and mineral licks for the livestock of the community. Other possibilities of investment could be, e.g. for Okamboro, employing herders and establishing stock posts, in order to move some of the animals to peripherial areas, with the aim of reducing the grazing pressure within the village and around water points. Organising the transport of livestock to the permit market or other activities, such as training measurements, could also be possibilities of communal investments. Additionally, a mobile electric fence, enclosing a reserved area for the DS, or investments, needed on the way to becoming a communally managed conservancy, could also be made. All of these measures require strong community institutions and the willingness of the farmers to cooperate and accept an organising committee. Also, the definition ‘livestock per household’ or ‘per family’, and the question of who actually owns how many animals, could cause some conflict when answered, and has to be defined clearly if and when related to water-livestock-fees, especially when absentee owners run their livestock within a herd of a household of relatives.

In Mutompo, the grazing pressure is not very high, but there is and will most probably be only this one water place for the entire livestock and people. Settlements in the inland Kavango region are established around drilled water places, so that each community can use this one water point. Only in case of emergency, when a pump is broken, neighbouring communities accept ‘foreign’ livestock or people, but demand a payment. The grazing pressure around water places can only be reduced by a better management of the accessibility of the water, for instance by offering water to livestock only in the mornings and evenings. In Mutompo, livestock should be herded, not only during the crop-growing period, but also all year round. However, human power is limited and mainly used for cropping, and the younger boys should better attend school and not have to take care of livestock all day. Providing crop residues or lopping bushes and trees on already harvested fields during a dry season could gather livestock on the fields, which would drop dung and urine to fertilize the soil. The grazing agreements among livestock farmers in Mutompo follow a rotational grazing scheme (Falk, 2007). This allows some of the grazing areas to rest for several weeks after rainfall, in order to provide better fodder during the dry season (see p. 176), which is also an opportunity to manage the communal grazing areas and an innovation already implemented by local farmers.

High concentrations of several nutrients in the soil, as well as higher values of nutrients in plants were reported to be restricted to a zone of around 150m in a study of Mphinyane (2001). This finding could not be confirmed, due to a different distance approach of this study. However, the significantly higher values of crude protein in WS, as well as the ash content of grasses in DS within the first kilometre from the water place, point out that there is a similar situation in Mutompo. Still, the possibly higher productivity in this distance zone near the water point cannot withstand the high grazing and trampling pressure. During the period before the sampling in May 2003, most of the green vegetation was probably already grazed around the water point and within the 0 - 1 kilometre zone. This would also explain the low figures of most of the grass parameters around the watering point.

Grass biomass values were also influenced by transects and their interaction with distance-classes in both communities, which means that there were additional effects from the five transects on the grass BM. Effects of the transects were found on the ground cover in the DS, the number of grass species and the Shannon index (H) in the WS in Mutompo, and on the ground cover and also the Shannon index (H) in the WS in Okamboro (see Table A 8 and A 9 in the appendix). Additionally, effects from the transects were also detected on the ground cover and the grass Shannon index in the WS in Okamboro, as well as on some grass nutrients (Table 17, p. 63). The graphical analysis of the transect effects and their interaction with the distance classes of the grass BM and the leaf BM is described in chapter 4.3.4, (p. 92 ff.). The parameters of grass cover and the density of trees and bushes are shown in the appendix (Figure A 5 to Figure A 8 in the appendix), because these parameters are of high relevance for the quantity of fodder supply. The preferences in grazing areas of communal farmers are investigated and discussed in chapter 5.3.5 (p. 160 ff.).

4.3.3 Browsing resources

4.3.3.1 Local differences of browsing resources

This chapter deals with the browsing resources, which are often neglected for calculation of carrying capacities, when estimating the forage potential. The first part describes the general situation and the differences between both communities. Then, the nutritional values of some bushes are presented and finally, the spatial aspects along the five transects of both communities are illustrated as box-and-whisker-plots and scatter plots for a number of woody resources.

According to own data of tree analysis, Mutompo's woody vegetation consists of 96 % bushes and trees with broad leaves, other than the *Acacia* species, whereas only 4 % of all tree and bush species belong to the *Acacia* family. In Okamboro, which is classified as an *Acacia*-highland-savanna, 53% of all trees and shrubs were of the *Acacia* species, 47 % belonging to broad-leaved species. In Mutompo, 16 % of the broad-leafed trees were *Bauhinia petersiania* (Wild coffee bean), while in Okamboro the *Catophractes alexandri* (Trumpet thorn) contributed 26% to the total woody species. *Acacia mellifera* (Black thorn or Hook thorn) makes up 15 %, *Acacia reficiens* around 15 %, and *Acacia tortilis* (Umbrella thorn; probably a part of it is *Dichrostachys cinerea*) and *Acacia erubescens* share only 0.3%, respectively 0.8% of the woody vegetation in Okamboro.

Acacia spp. belong to the leguminous family and has a high protein content, but displays chemical as well as mechanical defence mechanisms, protecting the fine leaves from being browsed. In Okamboro, some species were observed to grow green leaves before the first rain, governed by photoperiodic or temperature influences (Owen-Smith, 1982). The *Acacia*-trees growing along the dry riverbanks in Okamboro use the remaining soil moisture more effectively. They normally consist of a dense shallow root system but also include some of the roots going deeper (Smit, 1999). Typical browsers, such as goats and some of the wild animals (e.g. kudu, giraffe and springbok) are able to browse on *Acacia*-species, due to their long and flexible lips, as well as their narrow-shaped mouths. The share of 53% *Acacia* trees in Okamboro makes it difficult to use this forage resource effectively with cattle, due to the fact that they are not able to feed directly on the protected early green leaves on the bushes and trees (Moleele, 1998), except when leaves, pods or flowers drop to the ground. Especially in late DS, goats can make optimal use of these resources and therefore endure long droughts better, and without a massive loss of bodyweight. However, the chemical protection of some *Acacia* species, such as high tannin or prussic acid content, could be a factor, which reduces the intake rate of livestock, or the digestibility.

In Mutompo, the topography of the ground and the soil type seems to be the most important natural factor determining the nature of plant communities, as depicted in Kutuahupira et al. (2001), and in Mendelsohn & el Obeid (2003), (compare also p. 25). Bushes and trees taller than 1.5 m make up 26 % of the trees and bushes in Mutompo and 31 % in Okamboro. The mean hight of trees and bushes are 1.4 m in Mutompo, and 1.6 m in Okamboro (see Table 18). However, the figures for the hight of the trees do not reflect the real situation in Mutompo, where in the dry forests many trees are larger than 6, or even 10 meters. Most of these high trees are not included in this study, due to their largeness and immense crown diameters, as well as the resulting larger distances to other tall trees, and due to the relatively small size of the plots of 10 m x 20 m for the tree and bush analysis. Nevertheless, these tall trees shed large amounts of leaf-litter during the dry seasons. Leaf-litter was not included in this investigation either, but it provides additional organic material for the improvement of soils, and it also helps protect the soil's surface against erosion by wind or rain. In late the DS, this litter also provides livestock with some forage, even though it is of low quality. However, these large trees are competing successfully against smaller trees, bushes and shrubs for light, space and soil moisture. It is also quite probable, that grass biomass and small woody vegetation grows less under large trees in a dry forest area.

Table 18 summarises the descriptive statistics of tree and bush parameters of Mutompo and Okamboro, including the results from the BecVol-calculations for leaf biomass, browse leaf biomass and leaf volume per hectare.

Table 18: Parameters of browsing resources

	Type of data	Mutompo (n = 3,992)		Okamboro (n = 3,071)	
		Mean	SE	Mean	SE
Total leaf biomass (kg ha^{-1})	BecVol-calculation	1,947.6^{a}	233.6	1,422.5^{a}	110.7
Browse leaf biomass (height ≤ 1.50 m; kg ha^{-1})	BecVol-calculation	923.8^{a}	109.0	668.2^{a}	63.9
Density (n ha^{-1})	measurement	3,471.8^{b}	1,688.9	1,503.6^{a}	1,080.3
Tree or bush height (m)	measurement	1.4 ^{a}	0.8	1.6 ^{a}	0.1
Crown diameter (m)	measurement	1.0 ^{a}	0.6	2.0 ^{b}	0.2
Leaf volume (m³ ha^{-1})	BecVol-calculation	4,047.8^{a}	490.7	2,938.8^{a}	226.7

a, b means in rows followed by different superscripts are significantly different at $p < 0.01$. Means and SE-values on transect level see Table A 11; for the distance classes see Table A 12, both in the appendix.

The browse leaf biomass is the leaf biomass ≤ 1.5 m, which is supposed to be the forage available for livestock. Trees and bushes in Mutompo are not significantly larger, but grow over twice as dense (number per ha), and the crown diameters are significantly smaller, in comparison to the parameters of the woody vegetation in Okamboro.

The mean tree density in Mutompo was 3,472 trees per ha, which is very high, in comparison to Okamboro, where the mean density was only 1,504 trees per ha. Due to this situation, the values for leaf biomass as well as for the browse leaf biomass are also higher in Mutompo than in Okamboro. The mean leaf volume (m^3 ha^{-1}) is higher in Mutompo than it is in Okamboro, but the difference is not significant. These tree and bush parameters result in the mean leaf biomass per hectare. From the total leaf biomass of 1,948 kg ha^{-1}, 47.4 % were browsing resources (height ≤ 1.50 m) in Mutompo. Also 47 % of the total leaf biomass of 1,423 kg ha^{-1} was theoretically available for browsers in Okamboro.

These differences possibly arise due to the differing ecological conditions and vegetation zones. In the dry forests, trees and bushes occur in higher densities but generally grow smaller. This high density can cause strong competition between individual trees, which again causes smaller crown diameters, because the neighbouring trees grow so close by. As mentioned earlier, very huge trees (larger than 6 m height) were seldom detected by the applied method. Yet, smaller trees and bushes do compete with these larger trees for light.

In the study of Mphinyane (2001) in Botswana, the BecVol-software was also applied in order to estimate the browsing resources. The values for the densities on the Masaane cattle post (sandfeld; Northern Kalahari; free-range grazing management, 451 mm long-term annual mean rainfall) were high, with values between 1,600 and 1,920 trees and bushes per ha, but were comparable to the mean of 1,504 per ha in Okamboro. The mean leaf volumes were reported to be between 1,045 and 2,195 cm^3 per ha and the total leaf biomass yielded mean values between 436 to 835 kg ha^{-1}. The values for the leaf biomass of Mphinyane (2001) are very low, in comparison to this study for both communities. Especially in comparison to Okamboro, where the tree density is even lower, the maximum mean leaf biomass value of Mphinyane (2001) accounted only for 59% of the Okamboro mean value. Values for browse leaf volume ≤ 1.5 m of height are not given in the study of Mphinyane (2001). A study by Smit & Rethmann (2000) was carried out in the Northern Province of South Africa with the Mopane tree *Hardwickia mopane* (also known as *Colophospermum mopane*). This study resulted in comparable values (from BecVol) for the total leaf dry matter values of 1,537 kg ha^{-1} (rainfall 440 mm), 1,736 kg ha^{-1} (rainfall 223 mm) in 1990/91 and in 1991/92, respectively, but with a tree density of 2,711 plants ha^{-1}.

Knemeyer (1985) conducted a study, where the browse dry matter and the leaf volume were estimated in the northwest of Namibia. However, the values and method applied in his study are not directly comparable in this case. Only the initial design and method, which uses a standardization of trees with the measurements of the leaf biomass weight per cubic metre leaf volume, applying different standard shapes of trees (cone-shaped, sphere, or pyramid forms) to calculate the leaf volume per tree, are similar. The leaf biomass per tree can be extrapolated via the tree and bush density, in order to get the leaf biomass per area, which is measured mostly per hectare, (results form Knemeyer, 1985; see Table 3, p. 10). The mean leaf biomass was around 76 kg ha^{-1} [20] in the DS and 273.8 kg ha^{-1} [21] in the WS in the northwest region of Namibia. The mean of the leaf biomass of 273.8 kg ha^{-1} in the WS (Knemeyer, 1985) is only one fifth of the values for Okamboro of 1,422.5 kg ha^{-1}, which is approximately comparable, referred to the vegetation type (*Acacia*-savanna), but can be regarded as the maximum value during the WS. The values of the browse leaf biomass of this study (see Table 18) are not directly comparable to the values of Knemeyer (1985), because he calculated the browse forage for wildlife, e.g. the kudu, which is partly able to graze up to 2.5 m of tree height. The leaf volume values are also not comparable, due to the different sizes of units (g m^{-3}) in Knemeyer (1985), in contrast to cubic metre per hectare of the BecVol-software in this study.

In relation to the grass resources, the browse leaf biomass was around 99% of the grass biomass in WS in Mutompo, which is a dry forest region, characterised by a very dense tree and bush vegetation (3,471 per ha), with a mean tree and bush height of only 1.4 m. Bush fires, losses from livestock grazing, and a general low biomass production of grasses and herbages underneath the larger trees in forest areas could explain these values. In Okamboro, the values for grass biomass were not comparable, due to the drought situation, which occurred in May 2003. However, the results of other studies are not consistent as Rutherford (1982) stated e.g. that the shoot biomass of the woody species was greater than the peak season's herbaceous layer biomass of 780 kg ha^{-1}. In contrast, Owen-Smith (1982) found that in savanna communities in southern Africa, the peak standing grass crop dry matter was frequently about ten times greater than that of the herbs or woody plant leaves and shoots within the reach of a large herbivore. He stated that therefore, the total quantity of forage on offer to a grazer may be five times higher than that available to a pure browser, but due to the differences in the nutritional values, the protein availability could only be half of the regular value (Owen-Smith, 1982). In addition, for the Namibian *Burkea africana – Terminalia sericea* savanna sites, which are well comparable to the Mutompo area, Rutherford (1982) reported that the peak season of

[20] 76 kg ha^{-1} in the DS, is a combination of 121.0 kg ha^{-1} herbs and small shrubs + 10.0 kg ha^{-1} higher trees and bushes – 55 kg ha^{-1} herbs.
[21] 273.8 kg ha^{-1} in the WS, is a combination of 374.4 kg ha^{-1} herbs and small shrubs + 26.4 higher trees and bushes -127 kg ha^{-1} herbs.

herbaceous layer biomass in an above average rainfall season exceeded the woody plant leaf biomass by about 40%. However, during the investigated seasons (2002-2003), especially in Mutompo, there seemed to be a great potential for browsers, such as goats, as well as wildlife, and rainfall was somewhat under the long-mean average. Diverse local conditions, abiotic ones, such as the soil fertility and the rainfall amounts, but also biotic ones, such as vegetation types and species, and the local tree and bush density and height, as well as the utilisation by livestock can affect the leaf BM amounts, as well as the browse leaf BM. The mentioned studies are not directly comparable, either through their rainfall regime, or their vegetation types, or through the method of estimation applied. It could be that the browsing resources are by some means overestimated in this study.

In southern Africa, but also in other parts of Africa, bush encroachment starts with densities above 1,500 trees ha^{-1} (see Smit & Swart, 1994, in van Essen et al.; 2002). High densities of trees are reported to have a mainly negative effect on the grass production, because the plants compete for water, light, space and nutrients. It is important also to consider the type of trees causing negative impacts on rangelands as well as the productivity of livestock, especially cattle. In southern Africa and particularly in central Namibia, e.g. *Acacia mellifera* or *Dichostachys cineria* account for bush encroachment (Bester & Reed, 1997; Zimmermann et al. 2003; Smit 2004). *Acacia* species are well equipped with long thorns or double-spines, sometimes hooked, which protect the green parts of the plant against feeding stock. For cattle, this defence mechanism of vegetation is a problem, yet not for goats. Additionally, *Acacia* species produce a chemical protection, a layer of tannin, to reduce the feeding pressure. On the other hand, the *Acacia* species can enrich the soil, due to its ability of symbiotic N-fixation. A high density of small shrubs and bushes with broad and soft leaves, without thorns, as it was described for a lot of species in the dry forest of Mutompo, reduces the grass productivity underneath this dense woody vegetation, such as in any thicket with high tree-density. However, soft and less protected leaves can serve as fodder for browsing goats and cattle and do not necessarily pose a problem of forage supply for livestock on natural rangelands.

The nutrient values of seven forage bushes were analysed in the Mutompo region and *Catophractes alexandri* in Okamboro (Table 19). The crude protein content of these green and fresh leaf-samples was much higher than the values of the green grass samples (range: 4.8 – 11.8% CP; see Table 15, p. 63). Additionally, the lower crude fibre content found in the leaves of the selected bushes indicates a higher forage value, due to a higher digestibility. Values for the P content in browsing resources were lower than the P contents of the grass samples (mean: 0.12% P, see Table 15, p. 63). However, the concentration of tannins or other secondary chemicals in browse forage, which reduce the palatability as protection against feeding and can be very high, was not analysed in this study. The amounts of metabolisable energy (ME II) were higher in the leaf samples, but the equation used for the calculation of ME II, is based only on the crude fibre (CF) content of the plant material. It is therefore not reasonable to compare these values directly.

Table 19: Nutrient analysis of leaf-samples

		Crude protein (CP) (%)	Phosphorus (P) (%)	Crude fibre (CF) (%)	ME II (MJ/kg)
Mutompo (May 2003)	Local names (Rukwangali)				
Diplorynchos condylocarpon	Murere	17.57	0.05	26.82	13.57
Ochna pulchra	Muzwe	14.74	0.13	15.21	13.78
Terminalia sericea	Mugoro	14.49	0.05	17.65	13.74
Baphia massaiensis	Mbunze	10.38	0.03	23.48	13.63
Combretum spp.	Mupanda	10.51	0.04	14.81	13.79
Bauhinia peterisana	Mahusi	12.42	0.04	23.89	13.62
Croton gratissimus	Mbango	9.55	0.06	31.54	13.49
Means Mutompo		12.81	0.06	21.91	13.66
SD		3.43	0.03	6.28	0.11
Okamboro (May 2003)	Local names (Bantu)				
Catophractes alexandri	Okalyandi[1]	11.89	0.04	21.26	13.67

Analysed by the Agricultural Laboratory Windhoek, Namibia. [1]In the Okashana area this bush is named Okalyandi. Metabolisable energy ME II = 14.05 - 0.01784*CF; this formula for ME II is used usually for hay from second cut, where only crude fibre (CF) is needed, according to Kirchgessner (1997).

Diplorynchos condylocarpon and Ochna pulchra had the highest crude protein concentration in Mutompo. *Ochna pulchra* is a good fodder bush with high crude protein and low crude fibre content, as well as a high ME II-value. *Compretum* species had the lowest crude fibre content (14.8%, total mean: 21.9% CF), but a high ME II-value. The lowest value for protein and a high value for crude fibre were found in *Croton gratissimus*. *Catophractes alexandri* had slightly lower values, in comparison to the means of Mutompo. These bushes had grey, relatively hard leaves and appear with a high abundance in Okamboro. Goats, as well as cattle were observed feeding on it.

Fresh browse had more biomass available as forage (≤ 1.5 m of height) and higher nutrient values than the grass biomass and samples. For the leaf samplings, fresh leaves of certain trees and bushes were used, which farmers reported livestock to feed on. Especially goats feed on them, but during dry season, the litter also provides cattle with additional protein. Even in May 2003, (the drought situation in the Okamboro region), it was found, that the bush *Catophractes alexandri* contained high levels of protein and energy, which was not expected during a drought, or due to the small and solid structure of the grey leaves of this bush.

4.3.3.2 Spatial effects on browsing resources

Table 20 shows the results of the analysis for variance of bush and tree parameters, as well as the forage biomass related to distance classes, transects and their interaction. Mean browsing leaf biomass was tested as highly significant, referred to the distance classes in Mutompo, the same as in Okamboro.

In Okamboro and Mutompo, the same tree and bush parameters showed significant impacts, related to the distance. The transects and the interaction partly influenced the distribution of the woody vegetation, with high significance for the browse leaf BM in both communities, the tree and bush height and the crown diameters in Mutompo, whereas in Okamboro, the density and the leaf volume, as well as the leaf BM, were strongly influenced by the transects. Sometimes, the interaction of transects and distance classes also showed highly significant effects on e.g. the height and the crown diameters in Mutompo.

Table 20: Significant effect of distance classes, transects and their interaction on bush and tree parameters

	Mutompo			Okamboro		
	Distance classes (d)	Transect (t)	t * d	Distance classes (d)	Transect (t)	t * d
Total leaf biomass (kg ha^{-1})	*		*	**	***	*
Browse leaf biomass (height ≤ 1.50 m; kg ha^{-1})	***	***		***	***	*
Density (n ha^{-1})	*		*	*	***	*
Tree/bush height (m)		***	***			*
Crown diameter of trees and bushes (m)		***	***			***
Leaf volume (m^3 ha^{-1})	**	*	*	*	***	**

Distance classes: class 1 = 0 ≤ 1 km; class 2 = 1 ≤ 2 km; class 3 = 2 ≤ 3 km; class 4 > 3 km. t – transect; d – distance classes. Significance level: empty cells = not significant ($p > 0.05$). Detailed results of statistical tests Table A 14 in the appendix.

The box-and-whisker-plots illustrate the descriptive statistics of significantly tested woody vegetation parameters, referring to distance classes. Within the following chapter (4.3.4), significant results from the browse leaf biomass were visualised in scatter plots for single transects, including the grass biomass, which are both relevant as forage supply for livestock in both communities.

Figures 25 and 26 show the spatial distribution of the leaf biomass of trees and bushes for distance classes in Mutompo and Okamboro, respectively. In Mutompo, the highest value (median 2,369 kg ha^{-1}) was found in class 1 (0 ≤ 1 km), and a decreasing trend, proportional to an increased distance class up until class 3 (2 ≤ 3 km; median 713 kg ha^{-1}).

In distance class 4 (> 3 km), a slightly higher value of 1,458 kg ha^{-1} was investigated. A similar concave course of the medians was found for the browse leaf BM (up to a height of 1.5 m) in Mutompo (Figure 27). In Okamboro, the lowest values for both tree parameters were found in class 1 (Figure 26 and Figure 28), increasing up to class 3 (2 ≤ 3 km), which showed the highest value of leaf biomass (median 1,628 kg ha^{-1}). Class 4 (> 3 km; median 1,104 kg ha^{-1}), showed slightly lower values, compared to class 3, which resulted in a convex form. The same pattern was found for the browse leaf BM in Okamboro (Figure 28). In Mutompo, the browse leaf biomass was high in the distance zone 1, due to the high density of small bushes and shrubs around the water places (see Figure A 1 in the appendix), and an additionally high leaf volume of trees and bushes in this zone (Figure A 3 in the appendix). Moreover, the red soil zones occurring in this area have a high tendency to bush encroachment. The amount of browse leaf biomass is lowest in the dry forest zone, because there trees are larger, and the competition for light, space and soil moisture probably does not let small bushes grow well. However, the quantity and quality of leaf-litter, which can be used as fodder by the livestock, during the DS, seems to be rather important in this area, but has not been investigated, yet. The values in class 4 in Mutompo (only n = 7), came only from the transect 5 (the transect headed into the southwest direction, see Map 5, p. 46; Figure 30/5, p. 96, and Figure A 6/ 5, in the appendix), which was also the transect affected by fire in the zone of the distance class 3. Transect 5, which lay within the distance class 4, showed higher values for all significant tree and bush parameters. This could be explained with a different natural vegetation structure on more fertile red soil area zones. Moreover, illegal wood logging preferably takes place within this region, due to the proximity of a road next to the Mile 46 research station, which is linked to the B 8, the main tar road connecting Grootfontein and Rundu (see Map A 1 in the appendix). Smaller bushes and trees immediately fill the gaps caused by the logging of large trees. Within this region, patches of smaller bushes and trees were observed, which build bush thickets of higher density, in comparison to an open dry forest with large trees and proportionally sparse ground vegetation.

In Okamboro, all illustrated tree and bush parameters showed a maximum in the distance class 3 (2 ≤ 3 km) (see Figure 26 and 28, and Figure A 2 and Figure A 4, in the appendix), which results in a more or less convex course of the medians. Grazing pressure within the first kilometre negatively influenced the growth and establishment of smaller trees and bushes. The so-called sacrificed zone is the zone lying within the first distance class, up to 1 km (or less) around the central water dam, which is characterised as more or less bare soil. Within this zone, few small bushes or trees are found to resist this high grazing pressure.

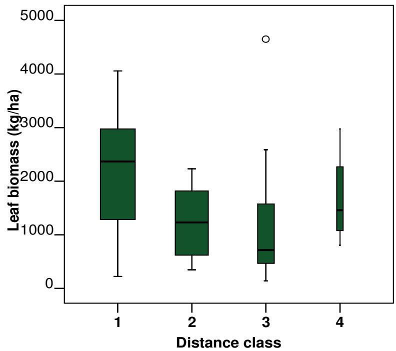


Figure 25: **Leaf biomass of trees and bushes for distance classes in Mutompo** (o = outlier value)

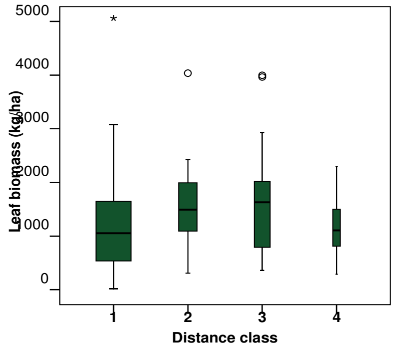


Figure 26: **Leaf biomass of trees and bushes for distance classes in Okamboro** (o = outlier value; * = extreme value)

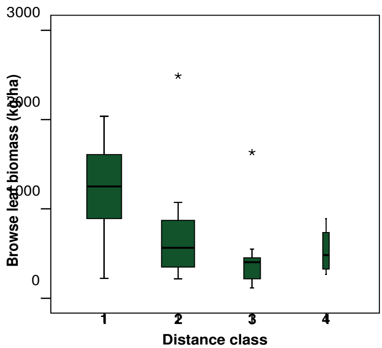


Figure 27: Browse leaf biomass of trees and bushes for distance classes in Mutompo (* = extreme value)

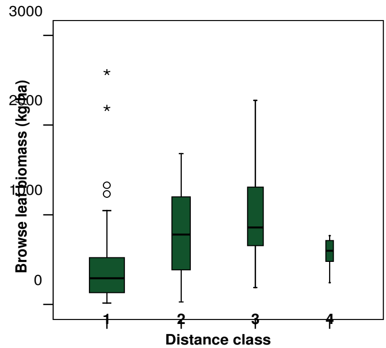


Figure 28: Browse leaf biomass of trees and bushes for distance classes in Okamboro (o = outlier value; * = extreme value)

Within a distance of one kilometre from the water point, the grazing pressure still seems to be high, also resulting in bare soil patches within the settled area of Okamboro, as well as in a low bush and tree density and leaf volume, followed by low values for the leaf BM and the browse leaf BM.

Just some of Okamboro's grazing areas can be referred to as bush encroached, but cannot be directly associated with the grazing gradients along the five transects. Goats control the bush density within the community grazing areas, and cattle also browse on bushes and small trees, due to the lack of suitable grass resources. However, in some areas, smaller patches of thickets can be observed, particularly in the former commercial farm 'Swakophoehe' . 'Swakophoehe' is used occasionally as a military training area today (see Map 4, p. 40) and serves as a grazing area for the livestock of Okamboro and the neighbouring settlements. Moreover, the former fence is broken to a great extent. Some regions within 'Swakophoehe' are encroached by *Acacia mellifera* of more or less one size and age-group, with relatively sparsely developed ground vegetation. This is probably caused by cattle grazing and some years of only spare utilization.

The grazing pressure influences some bush and tree parameters, such as density, leaf volume, leaf BM and forage relevant browsing resources near the water points in both communities, but in different ways. High bush and tree densities were found in Mutompo, near its water pump, whereas a relatively low bush density was found in Okamboro around its main watering point, the sand dam. An increase of browsing resources in the further periphery, over three kilometres away from the water point of Mutompo is associated more likely with changes in natural conditions, mainly soil conditions. Furthermore, other human-induced impacts on natural resources, such as the extended illegal logging activities of large trees, possibly also have an influence on the density of smaller bushes and trees. In Okamboro, the convex form of bush and tree parameters can also be explained by regarding the high grazing pressure near the dam, which reduces all vegetation in reach of the livestock, increasing grazing pressure up to a distance of three kilometres. The low values in the areas of over three kilometres distance from the water dam in Okamboro, are either influenced by the grazing pressure of livestock from neighbouring communities or are a result of an occurrence of different natural conditions, such as poorer soil or dryer areas, due to more slopes and rocks.

4.3.4 Spatial transect analysis of grazing and browsing resources

The following scatter plots, (with local lowess-curve fittings per transect and vegetation parameter values of the single sampling points, created with SPSS; see chapter 4.2.3, p.

54), were used to analyse the spatial effects of single transects and their interaction with the distances from the watering places, on grazing and browsing parameters in both investigated communities. The illustration of the spatial distribution of the grass and browse biomass, for both communities was selected, because these are important forage resources for the - mainly free-roaming - livestock, whereas the remaining rangeland resources during the DS reflect probably more evidently the impacts of grazing pressure.

The first figures (Figure 29/ 1-6) show the spatial grass dry biomass distribution of the single transects, and all transects taken together in Mutompo in DS 2002. This parameter was tested as highly significant for the effect of the five transects ($p \leq 0.001$), and weakly significant for the effect of the interaction of all transects with the distance classes (see Table A 8 and Table A 9 in the appendix). The course of the lowess-fitting-curve for Mutompo in total, in DS, increases from the point located near the water place, to a maximum of grass biomass of around 70 g m^{-2} in 2.5 kilometres distance from the water place, and shows a slight drop to 4 km of distance. The course of the curve for Mutompo is similar to that of transects one, two and three, but it is different to that of transects four and five. Transect four was very short in length, and with a maximum grass BM, located in an area less than 0.5 km distance to the water point. The curve of transect five has a very different course, with a minimum in the region of 2 km distance away from the water point. In this region, a wide area was burned by bush fire, decimating the vegetation, such as grass and weeds, drastically to nearly zero. The zone of the increase in grass biomass in DS, from the central water point to a distance of approximately 2.5 km, lies within the range, in which the dry forest begins, with a transition zone in between. Large or dense trees and bushes compete with the standing ground vegetation for light and soil moisture, which is confirmed by a significant negative correlation between grass biomass and bush density in the WS in Mutompo (see Table 22, p. 107), which also reflect the main growing period of the vegetation after rainfall. In DS, most of the trees and bushes shed their leaves, and light is no longer an issue of competition, but at the same time grass and weeds are also dry and no longer growing.

The figures of spatial distribution for grass cover in the DS of Mutompo are noted in the appendix (see Figure A 5/ 1-6). They show mainly similar trends and courses in the curves as grass dry biomass for DS 2002 in Figure 29. The grass cover in the DS in Mutompo, resulted in a highly significant effect on transects ($p \leq 0.001$), and in a weak effect for the interaction between distance classes and transects ($p \leq 0.05$) (see Table A 8 and A 9 in the appendix). Lowess-curves of browse leaf dry biomass (t and d*t with $p \leq 0.05$) in Mutompo (see Figure 30/ 1-6) show similar trends in the curves of single transects as the tree and bush densities (t and d*t $p \leq 0.01$) in Figure A 6/ 1-6 in the appendix, except for transects one and two, which show an inverse trend. The browse leaf biomass for Mutompo in total, shows a decreasing trend from the zero point (1,400 kg ha^{-1}) to around 450 kg ha^{-1} in a distance of 2.5 km. In further away distances, the lines maintain stable on this level until the end of the transect points nearly in 5 km distance. This trend in total is reflected by the lowess-lines of transects two, three and four; whereas a stable level from 3 to 5 km distance is generated by transect five in Mutompo (see Figure 30/ 5 for the transect five, and Figure 30/ 6 for all transects).

The preferred grazing areas in Mutompo lay in the areas of dry forest around the community and past the fields. The preferences of livestock farmers for the individual grazing areas in DS and in WS, the latter of which is also the cropping season in Mutompo, are analysed in more detail in chapter 5.3.3 (p. 140 ff.). Along transect 5, the fire impact is clearly detectable for the density of trees and bushes, but hardly remarkable in the lowess-line for the browse leaf parameter (see Figure 30/ 5). The short transect four points at a high amount of browse leaf biomass, but not higher densities of bushes and trees, in comparison to the other transects. For the area along transect four, this indicates a thicket with most bushes less than 1.5 m of height, likely situated on an area of red fertile soil.

In conclusion, gradients for the grass biomass and the browse leaf biomass, were found along the transects, with partly different patterns on the individual transects. Within a 2.5 km distance from the water points, human impacts, such as the clearing of a forest for cropping purposes, building huts within the settlement area, as well as the impacts of livestock can be a cause for these gradients. Within the dry forest itself, grazing impacts and natural aspects, such as inter- and intra-species competition both cause changes in the vegetation. Differences between transects can also be caused by natural aspects, such as soil differences and differences in vegetation types, and partly by human activities or livestock grazing. Fires burn large parts of the dry vegetation in every dry season, which is thus lost as livestock forage. Hot fires or a high annual fire frequency also destroy trees. Fires are caused partly naturally, by lightning during thunderstorms, but are often also caused more or less accidentally, by field fires which get out of control, or when farmers deliberately set fires to burn old grass in order to have a faster regrowth of fresh green grass as forage for livestock.

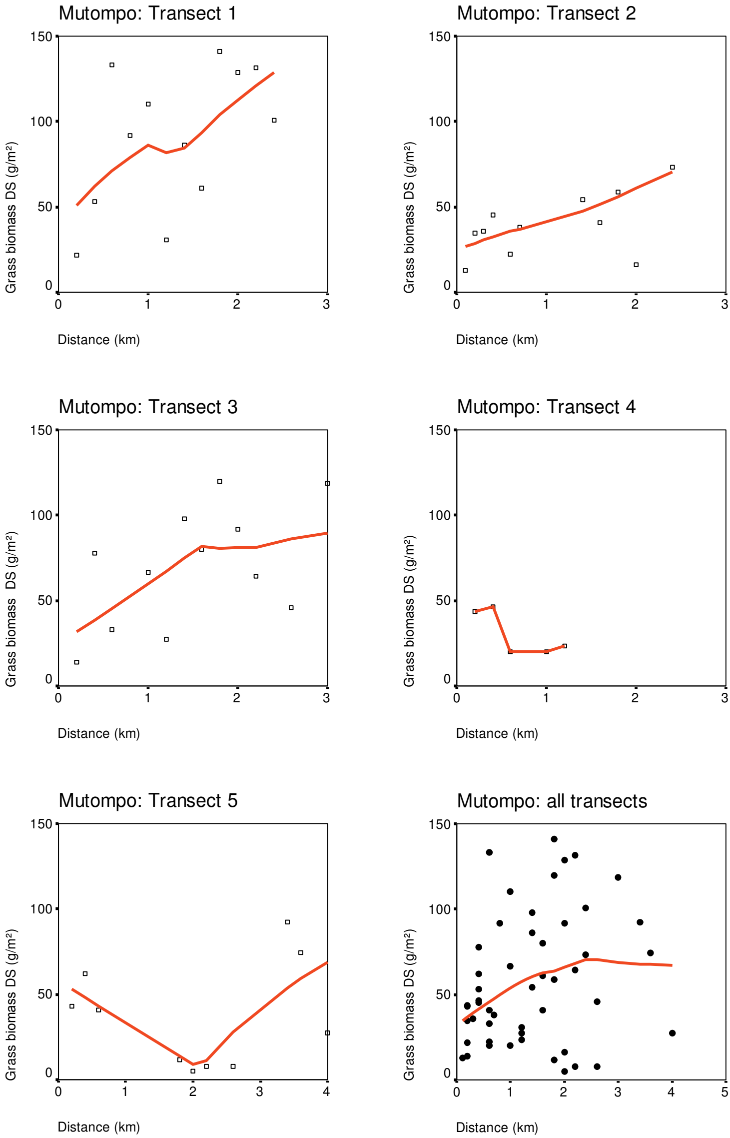


Figure 29/ 1-6: Spatial distribution of grass biomass per transect and all transects together in studied DS in Mutompo

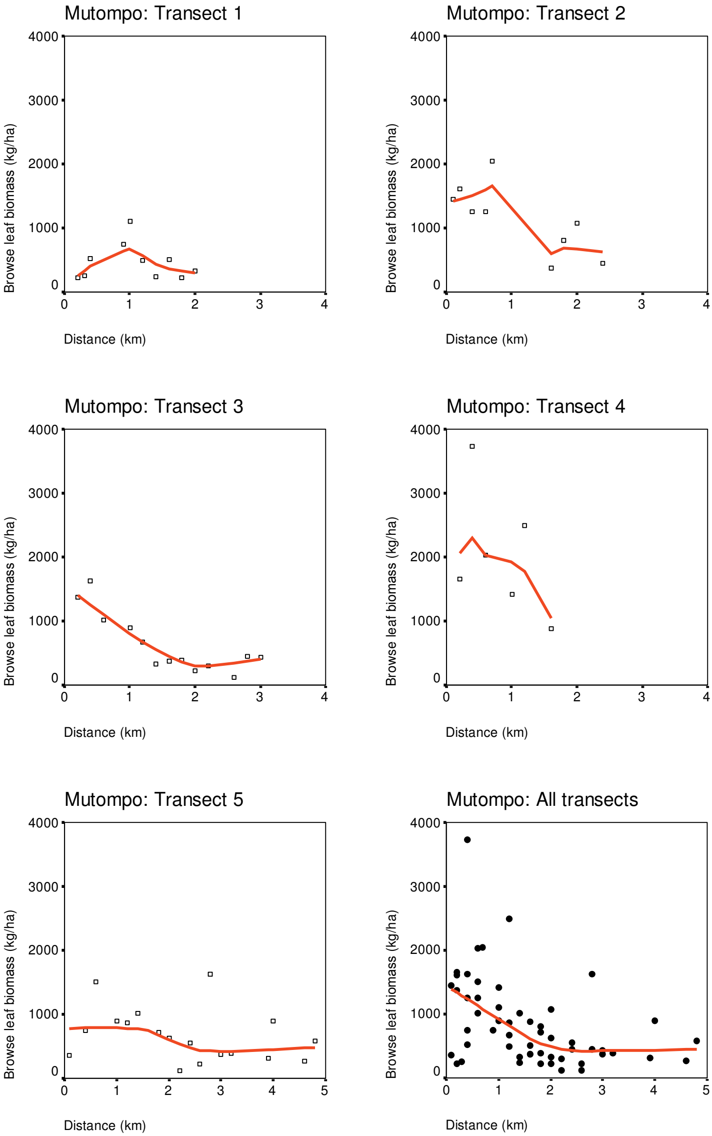


Figure 30/ 1-6: Spatial distribution of browse leaf biomass (≤ 1.5m) per transect and all transects together in Mutompo

For Okamboro**,** parameters such as grass dry biomass in DS, as well as the browse leaf biomass for the single transects and all transects together are illustrated on the following pages (Figure 31/ 1-6 and Figure 32/ 1-6). Other lowess-diagrams for the same kind of grass cover in the WS and the tree density for Okamboro are to be found in the appendix (see Figure A 7/ 1-6, and Figure A 8/ 1-6).

The first figures show the spatial grass dry biomass distribution in Okamboro during DS (Figure 31/ 1-6). The factor distance is highly significant for the grass biomass in the DS ($p \leq 0.001$), the transect parameter was tested as only weakly significant ($p \leq 0.05$), as well as the interaction ($p \leq 0.05$) in the DS, but not during WS. In total, for Okamboro, the grass biomass in DS describes an exponential curve, whereas values are stable on the level of a few kilograms per hectare up until one kilometre distance. Then, the curve rises up to 39 g m^{-2} of grass biomass. Only the curves of transects one, two and three are similar to the curve of all transects, whereas transect three increases to a value of around 53 g m^{-2}. On transect four, the curve shows a concave trend with a minimum on the 1.5 kilometres distance from the central watering point, and the values are always below 5 g m^{-2}. The values on transect five are also very low, with values below 4 g m^{-2}. The curves of grass cover in WS in Okamboro (Figure A 9/ 1-6 in the appendix) lay on a level of 10% cover, up to the three kilometres distance, and then they decrease to a 5 % cover. The transects one and two, show an increasing trend; transects three, four and five a decreasing trend. The grass cover along transect two has a similar course to transect two of the grass biomass in WS, but all other transects differ in comparison to the curves of grass dry biomass of this season.

Looking at the spatial distribution of the densities of trees and bushes (see Figure A 8/ 1-6 in the appendix), the course of the curves for all transects increases to a maximum of about 2,000 trees or bushes per hectare, around a 3 km distance. The curves of the browse leaf biomass (Figure 32/1-6) show a similar trend, with a maximum around a three kilometres distance from the water point. Few sampling points in a greater distance of five to six km distance from the central water point of transect three; cause a decline after the three-kilometre point. For all other transects, except transect four, which is the transect located in the military area in eastern direction from the dam, the curves of the bush and tree densities generally increase from the central water point to the three km-distance point (see Figure A 8/ 1-6 in the appendix).

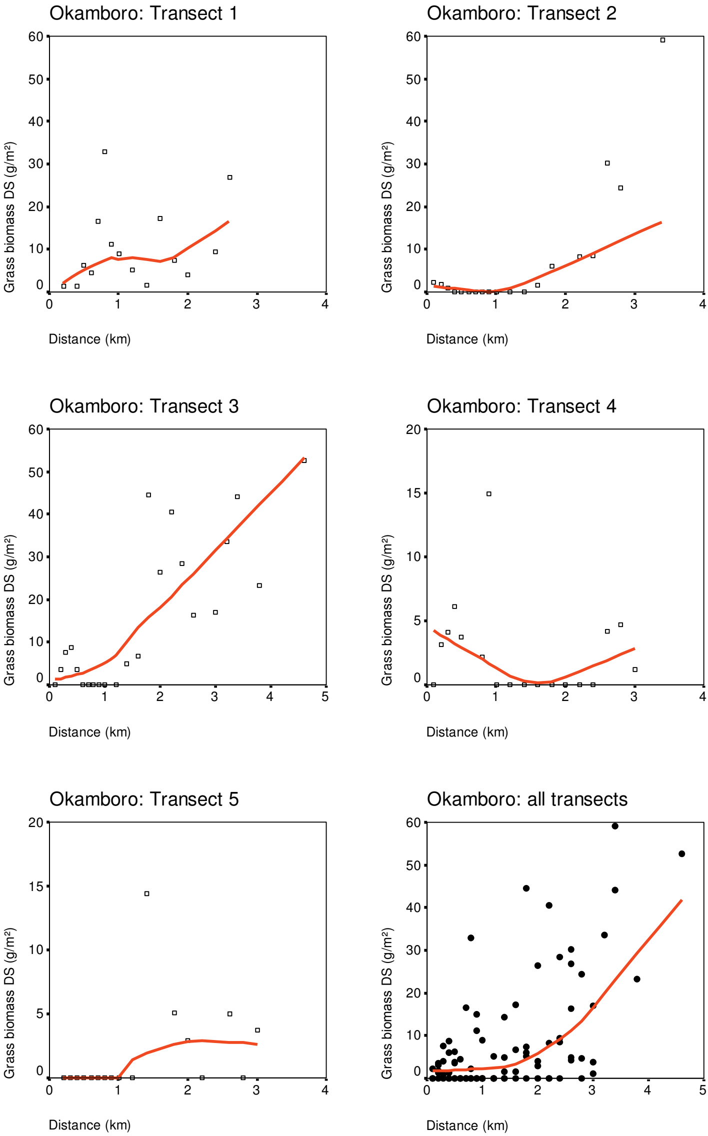


Figure 31/ 1-6: Spatial distribution of grass biomass per transect and all transects together in studied DS in Okamboro

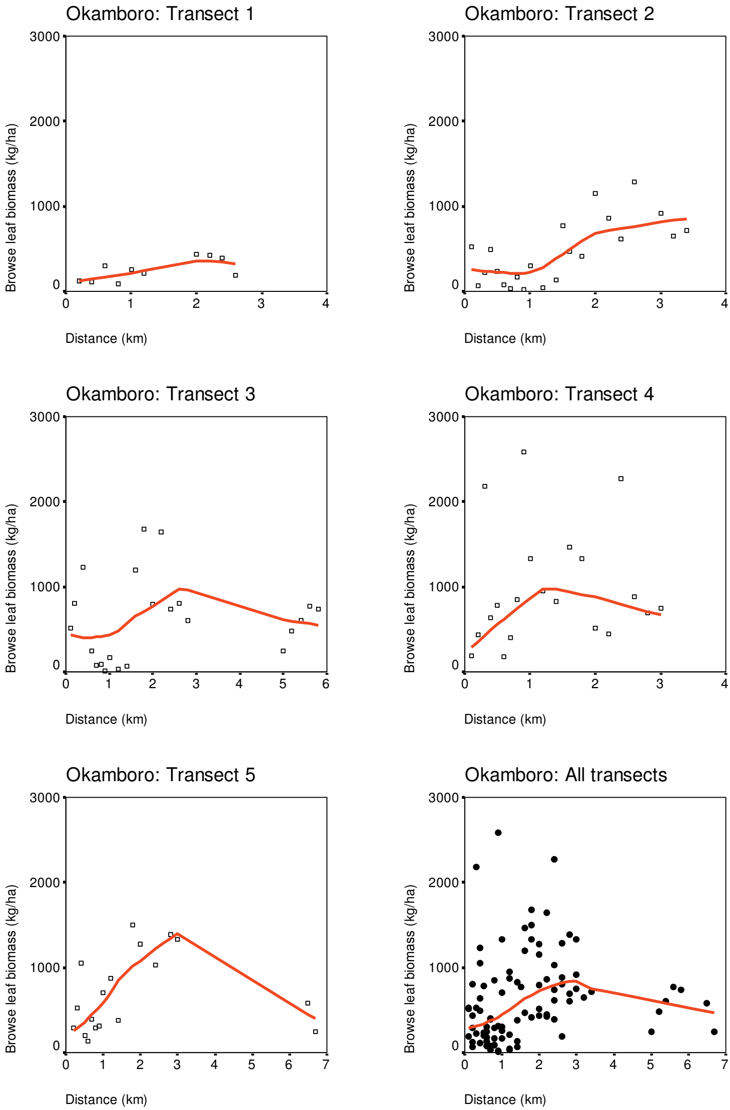


Figure 32/ 1-6: Spatial distribution of browse leaf biomass (≤ 1.5m) per transect in Okamboro

The three-kilometre zone around the central water dam in Okamboro seems to be the main walking orbit of livestock, goats and cattle, and the pressure through trampling, defecation and grazing seems to be highest near the dam, decreasing with increasing distance. Differences between individual transects can be interpreted as variations in topography on the one hand, and the structure of paths and roads along transects on the other hand, which guide the livestock through the area. Cattle avoid difficult topography, such as steep slopes, in contrast to goats, which are better in climbing.

Most of the values in the Figures 29 to 32 show a high mean variation, which already becomes obvious when regarding the boxes of the box-and-whisker-plots of grass, and tree and bush parameters. Additionally, the values are smaller with increasing distance, which is caused by the transect design (see chapter 4.2.1, and Figure 10, both p. 44). The lowess-curves confirm the zone of impacts from land use by e.g. woodcutting for fuel wood, as well as the impacts from livestock, such as trampling and grazing in direct proximity to the water point. Also, fire impacts influence the shapes of a fitting curve of a single transect in Mutompo (see Figure 29/ 5, as well as Figure A 5/ 5 and Figure A 6/ 5 in the appendix). The partly high differences in spatial distribution of parameters between transects, explain a high heterogeneity of grazing and browsing resources in the grazing areas of both investigated communities. This can be caused in general by the natural variability, which determines the primary productivity, e.g. by soil fertility, the topography, the partly steep slopes in Okamboro, the competition between the woody vegetation and the ground vegetation in the dry forest in Mutompo, or by more or less rainfall in some areas (small-scale spatial rainfall variability). Infrastructure, such as roads and paths, as well as the riverbed within the community, and steep slopes found in the subdivided landscape of Okamboro, guide livestock into special grazing areas. A thorny bush thicket, steep slopes or fences within a communal area can also block the routes to grazing areas, forcing livestock to take detours. On a plateau area, with relatively dense bushes, which lies on the transect in the direction to the north, approximately 1.5 km from the water point (see Map 6 p. 47), mainly horses and donkeys were observed, but seldom cattle. The temporal water points (ndombes in Mutompo or small water pools in the riverbed in Okamboro) can make certain areas within the rainy season more attractive for grazing to the free-roaming livestock than others. Nevertheless, it is not known, whether these animals are guided to these areas or whether they go there by themselves.

Most livestock in Okamboro is not herded, but after letting them drink at the dam once or twice a day, the farmers usually lead their livestock off into one direction. These directions seem to depend on the location of the household of the farmer, because farmers chose areas behind their houses or near their homesteads, so that the areas are split up into preferred grazing areas of the individual farmer, (see also 5.3.3, p. 140 ff.). However, livestock seldom uses the utmost periphery, and fenced camps block several routes into further away areas, so that livestock has to go a long way around these camps. Livestock comes to the kraal in the late afternoon, partly to suckle the calves, kids and lambs. In fact, most animals chose the area they want to graze in and the direction they walk of, as well as the duration of grazing. If livestock were not guided into peripheral areas, these areas could build a reserve ('hay on the stem') for drought or for the late dry season. In case of a drought or a scarcity of forage nearby the community, farmers can lead their animals into these areas, and thereby maybe establish some temporary stock post, in order to prevent long walks. The problem of water supply for the livestock and for the stock posts in the periphery could not easily be solved, so that livestock would have to walk back to the dam for drinking every second or third day. There seem to be no special agreements for not using special areas in the periphery within the community or purposely building grazing reserves. Within the general daily livestock management, free roaming livestock use the periphery less than the areas near the water points and the kraal.

Better control and herding of animals would definitely prevent losses of livestock and it also supports a more effective use of grazing and browsing resources of the community, which would be one step further into the direction of improving livestock production. In Okamboro, richer households could employ young herders, or young family members could help take care of the livestock. Another option could be a group herding of several households in a rotational manner, which is recommended for both communities. Two or three herders would lead the livestock of e.g. three households on a day tour and the following day, herders from other households would function as herders for the livestock. Arrangements on the areas of grazing should be made between the herders of the group, but also among farmers and herders of the community, in order to ensure a more homogenous grazing and also to protect special grazing areas as drought reserves. The herders should train each other in a simple assessment of the rangelands, and they could then share local knowledge e.g. about poisonous plants, treatments against parasites, good herbs etc. Possible disadvantages of mixed group herding, such as the spread of diseases, or uncontrolled mating, require the separation of the bulls, as well as consequent health care measures. These practises will be difficult to implement in communities such as Mutompo or Okamboro, because it demands the cooperation of all livestock farmers, as well as an effective extension and veterinary service, and e.g. appropriate infrastructure, such as a dipping tank, which is not always adequately available. However, the problems of an uncontrolled spread of diseases and uncontrolled mating also occur, when animals are not herded or bulls are not separated most of the time, as is the current situation.

Whether the relatively high stocking density in Okamboro has had a long-term negative effect on the vegetation in the periphery is not clear. Inside the village and nearby the water places many plots were without vegetation (60% of the sampling points were bare soil). The resulting overgrazing, thwarted by the drought situation during the WS 2002/3, which strongly impeded the vegetation growth, does not reflect a more or less normal year. A rangeland monitoring, stretching over several years, would be the best, in order to detect the regeneration capability and the resilience of the vegetation after a drought season, whether heavy grazing and trampling have effects and last, but not least, in order to analyse the availability and quality of the seed banks of herbaceous vegetation. However, droughts belong to the uncertainties of the arid and semi-arid climate conditions of Namibia, and a severe drought occurs approximately once a decade. Whereas, the drought-stricken WS 2002/3 in the Okamboro region, had only local effects, restricted to a specific region in central Namibia (see Map 2, p. 24), and caused by a six week rainfall gap. Such events probably occur more often than severe droughts. Severe droughts in southern Africa are mostly related to the El Niño phenomenon, or ENSO (**E**l **N**iño and the **S**outhern **O**scillation), which is a globally coupled ocean-atmosphere phenomenon, generating large-scale impacts on rainfall patterns (Nicholson, 2001). In addition, global climate changes could result in a general increase of drought events for southern Africa, as well as a higher frequency of the ENSO events. Climate changes and uncertainties of rainfall, increase the insecurity and vulnerability of livestock farmers, and could well result in a general degradation of the rangelands. This could be prevented, if opportunistic livestock management practises were supported, for instance with the mobility of communal livestock, or by supporting fast destocking during a drought, as well as consequentially fast restocking of livestock after a drought.

In Mutompo, herders prefer to lead their livestock in the forests for shade, which reduces the heat stress on the animals. Livestock prefer to rest and ruminate, lying near large trees. In Mutompo, many small cattle paths, leading into the directions of the different grazing areas, pass through field areas. Through the lack of topographical structures, as well as missing fences, only bush thickets or fields, which are protected by thorny branches, block or divert the routes of livestock from the grazing areas. Goats were observed to graze near the settlement, on small shrubs and bushes and in thickets dominated by *Acacia* species.

However, from the results of the statistical tests and their visual analysis, it is not possible to differentiate exactly between impacts of a biophysical heterogeneity (soil fertility, or soil structure), intra- or interspecies' competition of the different vegetation components, and the impacts of land use of local farmers and their livestock on the vegetation parameters. For the rainfall amounts, which largely determine the primary productivity, small-scale spatial heterogeneity was detected for Namibia, but it is assumed, that within a radius of 3 to 5 km, the rainfall and climate impacts can be neglected. If a clear grazing gradient, starting from the water point, were established for vegetation parameters, the periphery of the communal grazing areas, which are mostly aligned through the daily walking orbit of the livestock, could be used as a benchmark for unused and undisturbed grazing and browsing resources. In the case of this study, most of the investigated parameters showed no clear increasing or decreasing trends with an increasing distance from the water point.

Only for the grass BM during the DS 2002 in Okamboro, the mean value for the distance class 4 (> 3 km distance from the central water point) was 42 g m^{-2}, in contrast to the value of 3 g m^{-2} in the distance class 1 (≤ 1 km) (see Table 16, p. 66, and Figure 13, p. 68). The medians of the box-and-whisker-plots describe an exponential increase, correlating with increasing distance from the water point. Because no data of the grass BM of the WS 2001/2002 exists, it is difficult to estimate the initial maximum amount of the grass BM, as well as the total primary production before grazing. The maximum grass biomass amount is needed for the evaluation of the primary production, the status of the rangeland vegetation, and the impact of land use on the grass BM. The value of the DS 2002 principally reflects the remaining grass biomass of the WS 2001/2002. Therefore, it would be more appropriate for a determination of the rangeland status, to use the peaks of WS grazing resources and compare them with the data from the immediately following DS-period. In order to obtain a realistic picture on the reaction of the rangeland vegetation to different climatic conditions within the range of the variability, and due to the generally high climate variability in southern Africa, this approach needs to be repeated over a course of several years, in combination with regular rainfall measurements and soil analyses.

Considering the graphic analyses of the vegetation parameters for the single transects (scatter plots), a clear increasing trend along some transects with increasing distance from the water point becomes obvious. In Okamboro, along transect 1, 2 and 3 the grass BM in the DS shows a clear increasing trend with increasing distance to the water point (see Figure 31, p. 98), and for the grass cover these increasing trends were found in the DS along transect 1 and 2 only (see Figure A 7/ 1-6 in the appendix). For the browsing resources the total trend along most transects decline beyond 3 km distance in Okamboro. Only along transect 2, an increasing trend for the tree and bush density was detected (see Figure A 8/ 1-6 in the appendix), which could be a result of a water scarcity for trees and bushes, due to higher altitude of this *Acacia* highland area. In Mutompo, for the grass BM during the DS along the transects 1, 2 and 3, an increasing trend up to 2 kilometres from the water point was found (see Figure 29, p. 95), and for the grass cover, only along transect 2 an increase was noticed (see Figure A 5 /1-6 in the appendix). The spatial distribution of the woody vegetation in Mutompo (see Figure 30, p. 96) was influenced by the differences in landscapes, which occur between the grassland, with its smaller shrubs and bushes, and the dry forest area, with mostly large trees, and less ground vegetation. Assuming these peripheral areas of transects characterise a benchmark for the whole area without or with low grazing pressure (especially in Okamboro), presupposes a homogeneity of biophysical conditions of the entire communal area, which was not the case. However, the high values of grass BM in the periphery during the DS in Okamboro do indeed reflect a grazing activity gradient.

The various patterns of the box-plots point at different impact-zones around the central water points, whereas a combination of the diverse impacts mainly result in changes of vegetation parameters. These zones do not necessarily correspond with the distance classes, which were applied for the clarification of the data for the box-and-whisker-plots. A high impact zone, located directly around the water point in Mutompo and a larger zone, around the water point and within the settlement area of Okamboro was identified. Signs of degradation, such as bare soil patches, as well as an extremely low ground cover, were found in this sacrificed or high impact zone, and the primary production was apparently also impeded. This zone is succeeded by an intermediate zone and also by a zone of most likely lower grazing impacts. The intermediate zone in Mutompo is a zone of fields and fallow areas, whereas some areas are also covered with smaller bushes and shrubs. These areas are probably those with higher soil fertility, found in former inter-dune valleys (compare also p. 25). The grazing areas located within the dry forest, where larger trees allow some ground vegetation to grow, are characterised by the competition between trees, bushes and the ground vegetation, and also by impacts from grazing, as well as occasionally by fire events. In Okamboro, the high impact zone extends into the intermediate zone, the area in which the homesteads and kraals are located. Due to the relatively high current stocking density of livestock (42 kg ha^{-1}, see Table 33, p. 140), trampling is of great impact within this zone. However, during a good rainfall year, if and when a suitable seed bank were or is still available, a regeneration of the vegetation and the biodiversity within both, the high impact, as well as the intermediate zone, would be very likely. The resilience capacity is unknown for these rangelands. Former types of land use and their intensity could also have had an effect on the vegetation (see Figure 6, p. 29; Figure 7, p. 30). In Okamboro, moderate to heavy livestock grazing has occurred since the 1940s; in Mutompo, people have kept livestock only since the 1970s, and also with much lower intensity. Only within the settlements and directly around the water points, the impacts of land use, such as grazing, trampling and defecation of livestock, as well as the use of wood for fuel and for hut construction, have resulted in detectable changes, compared to the peripheral areas, which at least are only sparely grazed.

4.3.5 Correlation of grass and browse parameters

Correlations between distance (in km) and the vegetation parameters were carried out in order to crosscheck the impacts, as well as the tendencies, in relations to the distances. In order to analyse the amount of inter-species effects or competition between the grass parameters and the woody vegetation, these values were tested, too. Table 21 lists the coefficient of the correlation (r) and the significance of the correlation of the non-parametric Spearman-rank-correlation, related to distance, noting that these correlations examine just the linear relationship between the parameters. Most of the values of the determinants of correlation (r) are above the absolute value of 0.3, (absolute values < 0.3 stands for a weak correlation), and over half of these relations are highly significant.

In contrast to most significant positive correlations of the grass parameters (Table 21), all significant correlations related to the distance regarding the tree parameters, show a negative correlation in Mutompo, but not in Okamboro. The crude protein content in the WS 2002/3 in Mutompo, as well as the ash content during the WS show a negative correlation related to the distance, too. In Okamboro, the crude protein content of the grass samples as well as the ash content, both in the DS, also show a negative trend. Results of correlations with the distance from the water point, in the most cases correspond (marked grey cells in Table 21) with the significant results of ANOVA and the Median-tests (Table A 8, Table A 9 and Table A 10 in the appendix).

Table 21: Spearman-rank-correlation of vegetation parameters as related to distance

Parameter	Mutompo		Okamboro	
	R; significance		R; significance	
Grass biomass DS 2002		ns	0.450	***
Grass biomass WS 2002/3	0.342	*	0.387	***
Ground cover DS 2002		ns	0.629	***
Ground cover WS 2002/3	0.407	**		ns
No. of grass species DS 2002	0.532	***		ns
No. of grass species WS 2002/3	0.436	***		ns
Shannon Index (H) WS 2002/3	0.433	***	0.393	***
Crude protein (%) DS 2002		ns	–0.728	*
Crude protein (%) WS 2002/3	–0,461	**	no data	
Crude fibre (%) WS 2002/3	0.491	***	no data	
Ash (%) DS 2002		ns	–0.699	*
Ash (%) WS 2002/3	–0.537	***	no data	
Browse leaf biomass	–0.501	***	0.369	***
Density of trees and bushes	–0.514	***	0.257	*
Leaf volume	–0.238	*		ns

Significance level: *** = p ≤ 0.001; ** = p ≤ 0.01; * = p ≤ 0.05; ns – not significant = p> 0.05. Detailed data see Table A 14 in the appendix. Marked grey cells correspond with the significant results from ANOVA or the Median test.

The trends largely reflect the results visualised by the box-and-whisker-plots, whereas the convex curves result in a positive correlation, and the concave curves end with a negative correlation for both, the grass and browse parameters. This occurs, due to the similarity in a linear relation at the beginning of the curves, and because the curves of the different parameters are often flat and do not describe a clear concave or convex form. Additionally, the amount of sampling points in further-off distances gets less and less and does not contribute much to the effect, which is caused by the radiating sampling design along the five transects (see Figure 10, p. 44). Some exceptions are the number of grass species and the metabolisable energy (ME), both in the DS in Okamboro. In addition, in Mutompo, the Evenness index of the grass in the WS, as well as the metabolisable energy I (ME I) for both seasons are missing in the list of the significant correlations (Table 21), but resulted in significant effects in the previous spatial analyses Table A 8, Table A 9 and Table A 10 in the appendix). The total leaf BM in both communities also shows no significant correlation with distance, though the ANOVA resulted in weak significance in Mutompo, and in distinct significance in Okamboro (see Table 20, p. 89). It is also noticeable, that only for some parameters with high r-values (>0.5), such as the ground cover and the crude protein content in the DS in Okamboro, and the ash content during the WS in Mutompo (Table 21), no significant results of ANOVA or the median-tests could be detected (see white cells in contrast to the marked grey cells within the Table 21). The explanations for the differences within the results of correlations and the ANOVA or Median test could be, firstly the different statistical approaches, and secondly the sampling size, which is partly too small to deliver clear and certain results from the different ANOVA types. For instance, the ME content of the grass samples in Okamboro in the DS shows a an increasing linear line (Figure 24, p. 48), but reflects only eleven sampling points.

Correlations of grass parameters with tree and bush parameters (Table 21) point out negative relations in Mutompo, due to competition. Positive relations in Okamboro point out the encouragement between grass resources and the tree and bush vegetation. In Mutompo, all significant correlations were negative, showing a weak or distinct significant relation and with this, a competition between the listed grass parameters and the density of trees and bushes, as well as a high significance in the correlation with the browsing resources in both DS and WS. Trees and bushes inhibit the full growth of grass in their competition for mainly light and soil humidity. Competition for soil nutrients could also be a reason, but this phenomenon occurs more likely between plants of same size or similar root systems. The number of grass species during both seasons in Mutompo, was strongly influenced negatively by the browse leaf biomass, as well as by some other tree and bush parameters, but these correlations were just distinctly ($p \leq 0.01$) or weakly ($p \leq 0.05$) significant. The grass biodiversity index H correlates slightly negatively with the bush and tree density and the browse leaf biomass around Mutompo.

In contrast to Mutompo, in Okamboro all significant correlations are positive. The listed browse parameters of Okamboro in Table 22 have a positive effect on the grass biomass, the ground cover as well as the number of grass species, all in the DS. These results indicate the protection of the grazing resources by trees and bushes against the feeding of livestock. Seeds and seed banks under trees and bushes are also prevented from desiccation, after germination or washouts from strong rainfalls. Additionally, the more humid microclimate under the canopies of bushes, improves the formation of seedlings. Results of the correlations (Table 21 and Table 22) support and partly explain the results and curve forms of the spatial analysis, presented in the previous subchapters of chapter 4, for both communities, and also for the grass and browse parameters.

Table 22: Spearman-rank-correlations of grass parameters with tree and bush parameters

	n	Leaf biomass per ha	Browse leaf biomass per ha	Height of trees and bushes	Crown diameter	Density of trees and bushes	Leaf volume
Mutompo							
Grass biomass WS 2002/3	44	ns	-.408**	ns	ns	-*.352	ns
Ground cover DS 2002	42	ns	-.329*		ns	ns	ns
No. of grass species DS 2002	30	-.527**	-.611***	-.417*	-.396*	-.515**	-.526**
No. of grass species WS 2002/3	45	-.346*	-.423***	-.300*	ns	-.334*	-.331*
Shannon index (H) WS 2002/3	44	ns	-.332*	ns	ns	-.300*	ns
Okamboro							
Grass biomass DS 2002	77	ns	.342**	ns	ns	.358***	ns
Ground cover DS 2002	52	.301*	.460**	ns	ns	.315*	.294*
No. of grass species DS 2002	49	.370**	.458**	ns	ns	ns	.372**

Significance level: *** = p ≤ 0.001; ** = p ≤ 0.01; * = p ≤ 0.05; ns – not significant = p > 0.05.

In Mutompo, inter- and intraspecies competition seems to be of more importance than grazing pressure, whereas in Okamboro, the grazing pressure is higher. Due to the steep slopes, together with the trampling of cattle, the area of Okamboro is highly prone to run-off and soil erosion is visible in some places. Bushes and trees, especially the high percentage of thorny and defensive low-growing *Acacia*-species, serve as a protection from cattle grazing and a support of the grass biomass, and simultaneously, the developing of seed banks underneath bush canopies. In a study by Dougill & Trodd (1999) in Botswana, these results were also found, as remaining grass biomass was concentrated underneath the protected sub-bush-canopy niche of low growing dense bushes (e.g. *Acacia ataxacantha* and *Grewia flava*). At the bush encroached sites, sub-bush-canopy niches support significantly higher grass biomass (Dougill & Trodd, 1999). Even though some grass species have become rare, seed banks are still available and can germinate and grow in good rainfall years, in order to preserve biodiversity.

5 Livestock husbandry and forage utilization

5.1 SPECIFIC OBJECTIVES AND WORKING HYPOTHESES

Risk minimising through herd maximising, i.e. not selling livestock but keeping it, seems to be a traditional habit of pastoralists, which still dominates the livelihood strategies of rural livestock farmers in communal areas. This could lead to overstocking of the communal grazing areas, when compared with the recommend or modelled carrying or grazing capacity. Communal livestock keeping differs from commercial livestock farming in Namibia. To mention some differences: no fences restrict the movements of free roaming livestock, and the herds are composed of mixed species with different feeding preferences. The spatial heterogeneity of the quality of natural forages within the communal grazing areas, as well as the seasonal decline of vegetation quality could make carrying capacity calculations for an entire communal grazing area unrealistic, if they are not adapted to this special situation. Spatial and seasonal aspects, as well as the feeding behaviour of free-roaming mixed herds are not considered at all in the vegetation-oriented carrying capacity calculations, and hardly in most of the animal-oriented approaches.

The following working hypotheses are put forward:

1) **Stocking densities in available communal grazing areas exceed carrying capacity, and livestock suffer from protein and energy deficit in the dry season at Mutompo and Okamboro.**
2) **Communal livestock farmers of Namibia today prefer minimizing risks by maximising herd sizes, rather than adjusting animal numbers to existing or expected feed resources.**

Therefore, in this study a nutrient balance approach is applied, which integrates most of these aspects. Based on this modified carrying capacity values, the question, whether the grazing areas of the two investigated communities were overstocked or not, is to be answered, whilst considering the mixed livestock herds, the seasonal variability of the quality of the natural forage resources, as well as the spatial heterogeneity of the communal grazing areas. The measured seasonal rangeland data evaluated in chapter 4, are used for the calculation of the nutrient supply from natural rangeland in chapter 5. Some socio-economic aspects have been integrated within this study, in order to widen the purely natural science-based evaluation of rangeland resources towards a multidisciplinary approach. The questions arise, as to what or who exactly causes most pressure on the range resources in communal areas? What role does the livestock play for the farmers living in communal areas?

Within chapter 5, the herd structure on a community level, the ownership of livestock on a household level, as well as the sources of income of communal farmers in today's Namibia were analysed. The productivity of livestock as well as the determinants of farmers' preferences of grazing areas was investigated. Since due to climatic and experimental conditions during transect analysis the primary productivity was insufficiently estimated (chapter 4), a modelling approach of stocking rates was applied. This models use either the measured seasonal rainfall amounts or rainfall values cited from literature. The detected results of the models were compared with the recent stocking densities found in the communities. The nutrient balance of current livestock numbers was estimated from the results of the rangeland evaluation (see chapter 4) in order to find possible limitation factors during wet or dry seasons. In addition, the potential stocking numbers of the grazer and browser in communal grazing areas were calculated from the amounts of grazing and browsing resources during both seasons.

5.2 MATERIAL AND METHODS

5.2.1 Collection and analysis of socio-economic household data

Field periods in Namibia lasted from June 2001 to February 2002; from August to December 2002; and from March to June 2003. The last journey in August/September 2003 was used to present and discuss first results within the communities, accompanied by scientists and experts of Namibia. The first step in the beginning of the initial field periods was, to establish a good and trustful relationship between the German researcher and the people of the communities, as well as to other stakeholders. One task in the beginning was to inform people about the BIOTA project and the targets, as well as the planned work in detail. The number and locations of the households in the communities were identified and a socio-economic survey of all 14 households in Mutompo, and all 29 households in Okamboro was conducted, through which useful information on livestock and livestock husbandry was gathered (see Qu 2: Basic households questionnaire in the appendix). All households of the communities were included in the survey, because no lists of farmers or other information on the communities were available. The interviews took place at the homesteads. Heads of households were the preferred respondents. The interviews were conducted with local people as interpreters, preferably from outside the community, in order to avoid bias.

The followed information was gathered on household levels:

- The number of livestock species within the community and on a household level,
- the herd structure,

- the inputs, such as supplement feeding, minerals, or medicine for livestock,
- the sources of income on a household level and their level of importance
- the number of animals sold, slaughtered, or lost, and reasons for losses.

The livestock management, such as herding, daily watering or splitting of herds by livestock species or age classes, were analysed through a combination of semi-structure questionnaires (see Qu 2, module 3) of all livestock keeping households in the communities, supplemented by own observations. In northern Namibia, farmers grow millet, sorghum, maize and several other crops (surveyed with the questionnaire Qu 2, module 4 in the appendix). The sizes of cropping fields were measured with a GPS-system, and were entered in a GIS-based map.

Data entry and graphical design was done in Microsoft ® Excel and Microsoft ® Access. Calculations and statistical analyses were performed with both Microsoft ® Excel and the software package SPSS (Version 11.5 and 15.0), selecting mainly the procedures PROC FREC, PROC DESCRIPTIVE, PROC NPAR CORR, and PROC REGRESSION.

5.2.2 Livestock production parameters

The evaluation of productive performance of livestock in communal areas was a challenge, because there were very few documentations, in form of stock cards or vaccination reports from the governmental veterinarian office, not to mention records on body weight gains or data about ages of first calving, calving intervals etc. No data of productivity was available for the two investigated communal areas, therefore the progeny-history-technique (PHT) were applied. Only the numbers of livestock species were recorded by the Namibian veterinarian offices, during the yearly vaccination campaign in the Kavango region, and in the Ovitoto-reserve.

The progeny-history-technique (PHT, also referred to as “age history”; described in Kaufmann, 1998 and Hassan, 2000, analyses the livestock performance, based solely on the memory of the livestock farmers or employed herders and workers, who take care of the livestock. Semi-structured interviews on household levels, with key persons and stakeholders were carried out in both communities in Namibia in order to analyse the production systems and the rangeland and livestock management (see Qu 3: Progeny History Questionnaire in the appendix). Daniela Werner conducted structured PHT-interviews for goats in 2001 (n = 3 households in Mutompo, n = 3 households in Okamboro), and Frizzi Lange carried out the PHT-interviews for cattle in 2003 (n = 4 households in Mutompo, n = 9 households in Okamboro) (see Table 23, PHT-questionnaire for cattle see Qu 3 in the appendix).

The PHT-method is based on the lifetime histories of single individual breeding females, recorded as recalled by the owners' or herders' memories. Information was received from people, who were supposed to have a good knowledge concerning the animals. From this individual history of breeding females and their offspring, the average age of reproductive cows, the calving rates, the age of first calving and the calving intervals, as well as the off-take could be calculated. For goats, the age of reproductive does, the age of first parturition, the number of kids per doe, and the litter size, as well as the kid off-take rate was calculated. During data collection, every herd or flock was visited only once, either early in the morning or before darkness, when the animals stood in the kraals. Households for a PHT-interview were selected by the criteria, having a sufficient number of animals within the herd or flock, and that a person be willing to give answers was available, who knows the animals and their age history very well. It was attempted to collect data on approximately 20% of all producing breeding females of the herd or flock of a household. For herds that consisted of less than 10, all of the females were evaluated. Always, at least three breeding females of a herd or flock were assessed.

Table 23: Number of PHT-interviews and of weighed cattle and goats,

	Mutompo (Kavango)	Okamboro (Ovitoto)
No. of PHT-interviewed household for cattle	4	9
Cows evaluated	24 (52% of total females)	57 (12% of total females)
Progeny history calves evaluated	55	169
No. of weighed cattle	38	42
No. of PHT-interviewed households for goats	3	6
Progeny history does evaluated	14 (20% of total females)	48 (10% of total females)
Kids evaluated	54	134
No. of weighed goats	41	168

Source: F. Lange and D. Werner, unpublished data

For cattle, the age at first calving (AFC) was calculated as the time span between the date of birth (DoB) and the date of first parturition (DoP), for breeding females which were born within the assessed herd. For heifers, which were acquired externally, the age at first calving was calculated as the age at herd entry, plus the time span between herd entry and first parturition. Those with unknown ages at herd entry and other acquired adult breeding females (with former parturition) were not considered in this calculation.

Age at first calving (AFC, in months) = DoP- DoB + AHE (in month)

Given AFC = Age at first calving; DoB = Date of birth/herd entry; DoP = Date of first parturition; and AHE = Age at herd entry (AHE = 0 for breeding females born in the herd). The calving interval (CI) was calculated as the time span elapsed between two subsequent parturitions:

Calving interval CI_n (in months) = DP_{n+1}- DP_n,

Given CI_n = n^{th} Calving interval, and DP_n = Date of n^{th} parturition (with n = 1 to 10).

For goats, the parturition interval in months was calculated as the difference between the dates of subsequent births, as assessed by the respondents. In most cases, the answers given for the date of subsequent births related to years. The litter sizes of goats refered to the number of kids born per doe and per parturition. The kid off-take rate was calculated as the share of goat kids sold and slaughtered on the total number of kids born per herd within the investigated period.

Livestock numbers and measured body weights of livestock, weighed on an electronic scale, were used to calculate stocking densities on the available grazing areas. For all investigated animals, the body condition scores were visually estimated, ranging from 1 to 5, whereas 1 = very thin, 2 = thin, 3 = normal, 4 = fat, and 5 = very fat.

In order to understand the determinants of livestock keeping, the household data and the socio-economic dataset had to be analysed mutually and linked with the collected livestock data. Integrated into the semi-structured interviews concerning livestock on household levels, farmers were asked about their specific investments. Five different kinds of input or investments were interrogated (input concerning supplement feeding, veterinarian products, salt licks, labor for herding, or any other input). The ownership of livestock, within three wealth-groups, which are determined according to the assets of the household (livestock, means of transport, TV, radio), plus their economic activities (wage labourers, pension receivers, livestock keepers etc.) was analysed in both communities.

5.2.3 Modelled stocking rates and current stocking densties

First trials to predict the primary productivity of rangelands were expressed as the biomass of standing crop, available for forage at the end of the growing season, with linear regression models, using the annual or seasonal rainfall amounts. The rainfall models, developed by Walter (1939, in Rutherford, 1980) for Namibia were mentioned in Ward & Ngairorue (2000), who also applied a rainfall model based on vegetation biomass productivity in Namibia (all models see Table 35. p. 144). Different values from models applied in southern Africa are shown in Table 35, which are based on the following model:

Biomass production (kg ha^{-1} $year^{-1}$) = a + b * mean rainfall

with mean rainfall = mean annual rainfall in mm/year, a = constant, b = RUE (regression-coefficient).

Of course rainfall efficiency is affected by different factors, as mentioned already in chapter 2.2, p. 10 ff., but for an approximation of livestock stocking rates such models are helpful. The theoretical minimum and maximum stocking rates, based on the rainfall models used in this study, were calculated with a carrying capacity model, assuming a dry matter intake of 2.5% of the live weight of livestock, a proper use factor (PU) of 50% of the grazing resources, and Kempf's 'presumed values' for rainfall (PV, see Table 34, p. 142), for a period of 12 months. A model developed by Sweet (1998a), produced separate estimates of the capacity for commercial and subsistence livestock production, with the latter allowing a higher percentage of utilisation (equivalent to the proper use factor PU) of forage biomass (50% commercial; 70% communal). For a calculation of dry matter intake, a value of 2.5% is used also by Sweet (1998a) in communal areas, and 3 kg DM ha^{-1} $mm^{-1}year^{-1}$ as the rain use efficiency (RUE), which has been found reasonable for well-managed arid and semi-arid rangelands. It would be preferable to develop regionally adapted relationships among different soil and vegetation types, but this has seemed not to be practical. Therefore, Sweet (1998a) applied in his model different correction factors for physiographic or agro-ecological units (e.g. slopes, soil types, and vegetation type), and for different local site conditions (soil texture, bush density and range condition) within the individual grazing areas (Table 24).

Table 24: Correction factors of Sweet's carrying capacity model

Constraints	Correction factor
Slope 15- 30 %	0.15
Slope >30%	0.3
Moderately stony, sandy or erodible soils	0.15
Very stony, sandy or erodible soils	0.3
Moderately dense bush (30 - 40 % canopy)	0.3
Dense bush (40 - 60 % canopy)	0.5
Range condition poor	0.3
Range condition very poor	0.6

Equation: adjusted CC = rainfall CC x (1 + sum of correction factors); by Sweet, 1998a.

For Mutompo, a correction factor of 0.3 was used for Sweets model, due to the very sandy soil condition. The correction factor for Okamboro was 0.6, because of the combination of moderate slopes with a moderately stony area, as well as the poor range conditions in general (see Table A 15 in the appendix).

5.2.4 Contrasting livestock feed requirements and forage availability

The aim of the nutrient balance calculation was to find out whether communal grazing areas were over- or under-stocked, and in case they were overstocked, to establish as to which extent and during which time of the year this occurs. Additionally, the potential of the development of stocking rates could be estimated.

- Did the estimated forage meet the nutritional requirements of livestock in communal areas within the timeframes of DS and post-WS periods?
- What exactly were the differences between the communities and between dry season (DS) and wet season (WS) for grazers and browsers, respectively?
- What were the major limitations and deficits: biomass, energy or protein content of the vegetation, respectively in which period and for what forage type/s?

Appropriate stocking rates or grazing capacity are usually calculated for livestock grazing during the peak of forage production, after the rainy season and after the end of the vegetative growing season, where the standing crop is utilised. A modified equation, comparable to a formula adapted from Thalen (1979) and FAO (1991) for grazing capacity was applied (see also de Leeuw & Tothill, 1993).

Grazing capacity (G) = weight of standing crop (SC) / animal requirement (R) multiplied by the lowest of the following: the proper use factor (p) or the percentage of utilization (PU):

Grazing capacity $$G = \frac{SC * p}{R} \quad \text{or} \quad G = \frac{SC * PU}{R}$$

G is the grazing capacity in kg live body weight per hectare, either for the end of the growing season or for the non-growing season;

SC is the weight of standing crop dry matter (DM) per hectare, either at the end of the growing season, or non-growing season, in kg DM ha-1;

R is the animal requirement of DM per LSU or per kg live body weight (BW), either during the growing season or during the non-growing season (kg DM LSU^{-1}, or kg DM kg^{-1} BW of livestock);

p is the proper use factor, which indicates the maximum proportion of forage that may be grazed without causing rangeland deterioration through erosion, nutrient depletion, physical soil degradation or a change in vegetation;

PU percentages of utilization of pasture resources.

For an estimation of the real carrying capacity (or the short-term forage balance), the formula needs a forage production figure to calculate the forage balance dry matter production with the animal dry matter requirements. Browse is ideally included in the standing crop resources to calculate the carrying capacity and to obtain a grazing and browsing capacity; yet this is not often the case.

The percentages of utilization of pasture resources (PU) and the proper use factor (P), (or the so-called 'total permissible off-take' in Schwartz & Walsh (1991), is a combination of the proper use factor and a forage loss factor[22]), vary with and depend on the vegetation type and status of rangeland. It also differs with livestock species and climate zones, as well as biomass availability, palatability and digestibility, and fibre content could also play a role. Values from 20% up to 50% for grazing resources, and from 10 to 30% or more for browsing resources have been described in literature (e.g. Schwartz & Walsh, 1991) for similar climate zones such as arid and semi-arid zones in Namibia. An adapted scheme according to (Ma, 1996), for the 'degradation' degree and a recommended proper use factor (p) were applied. In Ma's study (1996), in the investigated province in China, the proper use factor lay between 12.2% and maximal 34%. Highland savanna had a proper use value of 22.5%, similar to the mountain areas. Differences between the areas and transects were found in Namibia, especially in Okamboro, so this required a separation of or into the individual areas. According to Ma (1996), the degree of 'degradation' determines p for grasses and herbs, which is always below 50%:

Not 'degraded' (ND)	=	50%
Slightly 'degraded' (LD)	=	40%
Medium 'degraded' (MD)	=	20%
Heavily 'degraded' (HD)	=	5%

In this study, the availability of grazing resources in the community was used as an indicator for the degree of deterioration. Sector areas of the regions of the transect sampling (described in chapter 4.2.1 and 4.2.2, p. 45 and p. 52), according to distance classes were classified as follows:

Mutompo

0-1 km-distance class – LD →	0.4 * 6.25% of the area = 2.5
1-2 km-distance class – ND →	0.5 * 18.76% of the area = 9.38
2-3 km-distance class – ND →	0.5 * 31.23% of the area= 15.61
3-4 km-distance class and further – LD	0.4 * 43.76% of the area = 17.50
	Sum = 44.99%

The proper use factor (p) for grasses and herbs of 45% was used for the calculation of the nutrient balances for Mutompo.

Okamboro

0-1 km-distance class – HD →	0.05 * 6.25% of the area = 0.3125
1-2 km-distance class – LD→	0.4 * 18.76% of the area = 7.48
2-3 km-distance class – LD →	0.4 * 31.23% of the area = 12.492
3-4 km-distance class and further – MD	0.2 * 43.76% of the area = 8.752
	Sum = 29.03%

[22] The forage loss factor is the proportion of the forage lost through trampling, fouling by excreta, decomposition or feed by termites, small mammals or other wild animals.

The p for grasses and herbs of 30% was used for the calculation of the nutrient balances for Okamboro.

For the total browsing resources of shrubs, a 'permissible off-take' or proper use factor of 50% for Mutompo, and 30% for Okamboro was used, as adapted from Schwartz & Walsh (1991), differentiated for the individual rainfall amounts of the two communities. The values of the permissible off-take of 30% for the shrub layer by Schwartz & Walsh were used at a median rainfall 200 – 300 mm, up to 50% for the shrub layer at median rainfall of 500 mm or higher. The 'permissible off-take' or proper use factor of the shrublayer were applied on the BecVol-calculated browsing resources up to a height of 1.5 m (chapter 4, and Table A 23, p. 250 in the appendix).

The nutritional requirement of livestock for dry matter, energy and protein was calculated using literature values for maintenance levels (Table 25), from datasets of the livestock census, gathered in semi-structured interviews on household levels, as well as the means of measured bodyweights of different species and physiological classes of livestock (see Table A 16 in the appendix). For a simplification in estimates of requirements of livestock, the maintenance levels were used.

Table 25: Daily energy and protein requirements of different livestock species

	Energy requirement (kJ/kg $BW^{0.75}$ *day)	Protein requirement (g total protein /kg $BW^{0.75}$*day)
Cattle	494	4.09
Goats	424	4.15
Sheep	389	4.74
Horses/donkeys	481	4.09

Based on NRC (1987), and Glatzle (1990), on maintenance level.

For covering activity and performance related requirement the values will have to be increased appropriately. Energy demands vary with the body functions which use up energy. The animals have to walk to water and grazing areas, which increases their energy expenditures above basal rates by 30 to 70% (Young and Corbett (1972); Lewis (1975); both in King, 1983). The needs to walk while grazing and trekking to water - called 'foraging'- is roughly calculated in this study with an addition of 50% to the total energy requirement for each livestock species, separately (see Table A 19 in the appendix). Requirements for the growth of calves, kid-goats and lambs, lactation, as well as pregnancy and draught of current livestock numbers were not included in these calculations.

The intake rates of livestock lie between 2.5% and 3% of their BW, but there were also mentioned dry-matter intake rates (DMI) of 3.8% of BW for lactating ewes in South Africa

(Palmer, 1999). A value for the intake rate of 2.7% or 3% of the live weight of livestock could be assigned to carrying capacity estimates in commercial areas, particularly in those areas, where exotic (*Bos taurus* type, e.g. Holstein-Friesian, Herford or Simmentaler), rather than indigenous cattle (e.g. Sanga-Nguni-type, Afrikaner type cattle) are kept (Sweet,1998a). However, Diarra et al. (1995), and Baars (2002) stated in their findings that the DMI of the TLU[23] is only 2.0 % in dry season. This occurs in situations, when the concentration of digestible nutrients is inadequate. Hence, the intake rate for the calculations of this study was assumed 2.5% of live weight for all kinds of livestock, because in the wet season, the value can be higher, but in dry season, when the grasses have a high crude fibre content, and low protein content, intake rate can be lower. Based on the live-weight of livestock, the daily DMI of 2.5% was applied according to empirical studies (see Table A 17 in the appendix).

The herd composition strongly affects the resource utilization, as cattle, sheep, and goats have different feeding behaviours. The diet of goats is dominated by browsing (Botha (1981) in Brand, 2000). They consume under semi-arid to arid conditions about 60% of their daily rations from trees and bushes, and about 40% from grasses and herbs (Botha (1981) in Brand, 2000; Oba et al, 2000), appreciation the whole year. Under the same grazing conditions, cattle and sheep are 50-90% grazers, and browse to a much smaller extent (Botha (1981) in Brand, 2000; Oba et al, 2000). Hence, regarding the semi-arid condition of Namibia, cattle behave to 80% as grazers and to 20% as browsers, goats browse to 70% and graze to 30%, and sheep are classified the same such as cattle., appreciating both, the WS and the DS. Cattle were observed frequently to feed on buhes and on litter, especially during the DS, both in Mutompo and in Okamboro. Horses and donkeys are mainly grazers, and are considered as grazers to 100%. The bodyweight of the different species were separated according to their feeding behaviour, in order to calculate the DMI for grazers and browsers (see Table A 16 and Tabel A 17 in the appendix).

The total available grazing area (estimated on maps and satellite images), covered an area of about 3,848 ha in Mutompo and 5,808 ha in Okamboro. The definite numbers for the total sizes of areas used for the calculations resulted from the calculation based on a radius of the total area of 3,500 m in Mutompo and 4,300 m in Okamboro. The design of the transect based rangeland assessment is illustrated in Figure 10 (p. 44) and described in the subchapter 4.2.1 (p. 44). Each two of the five transects demarcate an area, which is illustrated as a cycle sector, in order to represent the area between the transects. The cycle sector areas were calculated using the circular area formula ($A = r^2 * pi$; r = radius),

[23] TLU= Tropical Livestock Unit = 250kg body weight, see Jahnke (1982).

whereas the inner cycles were subtracted in each case, except for the most inner cycle (see Table A 20 in the appendix). From the quantity and quality of the vegetation sampling points, which represent the particular transect cycle sector, the total available biomasses (BM), crude protein content (CP), as well as the amounts of metabolisable energy (ME) were calculated for both communities. The forage values were extrapolated on a hectare basis, considering the sizes of the transect cycle sector areas, for the entire communal grazing areas (see Table A 21 and Table A 22 in the appendix). In order to find values for herb amounts, which are underrepresented in this study, a share of herbs was added in relation to the grass biomass during the month of measurements, based on Knemeyer (1985) for Namibia. The WS-values for herbs were supposed to make up the maximum standing biomass, considered seasonal, and were therefore corrected for further calculation of the grazing capacity. Herbs were calculated as 19.6% for the October 2002 grass BM-values (rest of the DS), and 18.6% for the May 2003 grass BM-values (post WS-period), added to the measured grass BM in both seasons.

Moreover, during the time of growth after rainfall, insects and small mammals, as well as wildlife and domestic stock had consumed parts of the resources, a decomposition and desiccation process of plant material continued perpetually. Therefore, the values of grass biomass measured during DS (October) marked only 32% of the level of the peak after WS during the seasonal changes; measurements in May depict approximately 82% of the maximum according to Knemeyer (1985). The values measured along the transects describe the amount and related quality of those grazing and browsing resources sufficient for a period of 3 months during DS, and 8 months after WS, as long as the following rainy season leads to growth of new fresh green biomass. This can be explained when regarding the sampling design; measurement of grass biomass along transects from October 2002 were assumed to be representative for the DS 2002 and were considered to be likewise during the remaining amount of the WS 2001/02. This natural forage had to supply the livestock for a period of about three months until the next sufficient rainfall, when plant material grew as new fresh green forage material. Measurements after May 2003 did not represent the maximum biomass productivity after rainy season. It was assumed to represent the conditions one or two months after the peak, so in most parts of Mutompo the grasses were already dry. Therefore, the biomass with the quality of May 2003 were used to represent the whole time after the rainy season, when its quality normally declines (see Knemeyer, 1985) due to decomposition processes as well as by trampling and feeding of livestock and game animals. The amount of vegetation found after the rainy season had to meet the requirements of current livestock for a period of about 8 months, until the next rainy season’s rainfall induced the growth of fresh and green new grasses and herbs.

The daily requirement of current livestock densities were calculated for a 3-month-period in dry season (DS) and for an 8-month-period in the rainy or wet season (WS) following the October 2002 and May 2003 sampling (see Table A 18, and Table A 19 in the appendix). The livestock requirement results were used, to compare the total forage availability for the whole communal grazing area between each of the two communities for the mentioned definite periods. The possible stocking rate (kg ha^{-1}) of a theoretical mixed livestock herd was calculated and separated into requirements of biomass (BM), crude protein (CP) and metabolisable energy (ME) (see Table A 23). Comparing the calculated available grass biomass, the protein and the ME supply with the requirements of current livestock numbers, a potential in production or the deficit of forage during a special time of the year could be detected. The maximum of stocking rates is determined by one limitation factor, such as the amount of BM, the energy or the protein content, and phosphorus (P) and calcium (Ca) as two of the essential macro-elements (Liebig-law), despite the amount of other available factors.

The given empirical studies were applied, to calculate the total P and Ca requirements of the total live BW of the current communal livestock (see Table 26). Based on the estimations on the total available vegetation biomass (grass and browse biomass), acquired from rangeland assessments for the entire area of the two investigated communities, as well as the analysed Ca or P-contents, the theoretical availability of these two “mineral-for-current-livestock” numbers were calculated for the dry as well as the wet season periods. The same proper use factors (p) like for grazing and browsing resources were used for the calculation of the potential stocking rate based on macro-elements.

Table 26: P and Ca requirements of livestock

Maintenance requirement level	Cattle	Goats^{+}	Sheep
Estimated mean bodyweight (kg)	250	30	60
P (g day^{-1})	6.0	2.1	2.4
Ca (g day^{-1})	8.0	3.0	2.5

$^{+}$ Maintenance level for goats plus medium activity in semi-arid rangelands, slightly hilly pasture, and early pregnancy. Source: Ffoulkes (1998), based on a dry cow and moderate level of productivity, and NRC (1981), seventh revised edition, update 2000; (NRC, 1996; Kott, 2004).

As grazing exclosures, 12 fence-*covered* cages of one cubic-meter size, covering an area of one square meter, were installed in the area of Okamboro in central Namibia, in order to estimate the primary productivity of natural pasture without grazing, trampling or other disturbances by livestock or wildlife, except insects, such as termites or small mammals. Initially, 12 cages - each of one cubic meter volume - were placed along some transects near the km points. Cages were made from a steel frame covered with a wire-mesh fence, so that goats could not climb in. Additionally, the cages were fixed with metal tacks into the soil, in order to prevent them to be moved. Biomass of grass and herbs and the number of species were measured inside and outside of the cages in the second half of May 2003 and were compared after a growing period of eight months. The effects of the absence of grazing (e.g. no defoliation and no trampling) on the grass standing biomass and the number of grass species on the square meter were statistically tested.

5.2.5 Farmers' preferences for grazing areas

In order to gather reasons for the preferences of livestock farmers in the utilization of distinguished grazing regions within the communities, household heads were asked to rate their preferences for these grazing areas by means of a further questionnaire (questions see the following paragraph), in both seasons for Mutompo, and on a scale (between -2 = do not like it at all; and 2 = like it very much). The main grazing areas within the communities were identified by the local farmers and mapped as well as visualised on community maps (see Map 7 and Map 8, p. 161 and p. 162). This interviews and data collection about preferences of communal farmers was carried out by Falk (2007) in 2003, and the survey originally included 10 variables in total. In Mutompo 8 households were included in this farmers' preference analysis, in Okamboro 15 households. Five variables of this survey, which are related to livestock and the utilization of rangeland resources, were selected for this analysis and were used as well for comparisons with results of the rangeland assessment:

1) **General preference for the different grazing areas** – How much do you prefer to keep your livestock in these areas during this season? (Scale ranging from -2 = *do not like it at all* to 2 = *like it very much*)
2) **Pasture quality** – How good or bad is the quality of the pasture in this area during this season? (Scale ranging from -2 = *very bad* to *2 = very good*);
3) **Distance from the community** – How far are the grazing areas from your house? (Scale ranging from -2 = *very far* to *2 = very close*);
4) **Water supply** – How much water can be found in these areas, during this season? (Scale ranging from -2 = *very little water* to *2 = very much water*); and
5) **Risk and security related –** Do you see any dangers or risks (e.g. thieves, carnivores) in these areas during this season? (Scale ranging from -2 = high risk to 2 = no risk).

Rankings were visualised in bar charts for the different areas, for the different seasons in Mutompo, and without seasonal differentiation in Okamboro, where a protection of growing crops in the WS by a seasonal change of grazing areas is not necessary.

5.3 RESULTS AND DISCUSSION

5.3.1 Livestock husbandry and their performance

The distribution of livestock within the communities was analysed on household level (Table 27). The total livestock numbers of the different species per community is listed in Table 7 (p. 31). Mean livestock numbers of the different species kept by the respective households of the investigated communities have to be examined. Moreover, the question also arises, whether the households in rural areas own an appropriate number of livestock in order to make a living.

The average herd size in Mutompo was 17 cattle, whereas the largest of the evaluated herds consisted of a total number of 65 cattle, and the smallest of two. The mean number of goats per household was 16, with a range between 6 to 66 animals. Sheep and donkeys do not play a role in Mutompo. Two of total 14 households in Mutompo did not own cattle, 43% of the households did not have goats, and only one household owned a flock of 12 sheep. Around 36% of the livestock-keeping households owned less than 25 animals in total. One household in Mutompo had the largest herd, comprising 104 animals, consisting of 65 cattle, 37 goats and the only 2 female donkeys. Six of the 14 investigated households (43% of all households) did not keep oxen. The average number of oxen for the livestock-keeping households was at 3.8, with numbers ranging between 2 and 16. One household kept one pair of oxen, two households kept two pairs; three households had three pairs and two households kept 15 and 16 oxen each.

In Okamboro, inhabited by Ovaherero, who are traditionally cattle farmers, 96 % of all households kept cattle, the average number of cattle per household laying at 36 animals, which is much higher than numbers in Mutompo. Nevertheless, in Okamboro, 46% of the animal-keeping households had an average of less than 20 cattle in their herds. The mean number of goats was also higher than that in Mutompo (24 goats per household). Around 46% of all households did not keep goats, and the size of goat flocks varying between 4 and 236 animals per household. Sheep seem to play a more important role in Okamboro, with an average of six sheep per household; however, 81% of all households did not own any sheep. The smallest sheep flock consisted of two animals, the largest of 74 animals.

Table 27: Mean numbers of animals per household and their values

	Mutompo (n = 14) Percentage or mean (SE)	Okamboro (n = 26) Percentage or mean (SE)
No. of livestock keeping households	12	25
Percentage of livestock keeping households	86	96
Total no. of livestock per livestock keeping household	33.7 (9.5)	66.9 (16.7)
No. of cattle per household	16.6 (5.4)	36.2 (10.3)
No. of goats per household	16.1 (5.6)	24.0 (9.6)
No. of sheep per household	0.9 (0.9)	6.0 (3.4)
No. of donkeys per household	0.1 (0.1)	0.5 (0.3)
No. of horses per household	0.0 (0.0)	0.2 (0.1)
Approximate market value of total livestock (NAD) [2]	443,588	1,498,558
Approx. market value of livestock per livestock keeping household (NAD)[1]	36,966	59,942

No. of animals always per livestock keeping household. [1]NAD (Namibian Dollar), 10 NAD ≈ € 1.

In Okamboro, the household owning the largest herd of animals had 304 animals' altogether, 38 of which were cattle, 236 were goats and 30 were sheep. This household, which used to run a small shop, left the area in 2002. The second biggest herd consisted of 207 animals, being comprised of 160 cattle, 42 goats, 4 sheep and 1 horse. About 48% of all animal-keeping households owned only cattle, whereas only two households of this group kept only goats.

A social stratification was found, where the better-off groups owned a high percentage of the livestock (Figure 33). In Mutompo, 86% of all households kept livestock, and Okamboro produced a value of 96% (Table 27). The ownership of livestock was analysed within three wealth-groups, which are determined according to the assets of the household (no. of livestock and their value, means of transport, TV or radio owndership etc.), plus the number of their economic activities. The best-off households (defined as the upper group of the calculated wealth points) owned 83% of all livestock in Mutompo, and 70% in Okamboro. These figures point at a relatively strong social stratification of households within each community.

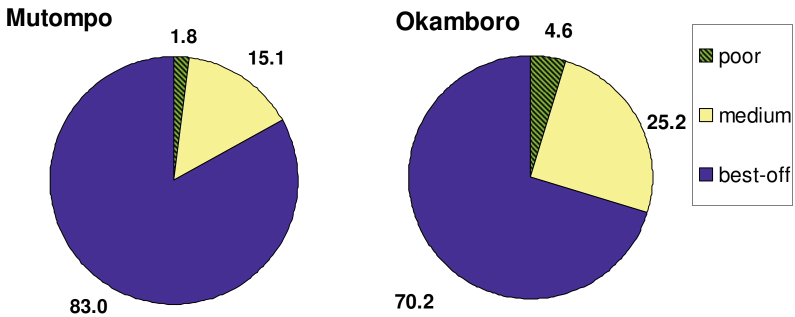


Figure 33: Percentage of livestock of households (in % of total LSU) of three wealth groups

In Mutompo, farmers mentioned only few investments in livestock. The governmental vaccination campaign (Foot-and-mouth-disease and lung sickness, the latter only in Mutompo) is free-of-charge for all farmers. Only 40% of the households invested in veterinarian products, and only one of 10 households offered salt licks to their livestock (Table 28). Often, there is no financial capital for buying means of additional input, and the transaction costs are usually too high, or farmers simply do not see any sense in doing so. In Okamboro, 56% of livestock farmers answered, they invested in supplement feeding, 60% bought veterinarian products and 84% of the livestock-keeping households bought salt stones used as lick (see Table 28). Additionally, investment in herding labour is an important issue in this community. These figures clearly underline the importance of livestock in the Ovaherero-community, but also point to the existence of more households with better financial endowments, who can evidently afford to invest in their livestock.

Table 28: Investment in livestock

	n	% of HHs invest in supplement feeding	% of HHs invest in veterinarian products	% of HHs invest in salt lick	% of HHs invest in herding labour	% of HHs invest in other input	Mean [%]
Mutompo	10	0	40	10	0	0[1]	10
Okamboro	25	56	60	84	36	0	47.2

HHs – households. [1] Hiring of ploughing services excluded.

The livestock data in Table 27 for Mutompo were confirmed mainly with the figures of the Kavango survey 1999, (see Jones.B.T.B. & Cownie, 2001). This report characterises the western inland area, as an area ranging far from the Okavango River, laying westerly of the B8 from Rundu to Mururani, and going into the direction of Grootfontein. Only the mean cattle number is reported for this region, 26 per household, which is much higher than that of Mutompo during the survey in 2001. Deniau et al. (1997) also found an unequal distribution of wealth, within three communities located in the North Central Region in Namibia; their districts bordering west of the Kavango area (see Map A 1 in the appendix). Here, 65% of the farmers owned cattle, (one household owned 29% or 270 animals of the herd), and goats were held by 73% of the household (also, one household owned 29% of the flock), whereas 8% of the households owned 30% of the goats. The results of a survey done by NOLIDEP 1996 in the Kavango region (in Hengua & Bovell, 1997) report that 71% of the households kept there own cattle, about 50% owned goats, 73% owned chicken and 5% held pigs. An earlier survey, conducted by the IFAD in 1992, (in Hengua & Bovell, 1997) indicates that only 34% of the households owned cattle and 23% owned goats. The average herd size per household, as conducted in different surveys in Kavango, ranged from 10 to 19 goats, and 17 to 26 cattle (Hengua & Bovell, 1997). A GTZ study (Bayer et al., 1991) mentions an average cattle herd size of between 20 and 25 animals for the Kavango region. Yaron et al. (1992) found a mean herd size of 25.6 per household, but a median of 13 points to a high number of households without any livestock. According to the IFAD survey (1992), the practice of caring for the livestock of other households is less common in Kavango, and is not found at all in Mutompo. Thus, the livestock within a kraal really belongs to the household it is associated with. According to Directorate of Veterinary Services (DVS, in Yaron et al., 1992) in Kavango, the required minimum herd size per household for sustainable commercial cattle farming is approximately 35, and it is expected to be even higher today. Less than 10% of communal farmers in Kavango met this criterion in the beginning of the 1990s. Moreover, 43 % of the households kept goats with an average herd size of 17. Only 6% of households owned donkeys, and 20% of the households kept pigs (Yaron et al., 1992). These days, only 24.4% of the households in Mutompo own 35 or more cattle.

In the Ovaherero-community of Okamboro, cattle are clearly the most common animals and livestock keeping is a central economic activity. In Adams et al. (1990), a commissioner in Okakarara (Hereroland West, interview carried out in November 1989) assumed, that a herd of less than 100 LSU (or cattle) was too little to provide an acceptable income; in his view, a herd of about 250 cattle would be sufficient. Bayer et al. (1991) mention that the various approximations of the minimum required number of animals needed for a secure income, also indicate differences in cultural values and the desired standards of living. They found, for instance, that a Himba-family of five people could apparently subsist with as few as 20 head of cattle, whereas for Ovaherero farmers, the minimum unit required for a family of similar size, is around 100 cattle. Moreover, among commercial farmers, the minimum viable herd size seems to be 500 beef-cattle (Bayer et al., 1991). In the Ovaherero-community of Okamboro, only four of 26 households had over 100 cattle in their herds, meaning that most of the households would have difficulties in securing their subsistence from livestock alone. In fact, according to Kruger (2001), it becomes more and more difficult for farmers in the communal areas of Namibia to sustain a descent standard of living on incomes derived only from animal production. Moreover, consistent with communal farmers in the southern, eastern and northern SARDEP programme areas, a household currently needs at least 150 pieces of small stock or 50 pieces of large stock in order to meet the basic needs of an average household size (Kruger, 2001).

In a community with a non-homogenous group, wealth in one species seems to be linked to wealth in the others: those farmers with a large herd of cattle are usually also the farmers with the large flocks of goats or sheep. Social stratification is explained in Bayer et al. (1991), for the Kavango region, including a shift from a household structure of typically three generations, which pools labour and income, distributing expenses according to needs, towards the formation of a nuclear family. In the past, the network of obligations of a three-generation-household extended to family clans, thus generating a relatively strong social security system, important especially for any disadvantaged members. Over the past decades or so, there has been a continuous shift towards the formation of nuclear families, with a related decrease of inter-family obligations. This is stated to be the most important cause of differentiation between better-off and poor households. Households, which are able to provide the necessary labour forces and business-related skills, can flourish whilst others fail as productive units and become poor.

The numbert of females in the herds and flocks was always noticeably high for all species in both communities (Table 29). For cattle, around 50% of the herd were cows or heifers, for goats, more than 70% of the flock were does and for sheep, the share of females in the flocks of Mutompo weret 67% and even 85% in Okamboro. Twenty-three percent of the cattle were oxen in Mutompo, which reflected the extremely important role of these animals for means of transportation and for ploughing. The share of calves in a herd made up 46% of the total number of cattle in Okamboro, but only 19% in Mutompo. With about 20% of kids in the flocks of goats and sheep, the values were similar in both communities. Only the share of lambs in Okamboro differed, making up for only 6% of the flock. Low numbers of offspring indicate either a high turnover rate (selling or slaughtering), or that the young females are counted already as heifers, ewes or does. In addition, most females were in a state of pregnancy during that time within the season.

Table 29: Herd and flock demography of the different types of livestock

Type of livestock	Mutompo (n = 9 HH) No.	Mutompo % of herd or flock	Okamboro (n = 24 HH) No.	Okamboro % of herd or flock
Oxen [1]	46	23	6	1
Bulls	11	6	22	2
Cows or heifers	103	52	482	51
Calves (< 1 year)	37	19	431	46
Sum of cattle	**197**	100	**941**	100
Goat castrates	5	2	1	0
Bucks	20	9	42	7
Does	160	71	475	76
Kids (< 6 month)	41	18	105	17
Sum of goats	**226**	100	**623**	100
Sheep castrates	0	0	0	0
Rams	2	17	14	9
Ewes	8	66	134	85
Lambs	2	17	9	6
Sum of sheep	**12**	100	**157**	100
Donkeys/horses	2		19	
Pigs	7		0	
Total number of livestock	**444**		**1,740**	

[1] Only the number of oxen differs significantly ($p \leq 0.01$) between the communities.

A high frequency of calves in the herds in Okamboro (Table 29) indicates a low turnover rate, and that most calves tend to stay within the herd. It could also indicate a long weaning time. However, the livestock numbers were recorded for this study before the important Ovaherero ceremony celebrated in Okahandja, which takes place in August each year. Farmers stated they would sell some of their stock in order to buy things they needed for this ceremony, to wich many visitors were expected. During the end of the 80s, for Hereroland West and East, it was stated that mainly weaners and store cattle were sold to feedlots and for fattening on commercial farming (Bayer et al., 1991), which means that people do not sell only old, unproductive animals, as it is often assumed. The selling of young animals was observed on the permit market, which took place in Okanjira (a village located within the Ovitoto-reserve) before the Ovaherero ceremony in 2002.

Another central economic and management issue of livestock is the frequency of male animals within the herds or flocks. Sex ratio male: female at birth is 50 : 50. A sex ratio with males < 50 means sales or mortalities of this male livestock. The different ratios (male : female) were calculated for the different livestock species in both communities and are listed in Table A 28 in the appendix. While the male: female ratio in Okamboro was only 6 males : 50 female animals, the ratio in Mutompo was 55 : 50. For goats, the male : female ratio was 9 : 50 in Okamboro, and 16 : 50 in Mutompo, for sheep the male ratio was a bit higher (Table A 28). The high male to female ratio in Mutompo pointed to the keeping of male calves in the herd, castrate and select them in order to become a draft animal. The low value for the male : female ratio in Okamboro pointed out, that livestock farmers sell or slaughter preferred young male cattle in contrast to females, considering the same loss and mortality rate of both sexes. For goats and sheep sex ratio is lower in both communities, meaning that more female than males are in the herds, but the sex ratio in Okamboro was the lowest for males compared to the other livestock species. This results support the finding of the further analysis of the disposition of calves below (see Figure 34 and Figure A 12 in the appendix).

Combining the information on the disposition of young animals among cattle and goats, with the apparent preferences of farmers when selling animals, may give an impression of the actual situation. One of the results of the PHT-questionnaires reflects on the disposition of evaluated kids or calves (Figure 34; for an overview see Figure A 12 in the appendix).

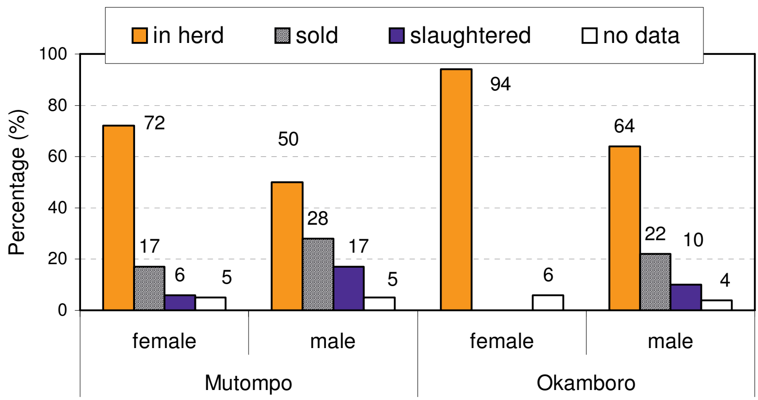


Figure 34: Disposition of the evaluated calves separated by sex

(Mutompo: female n = 14, male n = 23, missing n = 18, total n = 55; Okamboro female n = 73, male n = 71, missing n = 25, total n = 169; data compiled by F. Lange, unpublished)

The highest share of female calves remains in the herds (94% in Okamboro and 72% in Mutompo, respectively). Calf off-take during the selling process occurs to a low extent (17% female calves, 28% male calves) in Mutompo, and in Okamboro, the main reasons for off-take of only male calves is both selling (22%) and slaughtering (10%). It was noticeable that there is hardly any information on calf mortality for both villages. The shared value for calf losses due to carnivores or diseases does not exceed 6%. In Mutompo, the configuration frequency analysis (CFA, see description and Table A 29 in the appendix) results in a distinct significance that male calves remain in herds in Mutompo. This can be explained by the high importance of oxen for transportation and ploughing purposes in the prevailing mixed cropping-pastoral system, including its rather bad infrastructure and no other available means of transportation.

Highly significant results were achieved in Okamboro for the values of female calves staying in herds, as well as those of the male calves being sold (see Table A 29 in the appendix). Females are kept in herds, because they fulfil the production goal of herd maximizing, and because fast re-stocking after droughts is made possible with natural reproduction. The results from the PHT-questionnaire for cattle show that infertile cows were sold. Older cows were also sold, but mostly slaughtered. A breeding female was considered old at 5 to 7 years in Mutompo, and at 5 to 16 years in Okamboro. However, in Table 37 (p. 130) the mean age of cows at first calving in Mutompo were found to be 61 month, which is 5 years, and the mean age of cows within the herds of Mutompo were 8.8 years (106 month), which is also old, and is not conform with the statement above. Culling due to old age was usually carried out when animals look old, depending in general on their body condition. Sick cows with no prospect of cure were slaughtered and eaten. The meat of the sick animals was either cooked or dried into "biltong" (beef jerky, dried meat strips or pieces). The exchange of cattle against other livestock or goods such as food or cars etc. was not common. Only an exchange of female against male cattle was practised occasionally; especially when a household was in need of cash, it exchanged a cow for a male, in order to sell it afterwards. In general, females are rarely sold, because they are used for breeding and stabilising the herd.

Also for goats, a high share of kids of both sexes was kept in herds and within the communities (Figure 35). A higher percentage of male kids was sold in Okamboro, but this could not be statistically verified. In contrast, male kids were never sold in Mutompo, which is similar to the values of calves in this community, whereas one has to mention that only very few goats are sold in Mutompo at all.

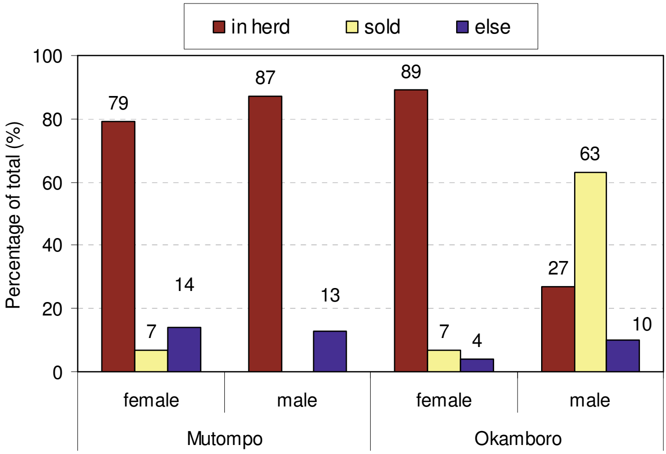


Figure 35: Disposition of evaluated goat kids separated by sex

(Mutompo n = 36, Okamboro n = 98; else = given away, slaughtered, lost, stolen, eaten, or abortion; data compiled by D. Werner, unpublished)

Altogether, the results of the analysis of the destinations of young animals explain the herd and flock compositions and demography very well. In Okamboro, male animals are sold or slaughtered preferably. Females are kept within herds or flocks, because they have a higher potential of reproduction, therefore ensuring herd growth. Additionally, during lactation, they provide milk, which is used by households, representing an important protein and calcium source for humans' nutritional needs. In Okamboro, the Ovaherero people - who constitute the main ethnic group - traditionally make sour milk from cows' milk filled into calabashes, which is eaten with maize, the main staple food. In Mutompo, oxen are nearly equally important as cows. Therefore, hardly any male calves are sold or slaughtered, except for some young bulls. Thus, the herd structures for cattle (see Table 29, p. 126) emerge according to the economic activities and preferences of both communities.

The bodyweight of cows and goats differed between the communities (Table 30). This is mainly a result of the different breeds of cattle and goats. In Mutompo, the middle-frame Sanga-Nguni-type of cattle is the main breed. In Okamboro, a local breed, Afrikaner, as well as Brahman, Simmentaler, and their crossbreeds are preferred, which are of large or middle frame build. Goat breeders primarily use the Kavango goat in Mutompo, whereas a mix of local breeds and Boer goats, the latter of which exceeds in weight, is preferred in Okamboro.

Table 30: Mean bodyweight of cattle and goats

Type of livestock	Mutompo n	Mutompo Mean body-weight (kg)	Mutompo SE	Okamboro n	Okamboro Mean body-weight (kg)	Okamboro SE
Cows	18	281.9	9.4	38	333.4	7.1
Bulls	2	422.5	47.5	2	544.0	24.0
Oxen	12	409.5	14.6	-	-	-
Calves		-	-	2	92.0	18.0
Does	41	29.9	4.2	165	37.8	5.7
Bucks				3	55.0	1.33

Data collected by F. Lange (2003) and D. Werner (2001), both unpublished.

Specifically for the cattle in Okamboro, the drought situation has to be considered during the time of weighing. The body condition score (BCS) of cattle was low in Okamboro, compared to Mutompo (Table 31). Fifty-one per cent of these cows had a condition score of two (thin), whereas 79% of the cows in Mutompo had the condition score 3 (normal), in a range between 1 and 5. Under these poor conditions, the bulls' body weight may also have been below their full potential. Nevertheless, the analysis of the age structure shows a significantly older cow population in Mutompo than in Okamboro. Seventy percent of the cows evaluated with the PHT-technique in Mutompo were aged between 73 and 108 months (6 up to 9 years); whereas 61% of the investigated cows in Okamboro were between 37 to 72 months old (3 up to 6 years).

Table 31: Mean values of performance parameters of cattle

Performance parameter	Mutompo n	Mutompo Mean	Mutompo SE	Okamboro n	Okamboro Mean	Okamboro SE
Age of cows (months)	10	106.0^{b}	3.5	54	69.0^{a}	8.9
Body condition score (BCS)	24	3.0^{b}	0.1	39	2.5^{a}	0.1
Age at first calving (AFC) (months)	10	61.0^{b}	5.2	49	31.0^{a}	1.8
Calving interval (CI) (months)	16	28.1^{b}	3.8	89	16.0^{a}	0.8
Average number of calves per cow (n)	24	2.2^{a}	0.3	57	2.9^{a}	0.3
Calving rate[1] (%)		36			60	

Data collected and compiled by F. Lange with the progeny-history-technique in 2003.
[a, b] means in rows followed by different superscripts are significantly different at $p < 0.01$.
[1] Data referred only to the previous production year 2002 and for a single herd in each community.

A higher age of most of the reproductive Nguni-cows in Mutompo is reflected in a lower productivity performance in this community, as shown in Table 31. Significantly higher values were found in Mutompo for the ages of the first calving, as well as the calving intervals. The number of calves per cow was lower in Mutompo, yet not significantly.

In Mutompo, most of the herders (n = 4) stated to be content with their cattle's performance, although the dry grass and the erratic rain were of concern to some. In Okamboro, all (n = 11) but one of the herders referred to the bad pasture conditions and the fatal rain situation during the wet season of 2003 as the main reasons for bad animal performance. The people complained that cows and calves died of starvation and that bulls suffered from a small amount of fodder and were too weak for breeding. In order to solve problems, such as a lack of good pastures, the herders asked private commercial farms for help i.e. with helping to move their cattle to better grazing areas on their farms. However, in consideration of the current drought situation, the commercial farmers did not have any free grazing capacities on their farms, and the offers they made were not sufficient for the community people, e.g. they would have had to give all newborns to the commercial farmers, in return, as a provision for the pasture. Regarding the lack of rain, the people merely prayed for more rain and that their cattle would stay alive. Simultaneously, most farmers started to move most of their cattle to grazing areas located further north and northeast of Namibia.

Similar results as in Mutompo for the calving intervals were reported for the Sanga-cattle in the communal areas in the North Central Region of Namibia, where cows were observed to calve every three years (Deniau et al., 1997). The low reproductive performance found in this study (compare Table 31), may well be related more to the management, than to the prevailing environmental conditions, considering that the body conditions of the animals were good - with a mean score of three - within a range of 1 to 5. This may be normal for the end of the rainy season, during which the investigation was carried out, yet, an adequate body condition is always a precondition for sufficient reproduction. Thus, the animals in Mutompo fulfilled this requirement, in contrast to the cows in Okamboro, who were affected more by the drought. In their case, the BCS was on an average of 2.5, (Table 31); however, their reproductive performance was unexpectedly high, compared to Mutompo. Comparing the ratio of number of calves in Table 29 (p. 126) in relation to the number of cows of Okamboro, then 89% of cows would have had a calve in 2001/2002, or animals older than one year were also counted as calves. The lower performance in Mutompo may also be associated with the fact that, in this mixed farming system, livestock takes up only a secondary importance, compared to the main focus on crops.

Unusually long calving intervals (CI) of over 2 years, which were noted in Mutompo, may happen due to conception problems and abortions. The abortion rate of 5.4%, however, does not indicate an exceedingly high abortion rate - taking into account that a considerably high percentage of multiple abortions have occurred with relatively few animals - which points more in the direction that diseases, such as brucellosis, may be a more probable cause of these unsuccessful pregnancies. This figure may also reflect a bad recalling ability of the respondents or even indicate a habit of ignoring the occurrence of abortions. However, given even farmers may not have noted early abortions, the abortion rates calculated from the progeny-history-data are nevertheless quite likely to be underestimated (Lange, 2003; unpublished).

As the Ovaherero in Okamboro own mainly crossbreds, with uncertain amounts of Afrikaner, Brahman and Simmentaler inheritance, it is difficult to find equivalent data. Registered purebred Afrikaner, however, showed averages for age of first calving (AFC) from 36 to 41 months, and for the calving interval (CI) from 440 to 460 days, (Scholtz et al. (2000), in Bester et al. (2001); and Farm Animal Conservation Trust (2001)). For purebred Simmentaler under extensive management, Schoeman (1989)) and van der Merwe & Schoeman (1995) reported for the AFC 26 months and for the CI 415-450 days. For Brahman, an AFC of 37 months and a CI of 441 days were reported in South Africa (Scholtz et al., 2000, in Bester et al., 2001). The value of the mean AFC in Okamboro was below the figures for Afrikaner and Brahman breeds, at 31 months, which makes the value obtained by the PHT for Okamboro questionable. The value of the CI was slightly higher than the values reported for the pure-breds under controlled conditions, but appears realistic.

The estimated calving rates in this study for Okamboro (see Table 31, p. 130) are high, but data refers to only the last reproduction period of 2002, which may have been influenced by the low rainfall and the resulting low food supply. On the other hand, the information obtained from the respondents needs to be considered critically in respect to their correctness, as some of the farmers - especially among the Ovaherero – tend to exaggerate, stating i.e. falsely that nearly all of their dams had a calf in the previous year (Lange, 2003; unpublished). The mean calving rate for the crossbred dams in Okamboro makes up to 60% (results from the PHT of 2003), but up to 89% considering the results of the herd structure analysis in Table 29 (p. 126, data of the year before), and thus lay in the range of the average calving rates of crossbreds within the defined breeding programs which vary from 80-90% (Light et al., 1982). The rainfall amounts in the rainy season 2001/2002 were a bit lower than the long-term average (Windhoek: about 272mm.[24]), but no drought situation occured. In Mutompo, the Nguni-cows reached an average calving rate of only 36%, which is also far below their potential. The highest reported calving rates for the Sanga-type cattle lay between 87% (Bester et al., 2001) and over 90% (Swanepoel, 2002). Admittedly, these very high results are obtained on Namibian research stations, under experimental conditions and are thus not comparable to on-farm conditions in

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[24] For historical wheather data in Namibia, see: http://www.tutiempo.net/en/Climate/datos.php?stn=681100

communal areas. However, these figures indicate that an enhancement of reproductive performance in communal areas is theoretically achievable.

The relatively bad reproductive performance of the Sanga-breed in the north is still apparent, if the average age of the evaluated cows is regarded in connection with the average number of calves per cow. The cows in Mutompo were on average 106 months old, but 50% of them had only one calf. Sanga type cattle are known for their longevity - up to 17 years - (Kruger, 1998), yet for a better reproduction rate, it may well be advantageous if farmers in Mutompo replaced older cows (Lange, 2003; unpublished).

The animal health status can be regarded as good for both villages, as there is access to basic veterinary services for all. A good vaccination status inhibits most of the important diseases occurring in these regions. No statements on tick infestation within herds confirmed the natural resistance of indigenous cattle breeds against these parasites, as described by Bester et al. (2001). Nevertheless, ticks were observed to be a problem with the goats in Okamboro. The generally missing practice of separating sick animals from the rest of the herd shows the lack of farmer's knowledge concerning the spreading of diseases within a herd (e.g. intestinal parasites).

Table 32: Mean values or medians of performance parameters of goats

Performance parameter	n	Mutompo Median/ Mean	SE	n	Okamboro Median/ Mean	SE
Median of age of does (months)	14	66.0 [b]	_	48	28.0 [a]	_
Mean age at first parturition (months)	6	22.0	2.86	44	17.3	5.0
Median parturition interval (months)	13	18.0	_	29	13.2	_
Mean number of kids per doe (no. per doe)	13	4.4 [b]	1.33	46	3.0 [a]	1.5
Mean litter size at parturition	14	1.2 [a]	0.09	46	1.3 [a]	0.05

Data collected and compiled by D. Werner with the progeny-history-technique in 2001.
[a, b] means in rows followed by different superscripts are significantly different at $p \leq 0.01$.

Similar to the low performances of cattle in Mutompo, the parameters for goats were also worse, compared to those in Okamboro (Table 32). For the age of does and lambing intervals, only a median was available, due to an uneven distribution of data. The median age of does was twice that of the does in Okamboro, but the number of kids per doe was significantly higher in Mutompo than in Okamboro. The age of the first kidding, as well as the kidding intervals show higher values for Mutompo than in Okamboro, but there were not enough cases listed - especially in Mutompo - in order to ensure clear and verified results.

5.3.2 The importance of livestock as a source of income

The surveyed households within both communities did not make up for their living from one source of income alone, e.g. their livestock husbandry or their cropping. In Mutompo 93% of all households generated their income from more than one source and 85% of the households in Okamboro did so. Around 42% of the households in Mutompo used more than three income sources for income generating, whereas in Okamboro only 11.6% of the household used more than three. In the agro-pastoral system of Mutompo, a significantly higher number of incomes (3.4 sources; n = 12) emerged through the cropping activity, whereas in the pastoral community Okamboro only a mean number of 2.3 (n = 26) occurred. In Mutompo, passive activities[25] were lowest in number, and with 16.5% of the total at the lowest share. In Okamboro 36.7% of the income sources were categorised as passive; one of them is the governmental old age pension. Namibia is one of the three African countries aside South Africa and Botswana, providing non-contributory pensions to elderly citizens. An old age pension scheme has existed since its introduction by the South African administration in 1949 for white residents, but it was extended to African Namibians in 1973. In 1994, the Namibian government eliminated the racial disparities in pension payments between the white and the different coloured or black ethnic groups (Devereux, 2001). Apart from providing a certain income against livelihood shocks, such as droughts, the social pension stimulates local trade, enhances the status of elderly family members, and often supports the costs of primary and secondary education (Devereux, 2001).

Most of the households practise livestock production as a main activity, but they do not necessarily mention it as the economically most important income source. People in Mutompo intimately depend on the use of natural resources with cropping and livestock keeping. The low number of cattle sold seems to continue a long-established traditional pattern, in which most livestock are not kept for commercial and productive purposes. The traditional pastoral strategy in uncertain environments is presumed to maximise the size of cattle herds or flocks of small ruminants (Irving & Janssen, 1992; Riethmüller, 2003; Vetter & Bond , 2003). Thus, smallholders in arid and semi-arid regions sell their livestock very seldom, for instance only when they are in need of cash (i.e. for school fees, medicine, food, or clothes). Katjiua & Ward (2007) found in their study of Ovhereo pastoralists in the northern Kalahari of Namibia that cattle played an important role in the production of milk and milk products for domestic use, and served as a source of cash income. Sheep and

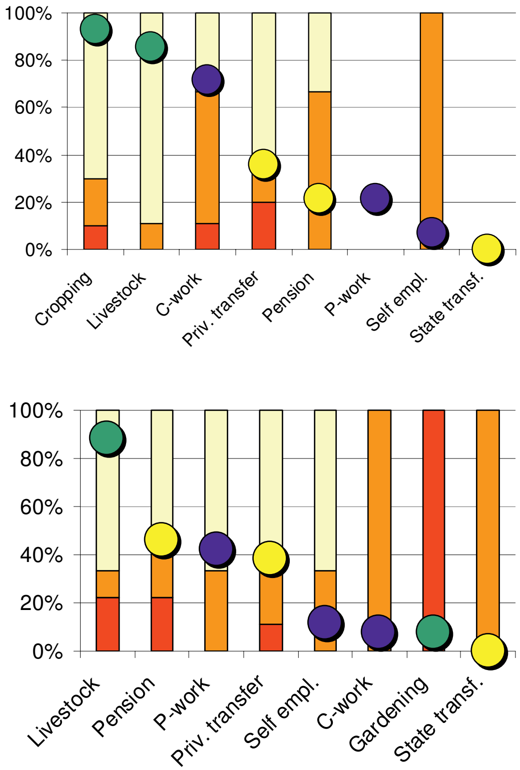
[25] Active income generating activities are characterised as livestock keeping and cropping, permanent work (non-farm as well as on-farm), occasional jobs, self employment, which could be e.g. small businesses or workshops. Passive economic activities are mainly state old age pensions, private transfer payments and other state transfers.

goats were kept primariliy for meat production. They found a high cattle offtake rate (15.3 – 16.5%), in particular of male weaners and young adults, which indicates that the pastoralists have commercialized their production system.

With old age pensions, private transfers (Figure 36 A), and the selling of parts of the harvest only in good rainfall years, people can get some cash. Part-time employment seems to be important in very dry years in Mutompo, in case the millet yield failed; additionally more livestock sales or exchanges take place in this situation (own observations, see also p. 139/140). Occasional work seems to be found mostly locally and on-farm, on the fields within a community or in the surrounding communities. This work is integrated into the system of hiring oxen with a plough and a person who leads the team of oxen. Cows are not used for cultivation or other draughting tasks in Mutompo.

The average cash demand has risen, e.g. due to the discontinuation of diesel subsidies in Namibia for water pumps, the need to buy staple food in shops, and for having to pay for school fees and transportation. Permanent work, such as labour migration, is more common in the communities nearby urban centres, as provided with a better infrastructure, e.g. in Okamboro (Figure 36 B). Self-employment with small enterprises (e.g. small shops, selling handicrafts or furniture) plays a relatively small role, but households in Mutompo mentioned it as medium important.

The social networking of families is considered very important, indicated through a relatively high share of households receiving private transfer payments. Around 40% of the households in Okamboro received old age pension, which is an important source of cash income for these households. In Mutompo, only 20% of the households obtained these state transfer payments. One reason for this is, of course the younger population found in this northern Namibian community (see Table 5, p. 26), the other is the difficulties of the pension money distribution in marginal areas of the Kavango region, with respect to its very poor infrastructure (paths on deep sandy soils). In 1993, only 38.5% of the people older than 60 years of age received a state pension in the Kavango region (Subbarao, 1998). Surprisingly, in the Otjozundjupa region (see Map A 1 in the appendix), likewise only 48.0% of the old people took delivery of their pension. One possible explanation for this could be that not enough social workers were employed in the provinces. Additionally, the system of registration and delivery was more favorable in central Namibia than it was in the North, this leading to more exclusion errors. Since 1993, the situation has clearly improved (Subbarao, 1998). Interestingly, these sources of income, that only few households mentioned, were ranked to a high percentage as medium or very important. This could be a sign for the circumstance that these sources of income (Mutompo: e.g. old age pension and self-employment; Okamboro: e.g. part time work or state transfer payments) are most desirable, but not easy or almost impossible to get for people in the rural, communally managed areas of Namibia.



A) Mutompo

B) Okamboro

Income source: use of natural resources, other active income sources; passive income sources.

Importance of income source: very important; medium important; unimportant.

P-work = permanent work. C-work = occasional jobs. Pension = old age pensions. Priv. transfer = private transfers. Self empl. = self-employment other than livestock and cropping. State transf. = state transfers except old age pensions.

Figure 36 A - B: Frequency of households using specific sources of income (dots), and their perceived importance (bars)

Yaron (1992) identified 10 main sources of household income in communities within the entire Kavango. Income from productive activities is regularly augmented by remittance payments from family members in formal employment and pensions, such as found for the Mutompo community. This diversification strategy is seen as a forced response of residents to the risky environment, with erratical production, mainly due to irregular rainfall (Anonymous, 2004). As an example for the amounts of income and the different sources of an inland Kavango area, the results of Omuramba villages were taken into consideration (Yaron, 1992). In 1991/1992, the total annual income of households in this area was 8,185 R[26], which was the lowest value of five analysed regions in the Kavango (mean annual income: 10,560 R). In Omuramba, thirty-nine percent of total income came from the formal sector employment, thirty-four percent of the total income was received from home production, and 16% constituted from animal sales. Sales of crop products accounted for only 0.4% (or 32 R), whereas the value of crops produced and used subsistencely contribute 2% to the total annual income (Yaron, 1992). Incomes from the informal sectors, pension incomes or remittance shares made up for only 1% to 3% of the total annual income in Omarumba. Aggregating the different sectors, agricultural activities accounted for 18% of the income, employment (formal, informal or work from home) for 76% and transfers for only 4% (Yaron, 1992). In 1999/2000, the average household cash income per adult equivalent in rural Namibian areas counts for an amount of NAD 283 per month (yearly NAD 3,396) ('Level of Living Survey 1999/2000', in Hochobeb, 2002). For the entire Namibia, it was reported to be at more than twice that amount (NAD 662 per month; in urban areas NAD 1,147 monthly; data from 'Level of Living Survey 1999/2000', in Hochobeb, 2002). However, the incomes from the informal sector, as well as from small enterprises, or from sales of local products seem not to have been integrated into these figures, so that these amounts are not comparable directly to the income quantities mentioned above. However, sales of livestock contribute only to a very small part to the household's income (see also MAWRD (1992), for the southern communal areas of Namibia). Additionally, the transfer payments seemed to be very low in the study cited in Yaron (1992). In Mutompo, 86% of all households kept livestock; and in Okamboro 96% of the households were livestock farmers (see Table 27, p. 122). Considering the estimated market value of livestock per livestock-keeping household, Okamboro's livestock keepers were the wealthiest, followed by Mutompo with about 53% of the Okamboro value (Table 27, p. 122).

It was expected that goats and sheep are more often sold or slaughtered than cattle because of the smaller unit and a much higher reproduction rate of small ruminants. In Mutompo, 13% of the animal-keeping households sold goats, and 22% sold cattle during the year 2001 (Figure 37). Forty-six percent of the animal keepers in Okamboro sold a few cattle; cattle were consumed only by 13% of the households. Nevertheless, more goats

[26] The South African Rand (R) was the currency during this time in Namibia. Today the NAD is linked to the Rand with an equal value.

than cattle (by 46% of the animal keeping households) were consumed in Okamboro. At a return rate of 10%, livestock can contribute to the annual household income with 3,700 and 6,000 NAD for Mutompo and Okamboro, respectively. With a proper management, 10 to 20% of cattle or 30 - 40% of gaots can be sold or slaughtered annually.

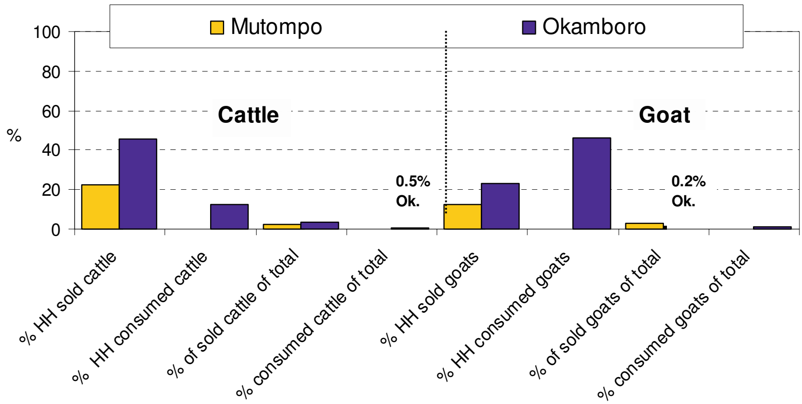


Figure 37: Frequencies of households, which sold or consumed cattle and goats, and share of sold and consumed livestock species of total livestock per household

Mendelsohn & el Obeid (2003) reported that in the Kavango, most sold animals belong to farmers with only small herds, whereas farmers with large herds sold only few of their animals. This is contrary to the situation found in Okamboro, where farmers with larger herds, especially with many cattle, sell animals more often than farmers with small herds. In Mutompo, no clear result concerning this factor could be detected, mainly due to the small numbers of households and due to the statements of only few farmers who sold some of their livestock. In a study carried out in the Northern communal areas of Namibia on cultural versus economic marketing and the reasons for keeping cattle (Düvel, 2000), fifty-eight percent of the farmers assessed the stock marketing facilities as poor or very poor, but supposed it not to be the most important problem related to livestock keeping in this area. Some of the most imminent problems were diseases, lack of grazing (overgrazing), scarcity of water (stock concentration), and drought. In addition to the lack of money for farming inputs and a theft problem, the poor markets were mentioned, and the danger of field-fires lastly. This corresponds with further results in Düvel's study, with his rating of importance within reasons for cattle keeping (Düvel, 2000). Ranked on last position (average importance with 6.8%) was the generation of income (commercial). Much higher ranked, on the other hand, was livestock, as a source of cash for the regular household support (ranked with 80% importance), and as a source of cash for specific purposes (evaluated at 66%). Additionally, the socio-cultural issues, such as payment of tribal authority fines, using animals for ceremonial feasts, or as a bride price, and as food supply (e.g. milk production) were ranked with 46% (Düvel, 2000). It is important to mention that the people in the central parts of Namibia are highly dependent on cash income and mainly rely on food bought in shops; cropping is not possible (MAWRD, Ministry of Agriculture, 1992), and gardening is successful only in good rainfall years. The purchased staple food from shops is supplemented by meat and milk from the own animals and, to a limited extent, by gardened products. Animals are milked regularly and sometimes a goat is slaughtered, in order to provide the households with meat. In contrast to this, in the northern parts of Namibia, the cropping of millet for subsistence provides the staple food required for most of the households in 'normal' rainfall years, given a season went without pests or other extraordinary losses.

However, people have to provide for their nutritional supply during a drought or a poor rainy season. It was observed that the people of Mutompo were forced to sell or exchange livestock - not only small stock- in case of food shortages i.e. due to a failed or very poor harvest. Cattle numbers were collected on a household-level, during a census of the Mutompo-region, in 2001. Six households were interviewed with the PHT-technique in 2003. For these six households, the number of cattle was found reduced by 42.7% from an amount of 171 cattle in 2001 to only 98 in 2003, and the main reason for this was not mortality. During this approximately two-year period, rainfall was not sufficient and harvest was poor in comparison to normal or good years. The respective six livestock farmers sold or exchanged seven bulls (which makes up for 64% of the total bull population); 42 cows (41% of the former number of cows); 12 oxen (26% of the total former number of oxen), as well as 12 calves (32% of former calf number). These numbers exceed the figures for sales during the first interviews undergone in Mutompo in 2001 remarkably, in which the numbers of sold and slaughtered or lost animals were gathered from recollections of livestock farmers for the previous year (see Figure 37). This obvious reaction to a year with poor rainfall encourages the presumption that keeping livestock serves by tradition as a form of insurance, and as an investment, or that it functions as a `bank account on hooves´.

In contrast, in Okamboro the number of livestock increased considerably between 2001 and 2002, except for sheep. According to a census of Okamboro's livestock by the Kambekura Farmer's Association Ovitoto in May 2002, the number of cattle has increased by 265 (plus 28.2%), and the number of goats by 271 (plus 43.5%). Not knowing the age class distribution or the exact bodyweight of the animals, the estimated LSU in May 2002 was about 1,073 (2001: 541 LSU), and the estimated bodyweight of the total livestock was 483,090 kg (2001: 243,372 kg). This results in a stocking rate of 83.3 kg ha^{-1} (2001: 41.9 kg ha^{-1}) in Okamboro, whereas cattle represent 88.6% of the bodyweight, which means again a very high share of grazers. In 2001, nearly every month, one or even two livestock permits took place in Okanjira, whereas between 87 and 248 cattle were sold at each time and bought from a single, mainly commercial farmer. The average prices per unit (kg BW) ranged from 3.0 - 5.4 NAD in January 2001, 2.7 - 5.7 NAD in August 2001 to 3.0 - 7.0 NAD in November 2001. During 2001, according to the list of the Kambekura Farmer's Association Ovitoto, 2,087 animals (mean per permit: 123; SD ± 40) changed their owners, and hence left the Ovitoto region. Assuming that farmers of each of the ten communities sold animals, 200 cattle were sold per community, whereas Okamboro is one of the larger communities. Therefore, probably more than 200 cattle (or 21% of the 941 cattle in total) with Okamboro origin were sold in 2001, which would make much higher records in comparison to the figure 'percent of sold cattle of total' in Figure 37.

5.3.3 Modelled carrying capacity and current stocking densities

The stocking density of 42 kg ha^{-1} in Okamboro was very high, compared to the other location, where natural conditions, resource endowment and possible pasture degradation had to be considered (Table 33). High stocking densities are observed in Okamboro, although forage growth is much more favoured by the higher primary productivity through higher rainfall amounts in Mutompo. In Mutompo, only 15 kg ha^{-1} of livestock uses the area for grazing. Furthermore, the species of livestock and the herd composition (grazer and browser) is important to know (Table 33), as is the amount of bush and tree biomass, in order to estimate the effective use of the vegetation.

Table 33: Available grazing areas and current stocking densities

	Mutompo	Okamboro
Estimated size of grazing land (ha) [1]	3,848	5,808 [2]
Estimated size of cropland (ha)	200	few hectares
Number of households in community (n)	14	29
Available grazing land (ha) per household, (and per livestock keeper)	271 (317)	200 (215)
Total number of livestock (n)	444	1,740
Total BW of livestock (kg), (donkeys/horses included)	57,828	243,372
Current stocking density of grazers (kg ha^{-1}) [3]	11.2	31.9
Current stocking density of browsers (kg ha^{-1}) [3]	3.8	10.0
Current stocking density (kg ha^{-1}) [4]	**15.0**	**41.9**

[1] The exact values are derived from the cycle sector model according to the estimates from satellite images. [2] About 10% of the area was fenced in. [3] Assuming grazers and browsers use the same total grazing area. [4] Calculated from detailed BW of livestock species and separated into castrates/male/female/young animals.

A detailed comparison of calculated grazing and browsing resources, the forage yield, from field samplings (see chapter 4.3.2 and chapter 4.3.3) with the calculated nutrient requirements of the current livestock was made in order to find values which approach reality of the sampling years 2002/2003.

In Okamboro, one household with large livestock numbers moved away in 2003, but was still included in values for stocking densities in Table 33. This household owned 38 cattle, 236 goats, and 30 sheep, which makes up around 17,343 kg body weight (BW), and 7.1% of the total livestock BW. Calculated for the whole Okamboro grazing area, the livestock of this single household result in a stocking density of 2.98 kg ha^{-1} alone. Only the animals belonging directly to Okamboro are integrated in these stocking densities. Assuming, that one quarter of the cattle of the three neighbouring settlements (Ourua, Bullskop-settlement and Ombupoori) graze preferably on one third of the grazing area of Okamboro, (the military area, as well as the eastern grazing area, where the BIOTA-observatory is located, see Map 4, p. 40), would mean an additional stocking load of 69.7 kg ha^{-1} for this area. For the calculation of stocking densities in the Mutompo area the livestock of two households from Epingiro, a neighbouring community, were integrated in the figure (Table 33), because these two households are not far away from Mutompo, and there livestock use the grazing area as well as the water place of Mutompo.

The entire dimension of the grazing area is included in this calculation, yet leaving important data unconsidered, such as special preferred grazing areas, maximum or normal daily walking distances of the different livestock species, or the position of the only water point, which animals have to go to once a day or at least every second day. The current stocking density estimation for the communal grazing areas doesn't reflect the reality of grazing activities in communal areas, but merely presumes that herds, flocks and single animals can graze the whole area during a day. Actually, normally no fences or gates restrict the animals from walking around freely, when or rather if they feel like walking at all. In reality, the area is shared mostly without herding, but animals are sent in different directions, according to their age or type, but without much regularity or control, thus, making it difficult to develop theoretical approaches to assess the areas used on a daily, weekly, and monthly basis, or during a whole year's time. This is the reason for not using the term 'stocking rates'; it implements a time scale and the duration of stocking, which is included in rates (numbers per area during a special time scale). Most of the commercial farms in Namibia have a camp structure, with camps sized up to several hundred hectares. In these cases, defined stocking densities can be calculated more easily and would result in values, which are more realistic, if detailed reports on utilisation times of camps existed.

The first approach to find comparable recommendations for stocking rates was the application of literature values. The second, was to use rainfall-based models, which calculate the primary production of rangelands, further the grazing or carrying capacity, and finally, to compare the results from literature with the model-based values, as well as the recent results of the field samplings and the knowledge of the rainfall for the productive rainfall season. Thus, a more detailed look was cast on models developed especially for Namibia or southern Africa.

It was also interesting to compare the results of these models, with the mean (or median) average annual rainfall, and also with the 'presumed value' of Kempf (see Table 34). These 'presumed values' and the uncertainty factors by Kempf, (2000), were useful in order to estimate the agricultural potential as well as risks of drought or dry years. Calculations for the amounts of primary productivity on rangelands based on rainfall may be better and more realistic when calculated with these values, instead of the mean annual rainfall, which is calculated from long-term rainfall measurements only.

Table 34: Measured and modelled rainfall characteristics of Rundu and Okahandja

Station, (years of measurement)	Long-term mean (M) (mm)	Corrected mean (CM*) (mm)	Frequency of drought year during measurements (CM <CM-10%) (%)	'Presumed value' (PV) (mm)	Rainfall uncertainty factor (RUF) (%)
Rundu (51)	589.3	548.4	27.5	522.5	11
Okahandja (92)	359.0	314.3	35.9	290.6	19

Source: Kempf, 2000. *Corrected mean (CM) = long-term mean, where the exceeding run-off in wet years was calculated as only 10% of the total mean, and was subtracted from M. Method described in footnote[27].

The community of Mutompo is located about 60 km southwest of Rundu, near a tar road B8 leading to Grootfontein. The 'presumed value' (PV) and the rainfall uncertainty factor for

[27] According to Kempf (2000, p. 57/58; translated from German): 'Table 4 [in his dissertation] reflects the calculation of presumed value (PV) of rainfall for 64 selected recording stations in Namibia, based on statistical data obtained by continuous monitoring over years. The PV, in turn, is based on the calculation of a corrected mean (CM), in which the excessive amount of soil surface run-off during strong rainfall years is considered only as a long-term mean value minus 10%, when calculated. In dry years, where the CM falls short over 10%, a deviance quotient – the average negative deviance – is also subtracted from the CM value. The ratio of the presumed value (PV) to the long-term mean creates a simplistic tool of measurement for the rainfall uncertainty factor (RUF), which includes the most important influencing factors (amount of dry years, mean negative deviance during dry years, wet years with excessive run-off and negative ecological effects)', Kempf (2000: 58 ff.).

Mutompo are therefore comparable to Rundu. The second community Okamboro is located near Okahandja and was expected to have similar climate conditions. The long-term mean of annual rainfall for Okahandja is 359 mm, this being much higher than the 'presumed value' of only 290 mm per year. The rainfall uncertainty factor (RUF) shows a value of 19%; and about 36% of the measured years were dry years, with rainfall being less than 10% of the corrected mean value of 314 mm of annual precipitation. In Mutompo, the 'presumed rainfall value' is by 67 mm lower than the long-term mean rainfall. The RUF is - with 11% - a bit lower than in Okamboro, but the frequency of drought years is still about 28%, meaning that nearly every third year is a drought year, with a rainfall 10% less than the corrected mean.

In comparison with the measured values of grass biomass in this study, all values calculated with the rainfall models were much higher. For instance, in Mutompo, the wet season grass biomass was found to be 915 kg ha^{-1} (in April 2003), which corresponds to around 80% of the peak biomass production. But even the 100% peak in Mutompo, referring to a value of 1,144 kg ha^{-1}, is comparable only to the values of Okamboro e.g. according to the model of Walter (1973, in Rutherford 1978), where a rainfall of 291 mm per year was used as a benchmark value (see Table 35). These values indicate that the environmental conditions were either not comparable (e.g. grassland savanna without shrubs and trees, no slopes, no homogenous soil texture, etc.), or the pastures in the investigated communities of this study were of lower productivity, probably due to poorer conditions or poorer soil fertility.

When calculating the rain use efficiencies (RUE) for the mean grass biomass amount of WS 2002/3, the values resulted in a RUE of 1.85 kg DM mm^{-1} $year^{-1}$ in Mutompo[28], and 0.05 kg DM mm^{-1} $year^{-1}$ in Okamboro[29], which are very low. Walter (1954), in Le Houérou, 1984) reported RUE-figures for southern Africa of 4.80 to 8.64 kg DM mm^{-1} $year^{-1}$. Also, Rutherford (1978), suggested higher values between 6.66 and 9.50 kg of herbage DM mm^{-1} $year^{-1}$ for South Africa, depending on the annual rainfall amount (100 to 600 mm), whereas sometimes it is not clarified whether only grass biomass is included, or whether the browse or herb resources are also a part of the aerial plant biomass. Values of RUE usually lay between 3.0 and 6.0 for the reasonably well managed arid and semi-arid grazing lands, but can be as low as 0.5 in-depleted sub-desertic ecosystems (Le Houérou, 1984.

[28] Mutompo: maximum sampling point: 3,702 kg ha^{-1}, RUE: 7.49 kg mm^{-1} $year^{-1}$; minimum sampling point: 39 kg ha^{-1}, RUE: 0.08 kg DM mm^{-1} $year^{-1}$.

[29] Okamboro: maximum sampling point: 318 kg ha^{-1}, RUE: 1.28 kg DM mm^{-1} $year^{-1}$; minimum sampling point: 0.0 kg ha^{-1}, RUE: 0.00 kg DM mm^{-1} $year^{-1}$.

Ward & Ngairorue (2000) suggested a gradual regression relationship (rather than a linear one) between rainfall and herbage production. From 20 mm up to 100 mm of annual rainfall, the annual grass production increased by about 6 kg ha^{-1} for every millimetre of increase in annual rainfall (see equation by Ward & Ngairorue (2000), the slope is 5.93, Table 35). Above 100 mm annual rainfall, the slope of the relation between herbage yield: rainfall regression should become steeper (around 8.5 kg ha^{-1} per mm of annual rainfall for undisturbed eastern and southern African sites, see Deshmukh & Baig (1983)), due to an increase in the standing crop of mainly perennial grasses which remain in the grasslands, even during low rainfall years. However, Walter's slope for his second equation of 1973 is only 4.8, and in the equation of Ward & Ngairorue (2000) for Namibia the slope is higher, with a value of 5.93. Ward & Ngairorue (2000) compared the rainfall: herbage yield relation detected by Walter (1939) with the data of 1997 in Namibia, and found that the grass production along a rainfall gradient in Namibia was half of the amount it was 50 years ago (a slope of only 5.93 vs. 10.34 in Walter, 1939). They concluded that, over the last decade, despite a degradation or desertification, grazing could not have been the cause of this reduced productivity. It would probably have taken longer, up to 40 to 50 years of intensive land use, to affect rangeland productivity negatively and on a long-term scale. Nevertheless, this certainly does not mean grazing did not affect the botanical composition in semi-arid and arid rangelands at all (Ward & Ngairorue, 2000).

Table 35: Primary production in rangelands of five rainfall-based models

Model/ community or area	Mean seasonal rainfall (mm/ season)	Walter 1939, in Rutherford 1980, (kg ha^{-1})	Walter 1973, in Rutherford 1978, (kg ha^{-1})	Deshmukh & Baig, 1983, (kg ha^{-1})	Ward & Ngairorue, 2000, (kg ha^{-1})	Own data Grass only 2002/03 (kg ha^{-1})
Constants		a= -401.3; b= 10.34	a= -100; b= 4.8	a= -200; b= 8.5	a= -328.6; b= 5.93	Mu a = 2.14 Ok a = 0.05, Mu b =1.85, Ok b = 0.05
Mutompo	428	4,024	1,954	3,438	2,209	915
Okamboro	248	2,163	1,090	1,908	1,142	(13)
Calculated with Kempf's rainfall 'presumed values' (PV)[1]						
	PV (mm)					
Mutompo	522.9[1]	5,005	2,410	4,245	2,772	970
Okamboro	290.6[1]	2,604	1,295	2,270	1,395	(14.6)

[1]PV – Kempf's 'presumed value' based on long-term rainfall data, see Table 34, p. 142; Mu – Mutompo, Ok – Okamboro; used rainfall models described in FAO, 1991; Ward & Ngairorue, 2000.

The measured grass data for Mutompo and Okambor and their calculated RUE[30] (b-values) were very low in comparision to the results from the models, used the measured rainfall amounts, or the presumed values by Kampf. Even the minimum values for the theoretical stocking rates, which base on the biomass levels from the rainfall models (Table 35), exceeded the recent stocking density by far for Mutompo, and were just beyond it for Okamboro (Table 33, p. 140). Such low values for RUE pointed out, that the measured grass biomasses in both communities did not represent the 100% biomass peak and that the grass biomass only can not used for calculation of the RUE values, thus are not suitable for a comparision with the listed models in Table 35. Using the total biomass, grass and browse resources, the RUE and b-value in the model for Mutompo is 6.7 (total 2,862 kg BM) and for Okamboro 5.8 (total 1436 kg), which is comparable with the b-values of the other models. Calculate the a-values for the total rangeland BM, the value is -5.6 in Mutompo and -2.4 in Okamboro.

The current stocking densities of communal areas were compared to the results in literature (Mendelsohn et al., 2002), as well as the rainfall-based model for carrying capacities (CC) in Namibia by Sweet (1998a) (Table 36). Sweet's' carrying capacity values were simply calculated, only in the last row in Table 36, values were corrected by Sweet's' correction factors. For a brief description of Sweet's model, see Table A 15 in the appendix and Table 24 (p. 113) for the correcting factors. In Okamboro, the current stocking densities even exceeded the values recommended by Mendelsohn (2002). In addition, these values went beyond the corrected carrying capacity figures calculated by Sweet (1998a) with seasonal rainfall, whereas in Mutompo only 20% of the carrying capacity was utilised.

Table 36: Stocking densities and Sweet's rainfall model for Namibia

Communities	Mutompo	Okamboro
Current stocking densities (kg ha^{-1})	15.0	41.9
Recommended stocking rates (Mendelsohn et al., 2002) (kg ha^{-1} year)	50-60	30-40
Corrected carrying capacity for communal ares, according to Sweet (1998a) (kg ha^{-1}year)	75.9	35.7

Sweet's model calculations based on 428 mm rainfall in Mutompo, and on 248 mm in Okamboro, the (see Table A 15 in the appendix).

In comparison to the recommended stocking rates by Mendelsohn et al. (2002), and the corrected carrying capacity by Sweet (1998a) (Table 36), there was a higher potential for

[30] Rain use efficiency (RUE) = BM production = a + b * mean rainfall.

Mutompo only. In Okamboro, the literature value, as well as the corrected value determined by Sweet (1998a) was exceeded (Table 36), thus, the available rangeland resources tapped the full potential, or the resources were even over utilised a bit. However, all of these models are based only on rainfall, but many other factors influence the amount of primary productivity. Also, the rainfall as well as the vegetation shows a high variability in space and time, which makes a realistic estimation of primary productivity for a larger area difficult, without fieldwork and local ground-truthing for values after the end of the rainy season, appropriate to reflect the situation in Namibia.

5.3.4 Livestock feed requirements and forage availability – a balance

Looking at the minimum requirements of livestock on natural forage quality, e.g. the content of crude protein should be around 6 – 7%, in order to meet a maintenance level, and the phosphorus content of forage is recommended to be at a minimum value of around 0.18 %, with a digestibility of around 50% (Legel, 1990; FAO, 1991; Ffoulkes, 1998; Saleem 1998). Pregnant or lactating cows even need higher values to meet their feeding requirements. FAO (1991) states, that a 3.8% crude protein content of forage is sufficient to maintain zebu cattle (*Bos indicus*). However, ruminants cannot compensate for the poor quality of forage by feeding more biomass (Breman & de Wit, 1983); the capacity of rumen is limited, and the dry matter intake rate is suggested to be between 2.5 and 3% of the live bodyweight. Additionally, with decreasing quality (e.g. crude protein, metabolisable energy, digestibility), activity within the rumen also diminishes, so that the dry matter intake capacity is reduced (Breman & de Wit, 1983). Even though goats can feed up to 8% of their bodyweight (Ranvig & Hansen, 1999), the maintenance level per metabolic kilogram of the BW is higher than that of larger animals, such as cattle or horses. Comparing the values of the quality of the grasses in April/May (see chapter 4.3.2 for grass, and 4.3.3 for the woody resources) with the nutrient requirements of livestock, this should at least result in a crude protein and phosphorus deficit, especially in the case of Mutompo (assuming that livestock feeds on mixed grass species without selection and ignoring leaves as additional fodder).

Number, type, and bodyweight of livestock were needed, in order to calculate detailed livestock requirements, and the differences between feeding behaviours of grazers and browsers also had to be considered. In Okamboro, the households kept 1,740 heads of livestock in total and 437 heads (without donkeys) in Mutompo (see Table 7, p. 31). The disposition of grazers and browsers results from the herd structure with around 75% grazers and 25% browsers of both communities, based on the distribution of the different livestock species, as described in Table A 16 the appendix. Only the considerably higher number of livestock alludes to the differences in agricultural systems of the two communities. However, Okamboro had about twice the number of households than Mutompo, but not twice the size of grazing area.

Separate values for grazers and browsers for the entire amount of livestock of each community within a model show the potential of stocking and the new recommended livestock weights and numbers during the ‘post WS-period’ (Table 37, and Table A 23 in the appendix). The period 8 months after the WS was selected, in order to represent the utilization of the peak biomass production by the livestock. This ‘post WS-period’ included a dry period of about 3 to 4 months subsequent to the sampling in April /May 2003 (see also explanation on p. 118).

Table 37: Potential stocking and livestock numbers of animals in the post WS-period

Type		Share of resources used[1] (%), and limitations in parenthesis	Additional stocking potential (kg; no.)	New stocking level (kg; no.)	New stocking level (kg/ha)	New stocking level: Share of initial value (%)
Mutompo						
Grazer	BW (kg)	16.2 (CP)	36,345	79,716	11.3	184
Grazer	No. (n)	16.2 (CP)	199	436		
Browser	BW (kg)	2.9 (BM)	14,038	28,495	7.4	197
Browser	No. (n)	2.9 (BM)	194	394		
Total	BW (kg)		50,383	108,211 (26.3% browser)	28.1	177
Total	No. (n)		393	830		
Okamboro						
Grazer	BW (kg)	3,032 (BM)	0	0	0.0	0
Grazer	No. (n)	3,032 (BM)	0	0		0
Browser	BW (kg)	14.4 (BM)	49,998	108,408	18.7	186
Browser	No. (n)	14.4 (BM)	562	1,218		
Total	BW (kg)		49,998	108,408 (browser only)	18.7 (browser only)	(44.5)
Total	No. (n)		562	1,218 (browser only)		

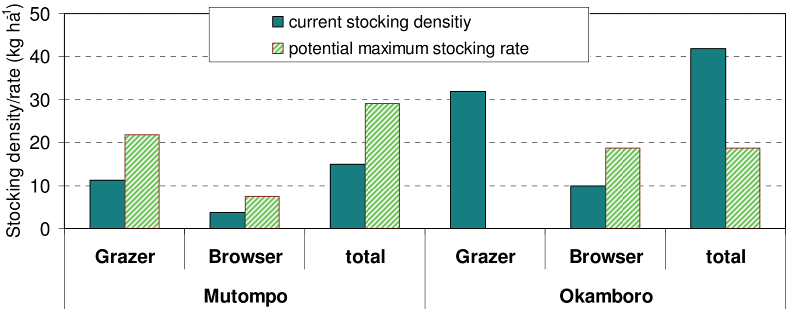
[1]Selection of highest values of utilization from calculations for biomass, energy or protein availabilities. BW – bodyweight, No. – number of livestock; CP – crude protein; BM – biomass. (Table for the DS and the post WS-period see appendix Table A 24).

In Table A 23 it was investigated, what type of the grass quality or quantity parameters (metabolisable energy, crude protein, or biomass) most likely indicates a limit for the stocking rates. The quality of grass resources, particularly the crude protein, is supposedly the limiting factor in the ‘post WS-period’ for grazers (cattle, horses, donkeys, and mainly sheep; for classification of the feeding behaviour see Table A 17 in the appendix) in Mutompo. During the DS-period, in both communities, the crude protein content of the grasses is the most likely limiting factor, whereas for browsers (goats, to a less extent also sheep and cattle), the browser biomass was the most expected limiting factor in both communities and for all calculated periods (Table A 23 in the appendix). However, with the current livestock numbers of Mutompo, grazers used only 16.2% of the grazing resources (Table 37), and the rangeland was not over utilised. The values, shown in Table 37, were always the highest percentages of utilised forage biomass, metabolisable energy or crude protein found in Table A 23. Browsers used only less than 3% of the the BecVol-calculated available browse biomass (≤ 1.5 m height) during both seasons in Mutompo, and 13.3% (DS 2002/03) and 14.4% (WS 2003) in Okamboro.

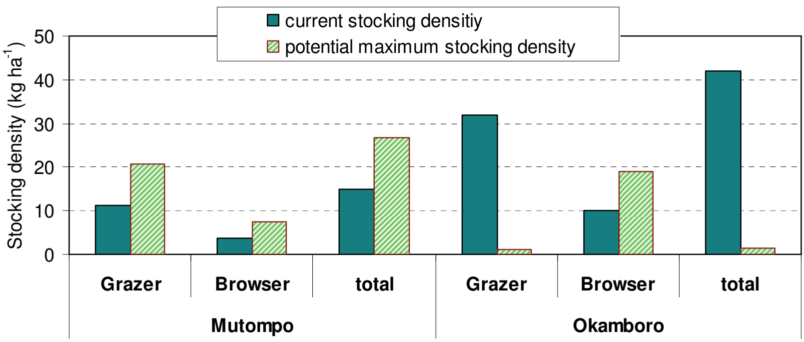
In Mutompo, an additional potential for 77% of current livestock numbers was detected by this calculation, whereas 26.3% of them should have been mainly browsers. Baas (1993) found for Central Somalia that the energy content of the vegetation during the DS limits the stocking rates. He stated that in areas with bimodular rainy seasons, energy restricts livestock keeping during the DS, because lot of plants are evergreen around the year, which corresponds with the model used by Schwartz & Walsh (1991) for Northern Kenya. Nevertheless, in areas with monomodular rainfall, the protein content of the vegetation is the limiting factor (Baas, 1993), although, Knemeyer (1985) based his carrying capacity calculation for potentional wildlife stocking in Namibia on the energy content of browse and grass during the DS. In this study, either the vegetation biomass or the crude protein content was the limiting factor during the DS-period, which can both cause a reduction of bodyweight and limit the productivity of livestock.

As mentioned earlier, in Okamboro, the wet season of 2002/03 was actually a drought. Calculations detect a vast deficit for grazers, mainly cattle, which constitute for 88% of the total livestock bodyweight (see Table 7, p. 31). According to the calculation of the grazing potential, no grazers were allowed to graze sufficiently on Okamboros' rangelands in the WS 2002/03; the previous number was 1,084 animals (or 31.9 kg/ha stocking density; Table 37, and Table A 24 in the appendix). Thus, this lead to a reduction of grazers through selling, slaughtering, or moving all heads, mainly cattle, or 184,963 kg of grazers' bodyweight (Table A 26 in the appendix). Despite the drought during the WS in Okamboro, there is an additional potential focussing on browsers. Theoretically, they used up only 14.4% of the available browsing resources during the 8 post WS-months. Despite the drought situation in Okamboro in May 2003, goats, which are mainly browsers, were in good condition, due their ability to find other fodder niches, such as litter and *Acacia* pods. In total, according to these calculations, around 1,218 animals (or 109,809 kg of BW) could be stocked in the area of Okamboro, whereas all of them should have belonged to the browser category (Table 37). This high reduction of cattle could mean a switch to more browsers, such as goats, during drought years.

The calculated potential stocking rates, shown in Figure 38 A and B, are derived from calculations of the nutrient balances, integrating the quality of resources, and separating the different feeding behaviours of grazers and browsers (Table A 23, and Table A 24 in the appendix). The calculated stocking densities of total livestock in 2001 were 15.0 kg ha^{-1} for Mutompo and 41.9 kg ha^{-1} for Okamboro (Table 33, p. 140). Assuming the dry season period is the main limiting factor for optimal stocking rates, as some authors suggest (see e.g. Knemeyer, 1985; Baas, 1993), and since resources are becoming very scarce and the quality of forage is decreasing, the stocking rate during dry seasons therefore needs to be considered as an adaptable value of a conservative stocking rate.



A) During the DS-months



B) During the post WS-months

Figure 38 A and B: Current and potential stocking during the DS and WS-months

However, due to the choice of different lengths of periods for the DS (3 months) and the post WS-months (8 months) as well as the seasonal corrections, calculated stocking rates were similar in in both seasons for Mutompo (Figure 38 A and B). The relatively long 8-months-period (referring to the samplings in May 2003) included those months of the DS, ranging up to the first rainfall of the following season, therefore comprising the period of greatest forage scarcity. Therefore, the post WS-months are used as a reference for the appropriate grazing and browsing capacity for the investigated season.

In spite of a high percentage of cattle 88% of the total livestock weight, there was still a potential for grazers in Mutompo, but not in Okamboro, for both seasons during the investigated periods. Current grazers' stocking densities were 11.2 kg ha^{-1} in Mutompo and 31.9 kg ha^{-1} in Okamboro (Table 33, p. 140). The potential stocking rates for grazers were 21.7 kg ha^{-1} during the DS-months during the post WS-period for Mutompo (see Figure 38 B). In Mutompo, for all livestock, a potential of almost 50% was discovered (current value: 15.0 kg ha^{-1}; potential maximum value: 29.1 kg ha^{-1} during DS and 28.1 kg ha^{-1} during the post WS-period).

In Okamboro, due to the crude-protein deficit of 2.3% occurring during the DS-month there is no potential for grazer (current value: 32.9 kg ha^{-1}), a high potential was found for the browsers (plus 8.7 kg ha^{-1}). For the total potential livestock density, which is obtained by simply adding up the potential values for grazers and browsers (Figure 38 B), the results show that the current stocking densities (41.9 kg ha^{-1}) exceeded the potential values by nearly double with an amount of 21.7 kg ha^{-1}, during the drought-stricken post WS-period in Okamboro. For the duration of the DS months, a similar potentially total stocking rate value of 18.7 kg ha^{-1} for browsers was found.

Browsing resources were possibly overestimated for the period of the DS-months, as well as the stocking rate of browsers in this season. A share of 39.7% of the WS-values was used for the DS period nutrient balance calculation, which was just an assumption, for most of the trees and shrubs were without leaves during the DS-period. Still, the leaf biomass of trees and bushes above the 1.5 m height were accessible for livestock when they became litter. Cattle in Mutompo for instance, were observed to feed on litter, while no other feeding resources were available within a burned area. In Okamboro, cattle started to browse on bushes during the drought-stricken post WS-period of 2002/2003.

During the DS-period in Okamboro, which followed the rainy season 2001/2002, in which also only an amount of 248 mm of rain fell (see Table 4, p. 22, and Figure 4, p. 23) a slight deficit of protein for grazers was detected, which meant a slight overstocking of 2.3% of the grazers' BW. Assuming a long-term mean rainfall of 360 mm, or the presumed value according to Kempf (2000) for the Okahandja region of 291 mm (see Table 34, p. 142), the expected grazing resources would probably meet the requirement of current grazers' stocking for livestock on a maintenance level or on a very low production level.

Nevertehless, regarding only the utilization of the grass biomass in the DS-period in Okamboro, whereas 62% of the grass BM was used, a stocking potential of 44.4 kg/ha of grazers would have been detected (plus 12.2 kg/ha). Grazing resources should be used more homogenously in the rangelands of Okamboro, and farmers should seize the opportunity of improving their livestock management practises, including breeding strategies, herding, supplement feeding and health care, in order to maintain livestock in good condition round the year to enhance productivity, and to reduce the vulnerability for diseases and nutrient deficits.

Yet, possibly some key resources (Illius et al., 1998; Scoones, 1995a) were underrated. They exist e.g. along the dry riverbed located in the grazing area of Okamboro, where most of the trees become green early before the first rainfall and keep green leaves very long, as well as some grasses, which grow when the grasses around this area have turned brown and dry. These key resources could buffer the biomass deficit during a drought, when they are protected during times when plenty of forage resources are available. Using the definitely low-quality standing “hay on the stem” of peripherial areas in the community could also be a way to overcome the biomass deficit. Through the lopping of green twigs beyond the reach of goats and cattle, by the collection and storage of litter, similar to hay-making, or by improved silage making (with urea or sodium bicarbonate, see Els et al., 1999), this more or less unused resource could be made available to the livestock. Supplement feeding with purchased fodder, establishing stock posts in the peripherial areas of the community, or moving a part of the cattle to areas with more rainfall (even within the Ovitoto area itself), are all possible strategies for coping with a drought situation in Okamboro.

Assuming that livestock feed on mixed grass species without selection, the nutrient requirement could at least result in a crude protein or a phosphorus deficit. However, this supposition on feeding behaviour is not realistic. Cattle - less than sheep and goats - will select nutrient-rich forage in natural pastures in order to meet their requirements, as long as sufficient biomass and diverse plant species are available. Selective behaviour of livestock, such as described e.g. by Squires (1982), Breman & de Wit (1983), Glatzle (1990), Baas (1993), Ayantunde et al. (1999); Breman & de Wit (1983), Hendricks et al., (2002), and Rothauge et al. (2004) for different livestock species, would buffer a potential protein deficit of grazers, caused by a low protein content of grass species during the DS-period. A protein deficit is likely to occur occasionally in both communities, especially in the late DS months, or during a severe drought. Pregnant or lactating cows, oxen under the plough, and young, growing animals suffer more from a protein deficit than adult animals merely having to supply their requirements on a maintenance level. When repeating the stocking rate calculations for grazers, and considering a higher protein content of 54.2% in selected fodder of grazers than is naturally offered to cows in the camel thorn tree savanna of central Namibia (Rothauge et al., 2004), the deficit during the 3 months of DS in Okamboro could be extinguished. However, it has to be a sufficient amount of natural fodder on rangelands available for feeding selection of livestock. Instead of a minor overstocking of grazers of 102.3%, based on the utilization of a theoretical CP content of grasses, which resulted in the destocking of the grazers (see Table A 24 in the appendix), the use of the CP would be only 66.4%. This would finally result in a potential of 1,448 grazers, and a new potential stocking rate of 42.6 kg ha^{-1}, instead of the current value of 31.9 kg ha^{-1}. Through the integration of forage selection, the new potential total stocking level for Okamboro during the 3 months DS-period would increase to a value of 62.2 kg ha^{-1}; the current stocking density is 41.9 kg ha^{-1}. Nonetheless, in the case of the drought-stricken post WS-period of 2003 in Okamboro, the enormous deficit relating to the grazers was referred to lacking grass BM (see Table 37. p. 147), thus, selective feeding was not possible.

In Okamboro, the share of actually utilised rangeland resources was higher than in Mutompo; values were calculated within the same timeframes, but with lower assumed proper use factors than for Mutompo (see Table A 23 in the appendix). Current livestock used theoretically a maximum of 102.3% of The CP content of forage resources in the DS months in Okamboro, in contrast to only 10.6% of the CP in Mutompo (Table A 24 in the appendix). These results indicate a slight overstocking in Okamboro, even during the season of 2001/2002, which is represented in the DS 2002 resources of October. The results of the drought-stricken season 2002/03 are not representative for a normal rainfall year, but then again, droughts are common in the semi-arid conditions of Namibia. This kind of drought situation or also an extreme rainfall event is repeated approximately every 6 to 9 years (Sweet, 1998b). Due to the 248 mm of temporarily unevenly distributed rainfall during the rainy season 2002/2003 in Okamboro (see Figure 5, p. 23), very little vegetation covered the ground in May 2003. The young grass was very short and with little biomass, yet a shoot of inflorescence for an early and fast seed production ensured a just-in-time reproduction. Mostly annual grasses and some herb species were found growing, but all of them with little biomass production, which means there was not enough biomass available to meet the requirements of livestock. It seems likely that cattle or horses were not able to ingest enough biomass to fill their rumens or stomachs sufficiently, irrespective of protein or energy values, as well as a presumable prolonging of grazing times throughout nighttimes, as observed for cattle.

Especially cows and their calves were found to be in a bad condition during the PHT-survey in May/June 2003, carried out by Lange (2004, unpublished). The mean body condition scores of the investigated cows in Okamboro (about 12% of total cow number) lay at 2.5, which means thin to normal, on a range of 1 to 5. However, 51 % of these cows had a condition score of two (thin). In Mutompo, the investigated cows (about 24% of total cow population) were in a better condition, with a mean score of 3 (normal) in May/June 2003, even though rainfall was less than normal. The last severe droughts in the Okamboro area occurred in 1988/89, from 1991 until 1993 (described in Sweet, 1998b), and in 1995/96. During the latter, some farmers from Okamboro reported a high frequency of losses (7 – 57% of the total herd) of their livestock due to death. In addition, the mortality of livestock seems to be increased, when another follows a season with dramatically reduced rainfall. For Mutompo, no detailed information was obtainable for the concurrency of droughts. In 2002/2003, less rainfall than the long-term average was measured, but it seemed not to have been a drought for the Kavango region (see Figure 3, p. 23).

The recommended stocking rate, according to the model of Sweet (1998a) was much higher for Mutompo at any time, than the current stocking value (Table 36, p. 145). Sweet's model did not consider the different seasons, but took the peak biomass value during the WS as the key value for calculation (see Table A 15 in the appendix). In Okamboro, the current stocking density of 41.9 kg ha^{-1} exceeded the assumed value of Sweet. Of course, during the months following the WS, the maximum potential stocking rate calculated in this study, was much lower than that recommended by Sweet, because in the recent study it was derived from the actually measured vegetation biomass and quality, and not purely on the rainfall amount and the empirical formula, in order to estimate the biomass amount. There was even a higher maximum potential stocking rate value during the DS-months in Okamboro, compared to the recommended carrying capacity calculated by Sweet's model.

Farmers, extension officers and researchers had initially calculated the recommended stocking rates from only common values of grass biomass of the WS maximum (e.g. the Grazing Register based on the biomass concept from Bester & MAWRD, 2003). If the total available grass and browse resources analysed in this study (see Table A 21 and Table A 22 in the appendix), were considered as merely pooled, ignoring the feeding behaviour of the different livestock species as grazer and browser, the maximum calculated stocking rate during the DS-months would theoretically have made up to 28.5 kg ha^{-1} in Mutompo, and 60.3 kg ha^{-1} in Okamboro. During the post WS-period, the values would have scored 28.3 kg ha^{-1} in Mutompo, and even so 58.5 kg ha^{-1} in Okamboro. In Mutompo, the pooled rangeland resources resulted in similar values, when considering the different grazing behaviours of livestock and no deficits were found. In Okamboro, the deficit for the grazers during both seasons was not really considered in the values of the pooled resources, leading to a much higher value of stocking rates. This does not reflect the real situation, but is the common way of calculating the carrying capacity of the rangelands. Lower values would be the result, if browsing resources were not integrated in these calculations.

Usually, the maximum standing herb (or forb) biomass, and partly also their quality, is used in models, as a reference to calculate the grazing or carrying capacity of a land. Thus, it can lead to unrealistic estimates, when applied to the communal farming system, even when the DS and WS-periods are considered, but the feeding behaviour of the regularly mixed herds is ignored. Therefore, the output of the methods and formulae used in this recent study should be called grazing and browsing capacity (GBC), instead of just grazing capacity (G).

Even though goats accounted for only 12% of the total live bodyweight of the livestock in the respective communities, their stock should be encouraged. Goats use different feeding resources than cattle; they are more flexible and better selectors in utilizing fodder resources (Ranvig & Hansen, 1999, Ngwa et al., 2000; Kamupingene & Abate, 2004); Magadzire et al., 2005), and their main feeding resource, such as leaves and sprouts, are most probably less effected by droughts. Browse as a feeding resource, has the advantage of a high protein level and some of the early sprouting trees provide forage even during the end of the DS. Goats are well adapted to the semi-arid environment of Namibia, therefore it is highly recommended to increase the numbers of goats on the communal land, and also to use the milk of these animals to a greater extent. Goats would provide households with animals of lower prices, which can be sold or exchanged more easily, because they are smaller and cheaper. Additionally, they have a higher reproduction rate and are more successful in coping with the variable environment and droughts (Silanikove, 2000; Magadzire et al., 2005). Particularly for poorer households, which can not afford buying a cow, or for which the investment in cattle which is too high of a risk, the alternative is to start livestock keeping with a small flock of goats, which could be a relatively swift way out of absolute poverty. Bester & Reed (1997) and Omphilie et al. (2003) stated that goats can also prevent bush encroachment of some thorny bush species, which represents a big problem especially on commercially managed farms in Namibia. Communally managed mixed herds of large and small ruminants are still widespread, thus, bush encroachment is not yet of large importance in communal areas of Namibia. Nevertheless, livestock keeping in the semi-arid Namibia, especially in communal grazing areas, should remain on an extensive level, combined with very good resource and herd management, including regular additional inputs (licks) and supplement fodder during periods of fodder deficiency. Additionally, small or large scale mobility is necessary to preserve the grazing and browsing pressure on a sustainable level. Even browse under high feeding pressure needs at least a resting period in order to regenerate. All of these measures are not very common within both investigated communities, due to different reasons.

In order to test whether a deficit of P or Ca occurs for the current livestock and if so, to establish when this happens, the P- and Ca-requirements of current livestock of the communities were calculated (Table A 25 in the appendix) and compared with the supply of grass and browse resources. Table A 26 in the appendix show these results, which are based on the available forage resources and the daily ration of livestock, particularly for grass and browse resources. In Mutompo, the macro element content of grass and browse was always lower than that of Okamboro. A deficit of P or Ca could cause severe problems in body growth, health and in fertility. Based on the daily forage intake (assumed to be 2.5% of live bodyweight) of the livestock, the P contents of grass are not sufficient to meet the requirements of mainly grazer in Okamboro in the post-WS period, averaging a bodyweight of 350 kg (Table A 26 in the appendix). There is no deficit of a Ca supply at all in Okamboro and Mutompo, just as no deficits of P were found for browsers in Okamboro and for grazers and browsers in Mutompo. Grazer need to supplement their P-needs with more browsing resources, or should be fed with additional phosphorus, such as mineral licks in Okamboro. In Okamboro, farmers provide their livestock with salt licks bought from AGRA, which is an agricultural shop in Okahandja. Phosphorus and calcium analyses of these natural salt-stones resulted in values of 3.22% for Ca, and 0.01% for P. The P-value is higher than that in the analysed soil-P. However, this salt lick cannot sufficiently supplement the P-requirements of the livestock in Okamboro, hence a higher P-content, comparable to that in mineral fodder, is necessary. The value for Ca in these licks is very high, compared to the soil-samples and the grass analyses. This natural salt-stone contains mainly NaCl, as well as a lot of other micro- and macro-elements, which were not further analysed, but are useful for livestock.

An estimation of the amount of crop residues as supplement fodder in Mutompo in northern Namibia needs to be based on literature data for crop yields in this area, because no yield measurements or estimations have been carried out. Powell (1985) made investigations on the relationship between grain yield and vegetative biomass yield, which can theoretically be consumed by livestock (in Preston, 1986). Millet is the main crop in the Kavango region; therefore, the following calculations focus on millet. Assuming a total harvest of 200 to 400 kg per ha for millet in the northern regions of Namibia (see Keyler, 1995; in McDonagh & Hillyer, 2003), the millet residue biomass adds up to 1,100 – 2,366 kg (see Table 38). However, in the same study, Powell (1985) differentiates the plant-parts, which vary in their relative nutrient content and digestibility. Only 75% of the leaf biomass and about 20% of the stalk are consumable parts for livestock. For an estimated mean yield of 350 kg ha^{-1}, the amount of consumable crop residues was at 566.6 kg ha^{-1} (Table 38). These crop residues can serve as livestock fodder, and it should be considered in the estimates of livestock potential in Mutompo. This plant biomass could also be used as green manure on the fields, in order to improve soil structure and as a possible means to increase soil fertility.

Table 38: Potential consumable leaf and stalk biomass of millet in Mutompo

Crop species	Part of plant	Regression model[1]	Millet or millet residues (kg ha^{-1})
Millet	Leaves	y = 78 + 0.92 x	400.0
Millet	Stalks	y = 178 + 3.3 x	1,333.0
		Sum	1,733.0
Consumable parts	75% of leaves		300.0
	20% of stalks		266.6
Sum of consumable millet residues			566.6 (32.7% of total)

[1]Assumption: mean grain yield of 350 kg ha^{-1}. Source: Powell (1985).

In Mutompo, around 200 ha of the total communal area are used for crop production. The share of millet amongst these crops laid around 74% (Yaron et al., 1992), which means that around 150 ha of all fields were cropped with millet, which results in 85 tons of crops residues. However, it was also observed, that some fields or parts of fields were not in use and lay fallow for longer periods of time. On the other hand, the 11 households who declared to be growing crops, then had an average field size of 15.47 ha (200 ha divided by 13 fields). This did not reflect the observed situation – fields for corpping are smaller. The areas cultivated by each household vary in northern Namibia, and are reported to be between 1.4 and 6.7 hectares in size, in the Kavango region, (Jones.B.T.B. & Cownie, 2001); or between three and six hectares in the inland Kavango region (Mendelsohn & el Obeid, 2003). Only very few, as well as the richer households can manage to crop larger areas, due to a resulting higher workload, with relatively low available human power. Thus, the amount of calculated crop residues was overestimated, in relation to the sizes of tilled fields per household. Calculations for consequently 6 ha per household (6 ha * 11 HH = 66 ha, 74% millet: ~ 49 ha millet fields), resulted in estimated 27.8 t of consumable parts of millet crop residues, which is a more realistic figure then the 85 t of crop residues from 150 ha mentioned above. Assuming these low harvesting amounts, and that the calculations according to Powell (1985) are adaptable to northern Namibia, the crop residues amount to only 2% of the estimated available grass resources of the whole community. If these crop residues are not collected and properly stored, not improved by urea treatments and fermentation, and then not fed to pregnant cows, young calves or bulls, it will not differ much for the maximum potential stocking rates, shown in Figure 38 A and B (p. 149), neither will it have effects on or improve livestock productivity. Moreover, the quality of cereal residues has been poor (low protein content, poor digestibility). Nutrient analysis of millet stover in Zambia found a nutrient content of 3.98% crude protein, 37.02% crude fibre, 0.19% Ca and 0.03% P (Siulapwa & Simukoko, 2000). At best, it is just good enough to prevent animals from losing weight and cover their maintenance requirements (Anonymous, 2004). Although free roaming livestock did nibble on crop residues lying on fields immediately after harvest in Mutompo, this additional resource could be used much more effectively. It could be collected and stored, and used expediently for oxen through strategic supplementation in the late dry season, in order to make up for high bodyweight losses and nutrient deficits, so that oxen have plenty of power when they start ploughing in early wet season. Crop residues could also enforce the fattening of e.g. young bulls in order to get a better price for higher bodyweight when selling the animal. Fodder supplementation and measurements to improve crop residues are common in the commercial farming systems in Namibia (Els et al., 1999), but are not common practises in the communal areas. Reasons for this seem to be the high costs of e.g. licks, as well as the lack of transport. Poor infrastructure in the rural areas is probably another reason.

The use of licks (e.g. a summer (WS) P supply lick, a winter (DS) protein supply lick and a production lick which is a supply of protein, energy and P), and supplement feeding with maize stover and maize grain from own production, 'chocolate maize' or urea treated crop residues, or fodder from planted pastures (especially *Cenchrus ciliaris*) are described by Els et al. (1999), such as practised within the commercial sector in Namibia. In communal areas, farmers do not provide enough licks to their animals, and the available crop residues are not stored or urea treated (Els et al., 1999). The easiest way to treat crop residues was a simple and cheap pit design (e.g. with mud bricks and mud coating; or a dug pit with cement coating) (Els et al., 1999). Alternatively, the failed crop material could be used, if it were harvested early enough and stored in plastic/ polythene bags, and then be conserved as silage, which after it has been fermented, has conserved its nutritional value and would be accepted eagerly by the animals.

A crucial point within the calculation of stocking rates of this kind in general, is that the proper use factor or the PU-value is just an estimation, and depends on several factors; e.g. the grazing intensity, the available forage and its quality (protein and energy content), which determine the DMI of livestock. In addition, the assumption of the dry matter intake rate (DMI) of 2.5 to 3% of the bodyweight is variable, and differs with the fodder quality and the livestock species. The DMI standard is given for conditions in the USA, e.g. by the National Research Council (NRC), for stall-fed sheep, beef cattle, dairy cattle and goats. These lay above those required for subsistence pastoralism[31]. An appropriate value of 1.5 to 2.0% of body weight can be taken as the daily maintenance requirement of cattle and

[31] As the Standing Committee on Agriculture (1990) stated *'most of the schemes developed in other feeding standard systems are applicable only to housed or other hand-fed animals. In other words, these intake formulae estimate what animals need to consume to meet energy requirements, not what they will consume ad libitum. Therefore, in many instances, voluntary intake of ruminants in free-ranging conditions exceeds that predicted by NRC (1987) or ARC (1980) intake equations.'*

sheep (FAO, 1991). However, the digestibility and the fibre content of the natural forage in pastures, which fluctuate seasonally in semi-arid rangelands, have a strong influence on DMI (DeRamus, 2004), and DMI rates differ also among livestock species, and probably also among the diverse breeds. Baars (2002) expressed grazing capacity in terms of a tropical livestock unit (TLU) weighing 250 kg with a daily DMI of 2.0% of live weight. Yet, considering the daily DMI, the quality of BM and livestock production levels are significantly higher during the WS (Baars, 2002). In the literature, utilization rates or the proper use values for good quality forage in arid areas are recommended as 50% or less (de Leeuw & Tothill, 1993), in order to prevent degradation. Baars (2002) even defines the percent utilization of poor and moderate quality grasses in a range between 5 to 30%, which is related to the protein content and the resulting DMI. The better quality grasses in his model were considered maximum percentage of utilization values of 30 to 50% (Baars, 2002). Keya (1998) analysed the percentage utilised by livestock and found higher values, e.g. a graminoid removal of 57.1 to 99.8% in a semi-arid zone in northern Kenya, and 24.2 to 87.2% for an arid zone (standing grass biomass under non grazed conditions in the arid zone: 55.3 kg ha^{-1}; in the semi-arid zone: 184.4 kg ha^{-1}). In addition, for the dwarf shrub layer, the percentage of utilization values lay between 40.5% and 92.3% in his study (Keya, 1998). Maximum stocking rates were estimated to be 109.3 kg ha^{-1} and 104.0 kg ha^{-1}, respectively, which were very high stocking values; but no accurate estimates were available (Keya, 1998). With such high stocking rates, livestock controlled the vegetation by grazing and browsing, and this explains the high percentage of utilization, which was not the reality within the investigated communities.

In order to get an idea of the actual percentage of utilization of grazing resources in Okamboro, grazing exclosures as fence-covered cages were installed within the grazing areas. Due to the poor infrastructure in Mutompo, this experimental design could not be successfully carried out there. Only 9 cages were analysed in Okamboro, because three of the initially 12 cages were moved away from their original location, probably by curious cattle. Due to the small number of cages analysed, the standard deviation is relatively high. Additionally, during the time of the grass collection during late rainy season (May 2003) the drought situation already described occurred, which influenced the results in an unpredictable way. The amount of grass biomass inside the exclosure is significantly higher than outside (Table 39). Only 27% of the grass biomass inside was collected on the outside, meaning that 73% of the grass biomass outside was used by the livestock. In comparison to the May 2003 mean of the grass biomass from the transect sampling points (1.3 g m^{-2}) the values were nearly three times higher outside and near the cages.

Table 39: Means and tests on the effect of grazing exclosures in Okamboro during the wet season

(n = 9)	Inside mean	Outside mean	SD	Differences (± SE)	t-value	df	Error probability
Grass biomass (g m^{-2})	11.99	3.23	9.77	3.26	2.69	8	0.028
Number of grass species (n m^{-2})	2.89	2.11	1.20	0.40	1.94	8	0.088

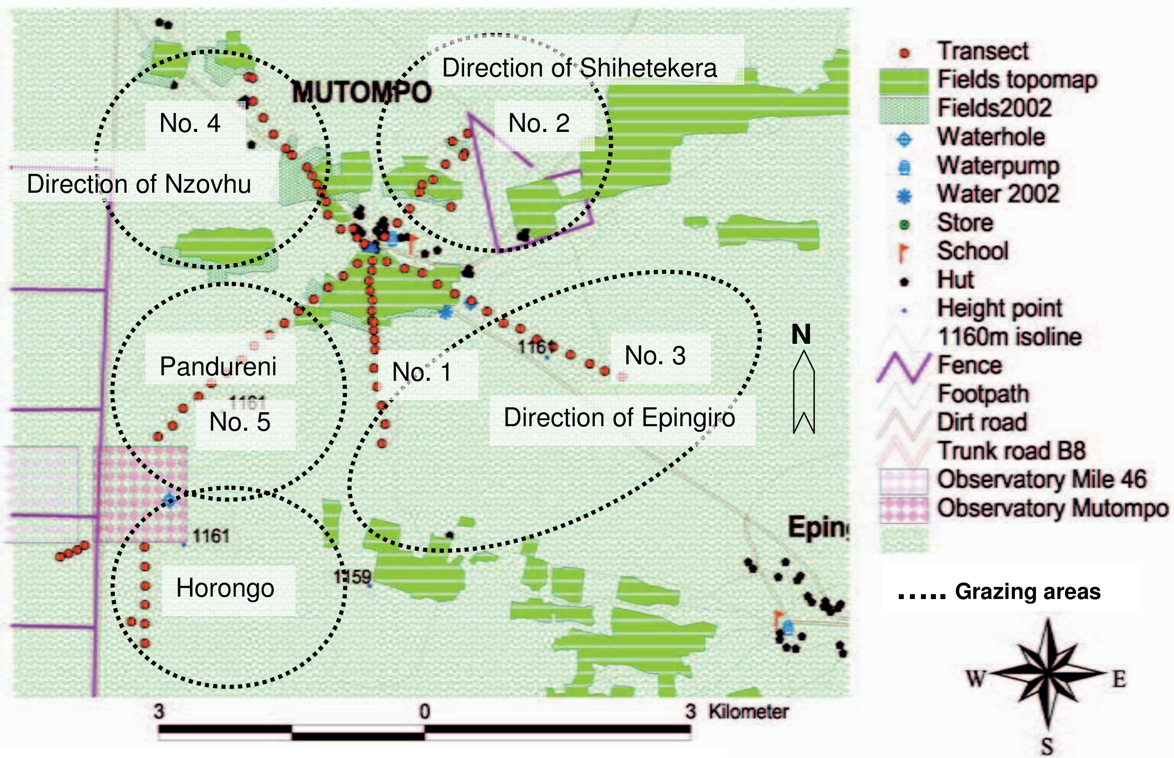
The main consideration regarding grazing exclosures is their positive or negative side effect on herbage growth (t' Mannetje (1978), in t' Mannetje & Jones, 2000). Negative effects could have been caused by reduced light intensity; temperature differences are likely to be negligible. The positive effects on the microclimate can improve the seedling establishment. A better micro-climate, with regard to wind velocity and increased relative humidity, or lower transpiration and evaporation inside the cages could have lead to an improved vegetation growth. Values of the number of grass species were higher inside the exclosures, but showed only a lower level of significance ($p \leq 0.10$). The value of 2.89 grass species m^{-2} inside the exclosures (Table 39) was comparable with the value found in Okamboro during the WS 2002/3 (mean 2.7 species m^{-2}) and also with the DS 2002 value of 2.75 species m^{-2} (see Table 11, p. 57). These findings can be interpreted as follows: livestock or wildlife utilised approximately 73% of the grass biomass, unless the biomass was trampled or somehow destroyed by livestock or wildlife, assuming insects and small mammals consumed similar amounts inside and outside the cages, ignoring the possible positive side-effects due to the resulting microclimate inside. Wildlife numbers can be neglected, so that in total the grass BM calculated was probably actually used by domestic stock. The proper use factors applied to the calculation of the forage capacity in Okamboro, were estimated to be around only 30%, according to Ma (1996; see p. 115/116). Additionally, for the calculation of carrying capacities, a utilization value less than 50% is recommended, in order to prevent rangeland degradation and a long-term damage of the vegetation. In reality, and during the drought situation in Okamboro, the livestock (here mainly grazers) utilised the grass BM to a much higher degree, probably due to the spacious scarcity of vegetation biomass in this special climate situation, and to try to meet their forage demands at least partially. However, the loss of vegetation through insects, especially termites, and by trampling and desiccation is probably also very high and difficult to estimate. Chandler (1983, in Baars, 2002) suggested that 70 to 80% of the total fodder available is lost due to trampling, termites and desiccation, and in certain areas, also to wildlife. Still, these losses by insects occurred also within the cages, thus, they could be neglected for an inside-outside comparison.

An approximate fraction of herbs of the total vegetation biomass (according to Knemeyer, 1985) was integrated in these nutrient balance calculations. However, they probably play a more important role within the first hundred meters around the water point, especially in Okamboro during the drought-stricken post WS-period. Todd (2006) found a relative high species number and a cover of 1% up to 200 m distance from the water place in paddocks on a farm in the Nama-Karoo shrub land (South Africa), which decreased with increasing distance. In Okamboro, on some less grazed areas, a relative high amount of herbs was found, but was not quantified.

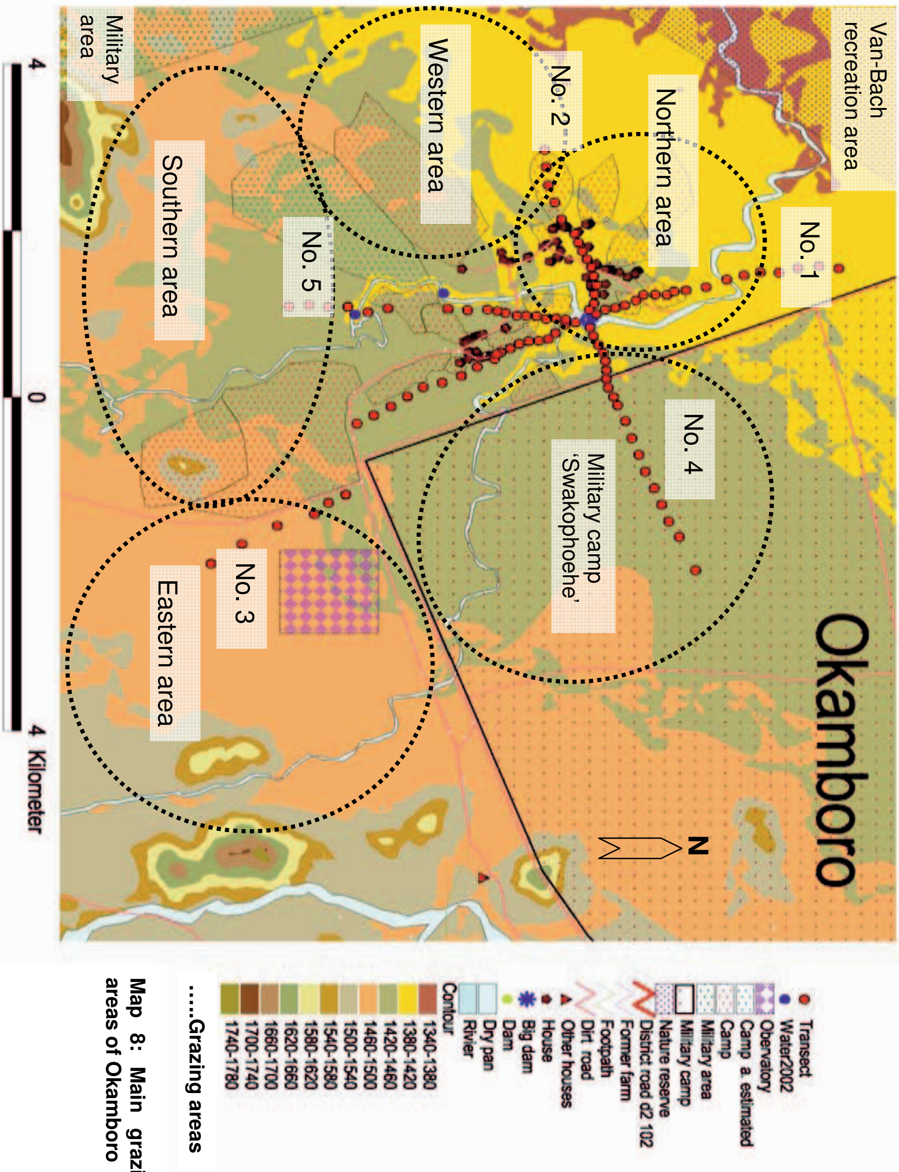
Due to the only estimated values for PU and the DMI, this type of calculation can only be used as a rough locally adapted guideline. Additionally, in semi-arid environments such as in Namibia, with its high rainfall variability, a sampling design of this broad extent, similar to this study, needs to be repeated for several years. Afterwards, when the current fundamental rangeland condition and forage quality are known, a reduced number of samplings would be sufficient, in order to analyse any changes - best twice a year (once during the time of peak biomass in the WS, and again within the late DS). Within these rangeland evaluations, more emphasis should be laid on the species level of some of the prevalent forage grass and bush species, which would have to be identified first. The key fodder species differ regionally, depending on the biophysical and climate conditions of the area. The different feeding behaviour of the animals in the herds needs to be considered in any case, when mixed herds of both grazers and browsers are kept on a rangeland.

5.3.5 Use of grazing areas and farmers' preferences

The grazing areas in Mutompo are located in the surroundings of the central watering point (see Map 7). Grazing areas were identified in the direction of Nzovhu in the northwest, in direction of Shihetekera (northeast), Epingiro (southeast), as well as in Horongo (southwest) and Pandureni (west) (see Map 7).
The grazing areas in Okamboro are directed in the surroundings of the central watering point for animals, which is a sand-filled dam (see Map 4, p. 40, and Map 8). Grazing areas were identified into the directions of the north, west, south and east, and an area referred to as 'military camp', which is also used irregularly as a military training area, called 'Swakophoehe' on the maps (Map 8). In Okamboro, as mentioned before, livestock is not herded round the year; therefore, no seasonal differentiation was necessary.



Map 7: Main grazing areas of Mutompo



Map 8: Main grazing areas of Okamboro

The western border of Okamboro is particularly well defined by the fences of a governmental military training area, as well as further north, by a fence to the Van-Bach recreation area (see Map 8). Towards the east, the communal grazing area borders the enclosed military camp 'Swakophoehe'. Nevertheless, the fence was partly damaged and permeable for livestock. Towards the southeast and south, the borders are not marked, and areas are shared with the livestock of other communities of Ovitoto, such as the Bullskop-settlement and Ombupoori.

Areas in the west (Pandoreni) and southwest (Horongo) were highly rated (Figure 39), while the grazing areas in the other directions were not liked at all[32]. In comparison to the other areas, all two mostly preferred areas were light dry forest areas, which were made up of mainly large trees, as well as some grass, and smaller shrubs and bushes covering the ground. The other herding-direction in the northwest towards Nzovhu was only used and favoured by two households living in the northwest of the community area of Mutompo. The disliked areas in the direction of Nzovhu and Shihetekera are partly covered by dense shrub vegetation, probably located on a more fertile red-soil zone, passing through the Mutompo area in an east-west alignment.

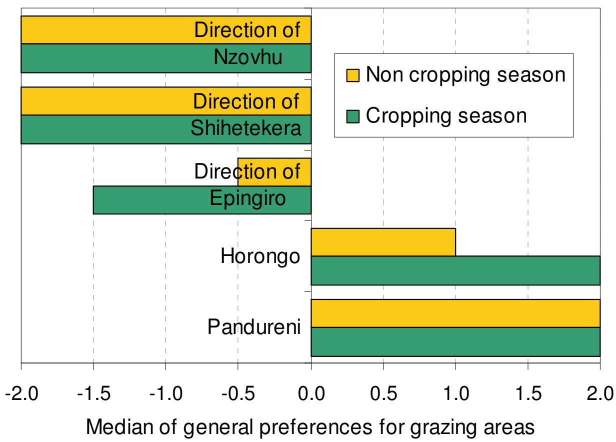


Figure 39: General preference of grazing areas in Mutompo

(n=7; -2 = do not like, 2 = do much like)

[32] Wilcoxon significance tests (conducted by Falk, 2007) proved that Pandureni and Horongo are in the cropping season significantly more favoured than the direction of Nzovhu and Shihetekera. Pandureni is also in the cropping season significantly more preferred than the direction of Epingiro, Nzovhu and Shihetekera.

The farmers' perception and knowledge of the pasture quality was used as the second important aspect of determining the preferences for grazing areas (Figure 40). Preferences differed little between cropping and non-cropping season regarding the favoured areas. Related to the pasture quality again, the areas Horongo (southwest) and Pandureni (west) are highly rated. Dense shrub and bush vegetation in these preferred areas, as well as their leaf-litter are a useful browsing resource for goats during the dry season.

It could also help keep cattle get in better condition and could serve as protein substitution to the low quality grass forage during dry season. Reasons for the selection of areas related to pasture quality, as mentioned by some farmers, indicate that e.g. many cattle from other communities already graze towards the direction of Epingiro, Shihetekera as well as Nzovhu, especially during the non-cropping season. Another reason for the decision against a specific area is the occurrence of field fires, which destroy the grass and herb biomass, leading to a lack of forage. Shortly before the questioning, a fire had burnt large amounts of the forage resources in the direction of Epingiro.

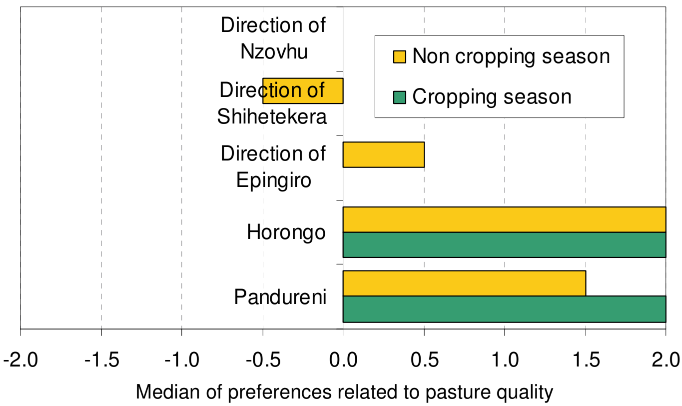


Figure 40: Preference of grazing areas related to pasture quality in Mutompo
(n=7; 2 = very good, -2 = very poor)

The diagrams Figure A 9 – A 11 (all in the appendix) show the individual grazing preferences related to the distance of grazing areas, the water supply, and the security and risk issues in Mutompo, respectively. Related to the distance from the community, the area of Pandureni was preferred most, in comparison to all other areas (see Figure A 9). On second position came Horongo, which is further away than Pandureni (see Map 7). All other areas were ranked lower during both seasons, except the direction of Epingiro, which was ranked with 0.5 during cropping season. The direction of Nzovhu was ranked low, however it is far away from the central water point, and farmers none the less avoid this area due to other reasons. In Mutompo, small temporal water places, so-called ‘endombe’, arise during rainy seasons, on grounds with a high clay content, which can hold water - at best - for up to one month after a good rainfall (according to a farmer in Mutompo). These water places exist in Horongo and in the direction of Epingiro, and they have an influence on the preference of grazing areas in Mutompo, especially during the cropping season, (see Figure A 10 in the appendix). The main water supply is a central borehole, equipped with a diesel pump, which is used to pump up water collected in a dam (see Map 3, p. 35). During both seasons, the aspect of the water supply does not have a considerable influence on the preference of the different grazing areas. A high preference relating to security and risk issues (mainly the danger that animals are stolen or lost) was put in the areas of Horongo and Pandureni during both seasons (see Figure A 11 in the appendix). Mutompo and Epingiro farmers use these areas, which are bordered by a fence towards the area of the governmental livestock research station ‘Mile 46’; the other three directions are not marked by such boundaries (see Map 3, p. 35, and Map 7, p. 161). However, farmers know where the area of Mutompo ends in the direction of the other villages. Cattle still tend to walk into areas of other villages if they are not herded during non-cropping season. This will only be a big problem, when livestock destroy cropping fields. Pandureni is the most favoured area, followed by the direction of Horongo, which is probably due to the shade produced by the tree canopies in these dry forest areas, which protect the soil and grass from evapotranspiration, and keep temperatures lower during the hot season.

In Okamboro, most farmers preferred the military camp area for grazing their livestock and the direction towards the west. Less favoured were the east, the south and the north[33], probably due to the poor pasture quality (Figure 41). Both, the ‘military camp’ and the area in the west were perceived as having the best available grazing resources in comparison to the north, east and south[34]. However, for the area in the west, a farmer reported “much grass”, and that it was a stony area. For the ‘military camp’ area, several farmers described a good grass situation, whereas some of them complained, ‘these days, many people and animals use this area’. It was often mentioned that the grazing amounts depended mainly on the rainfall, and if rainfall was high, suitable grazing areas could be

[33] For the pasture preference in Okamboro the Wilcoxon tests (conducted by Falk, 2007) proved that particularly the north was less preferred than the military camp and the west.

[34] The Wilcoxon tests (conducted by Falk, 2007) proved the trend that in the perception of the livestock farmers in Okamboro the military camp as well as the area in the west had significantly better pasture than in the north, south and east.

found near the community. In the drought years, or during the end of the dry season, farmers have to send their animals further away in peripherial areas.

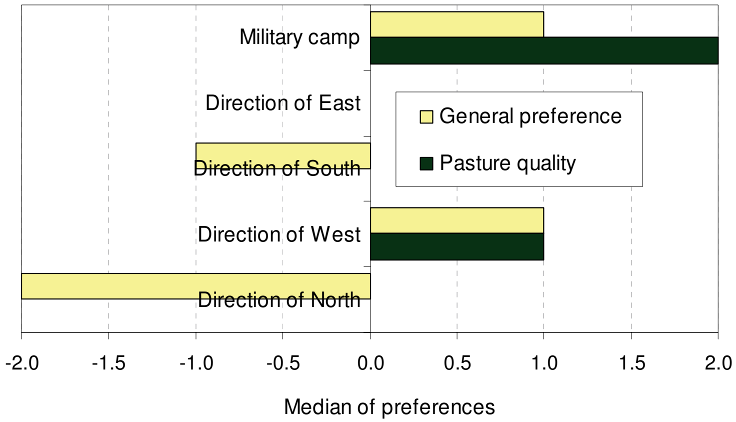


Figure 41: Preference of grazing areas in Okamboro related to preference and the pasture quality (n = 15; -2 = do not like, 2 = do much like)

The farmers' preferences related to water supply, distance, and security and risks are further important aspects, referred to livestock management (Figure 42) in Okamboro. Concerning the water supply situation, the ranking was lowest for the west, south and east. The main water place is located behind the sand dam, lying in the centre of the community (see Map 8, p. 162). After rainy seasons, some ponds along the - normally dry - riverbed fill up with water, which does not drain fast, yet these water places are not permanent. A larger dam could be found in the 'military camp' area and another one near Ombupoori, following the raod in the direction of the south (not on Map 8). During late dry season, only the dam near Ombupoori and the sandy dam of Okamboro provide enough water to meet the requirements of the livestock (own observations).

Results for the distance factor in favouring a grazing area show no clear trend (Figure 42). The northern region is ranked highest; the other areas are ranked zero. Livestock, grazing closer to the household of the owners allow more control and reduced risks. The selection of grazing areas in Okamboro, in relation to the security and risks (see Figure 42) shows, that the east is ranked highest with zero; all other areas were ranked with the code -1. However, animals from other villages also frequently visit the areas in the south and the east, and the risk that animals are stolen was found to be highest here, probably due to the close proximity of the road. On the other hand, dangers from predators (jackals, hyenas, or leopards), as well as from poisonous plants (e.g. Slangkop, a tulip-species, *Urginea spp.*; Burger, 2002)) and losses due to injuries in stony and steep areas, as well as theft, were reported for all areas of Okamboro.

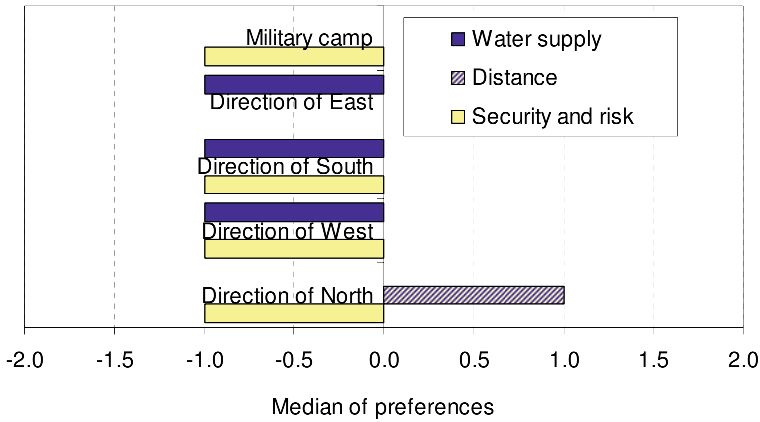


Figure 42: Preference of grazing areas in Okamboro related to water supply, distance and security and risk (n = 15; -2 = few water/far away/high risks, 2 = much water/nearby/low risk)

For the military camp area, an additional risk from soldiers, shooting animals accidentally during their training, was mentioned as well. Farmers of Okamboro avoid taking calves and goats into the directions of west and north, because of losses due to larger carnivores (hyenas and leopards), which probably enter the area from the Van-Bach-recreation area, located in the northwest (see Map 8).

The assessment of the pasture distribution proved that the Okamboro territory is well distributed amongst the households, depending on the location of the homestead within the community, but more considerably, also on informal institutions and agreements (Falk, 2007). This reduces the number of farmers utilizing one area and defines a custom among groups, which makes it easier to cooperate in the protection of all grazing resources. However, this result does not reflect, that the livestock in Okamboro, only rarely used the areas located in the periphery. The daily management in this community, such as sending the animals in one direction after watering, and letting them graze freely until they come back to the kraal in the early evenings, causes uneven utilization patterns. On the other hand, such a system is dynamic; either farmers react with a change in direction, if too many other farmers send their animals in their (at first) preferred grazing area, or as also mentioned, when other people go in a direction, farmers prefer the opposite direction. Cattle and goats are separated, and it was mentioned by some farmers, that they send goats in a different direction than their cattle. In Okamboro, in the mountainous and stony areas, more grass vegetation seems to be available, but cattle still do not like going into these areas. In addition, the lack of control of the livestock walking routes through the grazing areas makes an exact identification and division of the grazing areas difficult, due to the lack of fences between them. Moreover, a ranking, with reasons for certain preferences of the farmers was not obtained.

In Mutompo, it became obvious, which of the grazing regions are preferred by the farmers asked for this study; it was Pandureni, closely followed by Horongo. For Okamboro, this was not apparent. The military area, as well as the area in the direction towards the west, was both preferred, considering general preference and the pasture quality. Otherwise, the issues of water supply and distance to the community, as well as the security and risk issues showed no clear tendency for these grazing areas; each area has advantages, but also some disadvantages. Choosing one special area depends to a high degree on the location of the household within the community of Okamboro, which is supported by the highly structured topography of the area.

In order to link the farmer's perception of grazing areas with results of the rangeland assessment (chapter 4), the values of preferences of grazing areas were correlated with the vegetation parameters of different transects running through these areas (see Table 21, p. 105). In both communities, the high preferences of special areas were positively significantly related to grass biomass during the WS. These parameters represent the quantity of forage (grass and browse) and the grass biomass of rangelands. Ground cover in the WS seemed to be only important in Mutompo; however, in the WS 2002/3, the drought situation occurred, and the questionnaires were carried out within the timeframe of January until March 2003 in Okamboro, when the drought situation was already becoming apparent. The grass biomass and the ground cover during DS 2002 was all of apparent significance for the choice of grazing areas in Okamboro, during the time of the investigation. Negative correlations appear only for several parameters found in Mutompo. For instance, the ground cover in DS 2002 shows a negative correlation to the preference of grazing areas. This result maybe reflects the opinion of the local farmers, that old grass material is of low quality ('hay on the stem') and impedes the growth of new fresh grass. The numbers of grass species during both seasons, as well as the index of biodiversity (Shannon index) in the wet season are significant parameters for good grazing areas. A higher grass biodiversity ensures a better re-growth after fire, drought or dry season;

annual grass species ensure a fast re-growth after first rainfalls, both indicating an ecosystem of high resilience and stability. Additionally, livestock has the choice to select plant species of high quality, and less crude fibre content. Some of the data associated to grass quality could be related to the grazing area preferences in Mutompo. However, negative indicators for the quality of grasses are the crude fibre, which was positively correlated. Positive indicators for grass quality, such as crude protein and phosphorus content were negatively correlated during WS regarding grazing area preferences.

The evaluation of these results is complex. Some rangeland parameters may be related to the gradients, and show a spatial heterogeneity within the community. Additionally, the method used for coding the data of the preferred grazing areas along the five transects, of which the first kilometre of distance from the water points was excluded, may influence the correlations. Bush and tree parameters (such as their height), were also significant and positively correlated in Mutompo. Farmers prefer the light dry forests of this vegetation zone due to higher trees providing shade and allowing a moderate grass development underneath the canopies.

Table 40: Spearman-rank-correlations between farmers' preferences of grazing areas and vegetation parameters

	Mutompo		Okamboro
	Preference cropping season[1]	Preference non-cropping season[2]	Preference
	(r; significance)		(r; significance)
Grass biomass Oct. 2002	ns	ns	*
Grass biomass May 2003	**	**	***
Ground cover Oct. 2002	*	*	**
Ground cover May 2003	**	**	ns
No. of grass species Oct. 2002	**	**	*
No. of grass species May 2003	**	**	*
Grass Shannon index Oct. 2003	**	**	***
Crude protein May 2003	***	***	no data
Crude fibre May 2003	*	*	no data
Phosphorus total May 2003	***	***	no data
Mean bush and tree density	***	***	ns
Mean leaf biomass per ha	ns	ns	*
Mean browse leaf biomass per ha	**	**	***
Mean leaf volume per ha	ns	ns	*

[1]Cropping season corresponds with WS; [2]non-cropping season corresponds with DS. The other parameters, were tested too when data were available, but without significant results. Detailed data see appendix Table A 27.

A high density of smaller trees and bushes per hectare hampers grass growth, and thus was not preferred. The resources of browse biomass show a highly significant correlation in Okamboro, but a weak negative correlation in Mutompo. Browsing resources in the reach of goats are important in times of forage scarcity, also for cattle, which can feed on the dry leaf-litter on the ground. The reasons for a negative correlation could be that high amounts of browsing resources occur in denser woody vegetated areas, and those browsing resources, which are defined as leaves below 1.5 m height, are correlated with smaller trees and bushes. In Mutompo emerged no scarcity of browsing resources.

6 General discussion

6.1 RANGELAND EVALUATION

6.1.1 Methodology discussion

The gradient approach and the collection of grass samples, as well as the counting and measuring of the shrubs and trees are very time-consuming. However, small-scale approaches in communal areas are necessary, in order to get realistic pictures of the variable environment, with small-scale spatial and temporal patterns, including differences in abiotic conditions, soil conditions or rainfall distribution. High-resolution satellite images, combined with a thorough ground-truthing fieldwork, is essential for a suitable replacement of this small-scale rangeland assessment in 100 or 200 metres intervals, along five transects leading from the water place, which was applied in this study. A combination of both techniques would be an ideal method and quite useful for long-term monitoring, which is necessary, in order to estimate fodder resources and detect changes in the vegetation (biomass, or species level).

Due to the drought situation, which occurred in Okamboro, the rangeland assessment should be repeated for several years, during the wet season, in order to get clearer results on the rangeland conditions and the resilience of the grazing areas. This would concern especially the area in the proximity of the water dam and the inner settlement area. During a long-term rangeland assessment, a phase of reduced or no grazing should be tested (e.g. on larger exclosures), in order to determine whether the vegetation can recover during a good rainfall year, and in order to test whether a rangeland is beyond the threshold to recovery, or not (Friedel, 1997).

Samplings during the wet season should already have been carried out in March 2003, when the grass was still green, not late in April or May 2003, as in this study, which thus resulted in low nutrient values for the mixed grass samples. Additionally, the identification of the single grass, shrub or tree species would then be possible. A most flexible sampling technique would carry out the sampling relating to the rainfall amounts, best during the endmost months of a rainy season, and relating to the prevalent vegetation status, which in turn would need to be locally pre-tested before a sampling starts.

More attention should be laid on the agronomic value of the vegetation, such as the productivity of single species, their forage value and the perenniality of grasses, including, of course, all browsing resources, especially in communal grazing areas with mixed herd structures. A focus on the 10 to 15 most productive and forage relevant species would be appropriate for an estimation of the total forage values, considering the agronomic values, and maybe also the selective grazing behaviour or preferences of livestock. For an assessment of the rangeland conditions, an additional focus should be put on the abundance of species sensitive to grazing and trampling, or on invaders, which grow rampantly and tend to displace other species. Bush encroachment seems not to be a problem in the communal areas, because goats feed on small tree shoots. Bush thickets, on the other hand, can provide goats with fodder, in case of a drought or during a long dry season, because they can manage to feed even on the thorny *Acacia*-species.

A detailed analysis of stocking rate for an estimate of the appropriate and sustainable grazing pressure is necessary, especially supplemental to studies focusing on biodiversity and species levels; this has not been included in most of the studies on this matter so far. Based on an annual definition of various vegetation and climate or weather conditions, a locally adapted stocking rate could then be defined, according to the state- and transition-model (Westoby et al., 1989). State and transition models have surfaced in recent years, as a new paradigm in the understanding of ecological succession. Whereas the traditional understanding of landscape-change dynamics views a linear succession between well-defined ecological states, the new paradigm envisions a greater degree of complexity. Most of the existing rangeland management models base on equilibrium concepts, and are more or less appropriate for the complex dynamic dry land ecosystems of Africa (Ellis & Swift, 1988; Westoby et al., 1989). Sudden and non-predictable changes in the vegetation of a system, which is not at equilibrium, cannot account for a standard succession model, but the 'state-and-transition model' would allow these changes. In this model, a range may move from one state into a number of different states, or return to its original state, along a transitional pathway due to differing factors, where e.g. grazing pressure is only one element of those having caused the initial change. The 'state and transition model' was applied to rangelands and systems by Milton & Hoffman (1994) to the semi-arid grassy area of Karoo in South Africa, by Dougill & Trodd (1999) to the open savannas of the Kalahari in Botswana, and by Joubert & Rothauge (2001) to commercial livestock farming in Namibia.

A repetition of grass sampling quadrants (1.0 x 1.0 metre) on the same sampling points did not take place in this study, due to a limitation of time during the fieldwork and the lack of human resources. In order to reduce a high variability of the data points and provide clearer datasets, a sampling design should be integrated with a three-time replication of a 0.5 x 0.5 metre plot for grass sampling. An alternative approach could also be line sampling (0.5 x 5 m). For the browsing resources, a 10 x 20 m plot was put up in Okamboro, but the dense bush and tree vegetation of the dry forest and the outskirts of the forest in Mutompo, requires plots half that size. Plots for the tree and bush inventory should also be replicated three times, in order to obtain a more representative display of the woody vegetation. A more participatory approach to integrating the local farmers into a rangeland evaluation process would be for instance, to undertake transect walks (Barton et al., 1997) with the local farmers (along the transects used of the rangeland evaluation applied in this study), in order to learn more about the farmers' perspectives regarding e.g. their criteria for a good or poor rangeland, and their ranking of these criteria. As a starting point, participatory mapping, or historical mapping of the communal grazing areas could also be appropriate tools. The local perspectives could then be used, to analyse and describe the rangeland conditions during different seasons and years, applying a similar transect approach, starting from the central water points. Group discussions on the main problems, regarding the livestock and follow-up workshops could be an option to overcome problems, and improve the rangeland management, the drought seasons feeding, and the livestock productivity.

6.1.2 Impacts of grazing on communal rangelands

The amounts of standing grass biomass in Mutompo were comparable with results of other studies in northern Namibia, and the grass nutrient contents were low. The mean crude protein content of mixed grasses was only 4.0%, the average P content only 0.028% in WS, and the crude fibre content was higher in WS than it was in DS, with a value of 42.3%. A possible explanation for this rather poor quality of the vegetation during the WS could be, the late sampling after rainfall within the WS, while the grass was already brown and dry. However, this information points out a fast decrease in quality, when already in May, during the month of the sampling, the grass analysis resulted in such poor values, especially for the protein content. The late sampling seems to be also the reason for a lack of seasonal differences for most of the grass parameters, except for the grass biomass. Another reason for the low quality of grasses could be a generally low soil fertility of the leached deep sandy soil, with its very low organic matter content (0.70 % OM). Only in areas with red soil, which form the former dune valleys, the soil contains more organic matter and clay, including more minerals and nutrients. These areas are preferred by the local farmers when establishing fields for cropping in a kind of rotational fallow-system with an unknown length of fallow periods.

A relative low RUE-value for the grass was detected for both communities, which means low productivity and a poor response to rainfall. This could be a first sign of rangeland degradation, but needs further monitoring, in order to become a verified result. Moreover, how productivity responds to rainfall seems to be a very important factor, as such semi-arid ecosystems are described as disequilibrium systems, where usually the amount of rainfall determines the primary production, and livestock or human impacts are only of low relevance. The validity of the disequilibrium and equilibrium theory, and the resulting consequences for livestock management, and whether land use actually effects the vegetation in semi-arid or arid regions are all still up for discussion. Kuiper & Meadows (2002) have detected both – disequilibrium, as well as an equilibrium component - for the southern Namibian rangelands, occurring side by side. But the comparison of two different land use systems in Kuiper & Meadows (2002), described as communal (Nabaos) and commercial (Gellap Ost) is lopsided, because Gellap Ost has been managed as a research station since 1938, being one of the oldest governmental research stations in Namibia (Falk, 2007). Gellap Ost runs a breeding programme for Karakul sheep, and has developed the sheep type 'Gellapper'. Stocking densities are very low most of the time, and mainly sheep graze there, instead of the goats and donkeys in the communal areas. The often seen and well recognizable fence line contrast supports that the neighbouring camps of the two 'farms' (communal: damaged and degraded; research station: plenty grass biomass) are not suited for a comparison between commercial and communal farming in Namibia, as it is done by Kuiper & Meadows (2002). However, opportunistic livestock management strategies that aim to reduce losses in a drought, and the necessity to react quickly to the highly variable and unpredictable climatic conditions in Namibia, are generally accepted without controversy, and are considered valid for communal farmers, as well as for commercial farmers in Namibia. Within the development and policy implications, opportunistic strategies need to be considered, and infrastructure and market development, as well as possible price subsidies during a drought should also be discussed.

People have settled in the Mutompo area since the 1970s, with an increase in household numbers since the 1980s. Before the 70s, most likely only few nomadic people used the inland Kavango area as rangeland, due to the missing infrastructure. The livestock numbers in the Kavango region have increased since 1996, from a stocking density of 5 kg ha^{-1} to around 11 kg ha^{-1} in 2000 (see Figure 6, p. 29); and the stocking density in Mutompo was at 15 kg ha^{-1} in 2001. However, heavy grazing by livestock is restricted to the area around the water point and around the huts within the settlement. Small cattle paths lead the livestock from the central water point into grazing areas in different directions, which are preferred to the dry forest areas. No fences of private camps and no topographic structures block the routes of livestock on their way to the grazing areas, as is the case in Okamboro. The shapes and types of the curves functioning as signs of land use in the rangelands of Mutompo, and around its central water places, confirm that, within the first kilometre from the central water point, the impacts of land use are detectable, in most of the tested parameters for grass, trees and bushes. The area of the so-called sacrificed zone (Tolsma et al., 1987; Glatzle, 1990; Jeltsch et al., 1996; James et al., 1999; Mphinyane & Rethman, 2003) is the area only in direct proximity around the water place (~150 m distance to the water point). This zone is nearly without vegetation, due to trampling and only grazing resistant annual grasses are able to grow and persist. The clearing of forests for the establishment of cropping fields, has totally destroyed the natural vegetation, but these patches, with high soil fertility, provide locals with staple food. The humanly induced impact zone around the village has a radius of approximately one kilometre, whereas along most of the transects, a dry forest area starts. In these forests, the grasses and ground vegetation, as well as the young bushes and trees compete with higher trees for light, soil water and nutrients, each using different strategies (e.g. the development of very deep or very flat but extended root systems). The inter- and intra-species competition within dry forests seems to overlap the impacts of the grazing by livestock.

Additionally, in this area frequent bush fires influence the ground vegetation to a high extent on a short-term, on the one hand, but on the other hand, fires also have a more long-term impact on the woody vegetation. Annual grasses regrow faster after a fire, given there is sufficient rainfall and the seed bank is available. Perennial grass species regrow more slowly, due to the reserves in the permanent root system of the grass tufts. Yet, bush fires of high frequency (annual or more often), occurring after long and harsh dry seasons, will damage not only trees and shrubs, but also the tufts of perennial grasses (Trollope, 1982). Large areas of grazing are lost to bush fires, especially when fires get out of control. In the Kavango region, from 1989 to 2001, between 21 - 50% of the region was burnt each year (Mendelsohn & el Obeid, 2003). In addition, the fires destroy many young trees, also some fruit trees. Fruit trees supply the people in Mutompo with extra food; especially very poor households depend on these kinds of natural resources to a large extent (Flower & von Rooyen, 2001). Goldammer (1998) highlighted, that the decline in nomadic habits of the indigenous people, together with the growing population of Namibia, caused an increase in the incidence of fire in the woodland areas. Consequently, it can be assumed that areas close to human concentrations are most prone to fire than those further away. Initial comparison between the settlements in the Kavango region and the number of fires associated with unsettled areas show, that it is contrary, whereas one reason is probably the low herbaceous fuel load due to heavy grazing (Graz, 2004). Nevertheless, each bush fire represents a further decline of grazing biomass, and a loss of soil nutrients into the atmosphere, which is a loss in the nutrient cycle and thus an additional reduction of the already poor soil fertility in this region.

In Mutompo, the rangeland resources are strongly influenced by the differences in soil quality and conditions within the former dune valleys, which results naturally in a thicket vegetation (observed along the transect number 4, in northwest direction, see Map 5, p. 46), and is preferred by farmers when establishing fields. A heterogeneous distribution of different vegetation types, which are e.g. areas in riverbeds or the bush thickets running alongside the former dune valleys, or areas, which are intentionally not grazed during wet season, are referred to as key resources (Scoones, 1995a). These key resources could provide forage for livestock in the late dry season or during droughts, while a scarcity of good quality forage or even of biomass could probably occur. Improved strategies for dry season feeding are discussed in the subchapter 5.3.4 (see p. 146 ff.). In order to preserve grazing resources for late dry season, and maintain a seed bank of grasses and herbs, some households in Mutompo have made informal grazing arrangements (Falk, 2007). After the first rainfall, when fresh grass begins to grow, the herders decide on whether certain areas should rest for some weeks and others shouldn't. It was reported that between January and July, during the time of the peak in biomass production, as well as shortly afterwards, a regular rotation between grazing areas was arranged, yet these instruments of rangeland management did not always work. Some households criticised that other households simply used those places originally defined as reserved areas, although this did not happen most of the time and this kind of communal rotational grazing does indeed not have the desired effect on the pastures (Falk, 2007). These kinds of rangeland management instruments are a first step in regulating grazing resources, which requires good community cohesion and strong institutions (see also Els et al., 1999). However, in Mutompo, where the rangeland is not overstocked or overused, the signs of grazing and trampling caused by livestock were regionally limited, and on an acceptable level.

In Mutompo, the areas of the cropping fields constituted around 5.5% of the total communal area (or around 200 ha) of the estimated 3,848 hectares; fallow fields were included in this field figure (see Map 3, p. 35). Fields have been systematically established on areas with better (darker, redder) soil representing the old inter-dune areas, which are filled by soil completely these days, and the dune riches are eroded by wind today. On satellite images of the Kavango region (see e.g. Mendelsohn & el Obeid, 2003) this dune-structure with east-west alignment is clearly visible. The share of red soil, which is appropriate for establishing new fields, came up to 41% of the Mutompo area in 2002, which was measured in satellite images (4,053 ha total Mutompo area; red soil or *Acacia* thicket area: 1,671 ha). This means that the red soil areas are not a limiting factor for cropping, because enough of these areas are available, although they are not always located near the homesteads. The change detection analysis via satellite images of the Mutompo region from 1991 and 2002 shows, that on only 8.13% or 137 ha of an area of 1,700 ha, a change of the vegetation has been detected (Table 41). An increase of the vegetation is either a field with growing crops, a green fallow or a new-grown forest, and a decrease of vegetation means clearing activities or a fallow field. The red, more fertile dune valleys are used for establishing new fields. During the year of investigation in 2001, the fields made up to 5.5% of the community area, but not all of the measured area was under tillage. This means that the cleared land has only a share of between 5.5 and 8.1%, including the fallow areas.

Table 41: Change detection method applied to an area around Mutompo

Category	No. of pixel	Approximate size (ha)	Percent of total changes
Not changed	18,433	1,550.2	91.9
Increase of vegetation	240	20.2	1.20
Decrease of vegetation	1,391	117.0	6.93
Total pixel	20,064	1,687.4	
Changes (plus and minus)	1,631	137.2	8.13

Timeframe: 4/1991 - 4/2002; within a period of 11 years; size of pixel: 29m x 29m; (Compiled by M. Vogel, 2/2005; see also Vogel, 2006).

The farming system seems not to be classified such as a shifting cultivation system, due to farmers' use of fields over several years. Clearing forests on their borders in order to extent these fields, e.g. when a good rainy season occurs, and enough work force is available is a common practise. On the Map 3 of Mutompo (p. 35) the shape of fields from the topographic map of 1998 (Fields topomap 1998) differ little from the fields in 2002. Nevertheless, the clearing of bush and forests for the preparation of fields, presumably has the utmost detectable impact on natural rangeland resources in the Mutompo region, and larger fields reduce the available grazing areas for livestock, and decimates the bush thickets, which are possible key resources for grazing during late dry season. Most of the larger trees have probably disappeared from the areas around the settlement. The grazing of livestock, as well as the collection of fuel wood, influences rangeland resources less in the periphery of the community, than it does around the central water place and the areas in which the huts are located.

Okamboro has the longer history of land use, compared to Mutompo, starting in the 1920s already, and the stocking densities of mainly cattle were relatively high during that time (a range between 30 and more than 60 kg ha^{-1}) (see Figure 7, p. 30). Before the 50s, the ethnic group of the Ovaherero lived within these regions since the 1700s (Mendelsohn et al., 2002), but these people used to manage their livestock in a nomadic manner. These days, mobility of people and their herds is restricted due to private land ownership and fences.The inhabitants of this region are still Ovaherero, which are traditionally cattle keepers, and cattle are used multi-functionally (milk, meat, bank account, prestige, religious functions e.g. the ancestor herd, bride price); owning cattle is of high importance for these people, and moreover, much cattle means prestige and a high status.

During the drought-stricken WS 2002/3 in Okamboro, cattle may not have been able to ingest enough plant biomass to fill their rumen, and thus meet their daily biomass requirements. Cattle, especially calves, were in very poor conditions in May 2003, with the imminent danger of high mortality. However, goats were still in good condition because they compensated the low quantity of grasses by feeding on browse. Some of the *Acacia* species, which make up to nearly 96% of all trees and bushes in Okamboro, produce leaves before the first rainfall. Goats are mainly browsers and able to select good quality forage within this forage range, better than cattle (Glatzle, 1990). These *Acacia* trees prevent bodyweight losses of goats in this early state of dry season, but it is not clear, how long this is sufficient, referred to the forage quality and quantity in the following dry season months. It was observed, that the cattle came back only every second or third day, most likely grazing the whole night in order to prolong grazing time and enhance their biomass intake, such as found by Becker et al. (2000) for livestock in western Niger.

The sacrificed zone is larger in Okamboro than detected in Mutompo. This zone of mainly bare soil also stretches into the areas of the community, in which the houses and homesteads are located. Livestock stay in kraals near the houses over night, and walk around and sometimes graze in this area. It was observed, that livestock linger near the dam during the day or in the evening, which enhances the pressure on this area. Nevertheless, the entire area is covered by mainly *Acacia* trees, which are without leaves during DS, but the extended root systems reduce (or prevent) soil losses through water erosion. Patches of bare soil found underneath the *Acacia* trees could be a sign of rangeland degradation, however, there seems to be a high resilience of this ground vegetation, and in case of a normal or good rainy season, these areas become green again (according to personal recall of local farmers). These are probably mainly annual species, which can react fast to small amounts of soil moisture, producing only small amounts of biomass. So, there is some forage available, and this fact shows, that a sufficient seed bank is still available. Annual grass species are preferred by Ovahimba farmers (northeast Namibia) in areas near the communities, due to the fast growth reaction on rainfall providing fast fresh forage with good quality, whereas perennials take longer to react on rainfall (Bollig & Schulte, 1999). Perennial grass species, such as *Stipagrostis uniplumis* (Silky Bushman grass; or Ongumba in Otjiherero) were found only in areas further away from the water dam. Farmers mentioned that this grass is of high forage value, and that it is becoming scarce in this area.

In Okamboro, correlations between the tree and bush parameters and the grasses show a significant positive correlation for most parameters (see Table 22, p. 107), meaning that bushes protect grasses from grazing, serve as traps for seeds, and ensure the reproduction of grasses in this area of high grazing pressure. Even during DS, the correlations were positive between e.g. bush density and grass dry biomass, as well as the ground cover, but large trees with large crown diameters did not protect the vegetation growing underneath them. The resilience capacity seems to be supported by seed banks, which stay protected under thorny shrubs and bushes. A recommended value for the minimum vegetation cover of the Sahelian and Sudanian zone of Africa retained at the end of the dry season (Wylie et al. (1988), in de Leeuw et al., 1993), that builds a protective cover is 0.2 t DM ha^{-1} (equivalent to 20.0 g m^{-2}). The mean values of grass biomass in DS 2002 (8.6 g m^{-2}) and in the drought-like WS 2002/3 (1.3 g m^{-2}) fell short of this value in Okamboro. Whether there are different values for the minimum vegetation cover in the different ecological zones or rainfall regimes (monomodular or bimodular rainy seasons) still requires some more regionally-focused investigation. However, bare soil is highly prone to soil erosion, particularly when the landscape is well structured, and when thunderstorms with heavy rainfalls occur, such as is often the case in Okamboro. Sheet soil erosion, and partly also gully erosion are common in Okamboro, as the high amounts of soil deposition within the dry riverbed, as well as the sand dam and the partly bare rocks in some areas confirm. Grass or herbaceous vegetation cover could protect the soil from erosion, and lower the run-off amounts. In Mutompo, soil erosion is not of relevance, due to the flat topography, and the mainly sandy soil, where rainfall does not result in run-off.

Leggett et al. (2003a) carried out a transect approach and investigated the rangeland vegetation conditions and changes in the Hoanib river catchments in the northwest of Namibia (a Mopane-tree zone). They interpreted that a lack of perennial grasses and browse availability in the investigated areas indicates that the ecosystem did not have a great degree of resistance and resilience to permanent disturbance caused by grazing animals and drought. A recommended implication for management on a larger scale is firstly, the keeping of an open range, which allows wildlife and domestic stock the freedom of movement during both seasons. Although the high impact zone around the water points emerges to be relatively small, the authors see a danger of an addition of further water sources in an arid area. This would have the effect of intensified grazing and browsing, and would possibly lead to an increase of these impact zones. A more appropriate distribution of water points is suggested, together with a co-ordinated highly flexible and adaptive grazing management system. However, Leggett et al. (2003a) did not elaborate in more detail on what this flexible and adaptive grazing management system should look like, nor did they go into detail into what exactly their suggestions for this, mainly communal managed area, in north-western Namibia would be.

Sacrificed zones are zones with the highest degree of grazing, trampling and defecation, which have resulted in visible impacts on the vegetation cover and standing biomass. However, such sacrificed areas, as those found approximate to water points or settlements cannot be used to make generalizations about land degradation in the arid and semi-arid zones (Sullivan, 1999; Oba et al., 2000). Questions on the limitation of numbers and the density of water places and their impacts on the ecosystem have arisen. For instance, that when too many water boreholes are established, the danger emerges that the different impact zones grow together and build huge areas of e.g. bush-encroached areas, e.g. in the Kalahari of Botswana (Dougill & Trodd, 1999), or in the Kruger National Park of South Africa (Brits et al., 2002). Recommendations for better practises of management in such places could be e.g. the alternating use of water points, in order not to enlarge the disturbed zones, and to prevent a change of vegetation. However, Moleele et al. (2002) stated, that a continual shifting of artificial water points within grazing areas has resulted in a spread of the distribution of bush encroachment species across Botswana, because around these foci points, heavy bush encroachment has developed. This is probably only the case, when mainly cattle use these rangelands, and only few browsers keep shrubs and bushes within a certain limit.

In conclusion, and as a response to the hypothesis of chapter 4 (see p. 45), a heavily used sacrificed zone with bare soil was found in both communities, and gradients were found also for some grass parameters, especially in Okamboro. The heavily used zone covered also the settled area of Okamboro, whereas in Mutompo, this bare soil zone was smaller, with partly dense bush and shrub zones surrounding the only water point within the community. Because of the very different vegetation types (Okamboro: *Acacia* highlands; Mutompo: Dry forest), and due to the different biophysical and topographical conditions, land use impacts may occur in different ways, and maybe also in different patterns. The land use of communal farmers, mainly with the keeping of livestock and to a lesser extent through fuel wood harvesting, have affected the vegetation, and resulted in gradients and detectable changes, assuming that the more or less natural vegetation status was found in the periphery of the communities. In Mutompo, this intermediate zone, which surrounds the sacrificed zone, covers the cropping areas and some grazing areas (those without larger trees), well into the forest zone. In Okamboro, this intermediate zone covers the grazing areas close to the homesteads of the farmers, in which some of the fenced areas are also located. Beyond this intermediate zone, and with a clear boundary, the dry forest area starts in Mutompo. In Mutompo, these zones are blurred by the patchiness of the vegetation, due to an uneven distribution of the fertile soil areas, which are oriented along the former sand dune structure. However, bare soil directly around the water place is a sign of impacts from livestock, yet within these areas no or only little vegetation can grow, due to heavy trampling and grazing activities. Bush encroachment is not a problem within both communities, because the farmers keep mixed herds, and goats browse largely on shrubs and bushes, when grass becomes scarce. In Okamboro, the drought situation may overlap with the real rangeland status and the resilience potential of the vegetation, resulting in very poor biomass growth, and large areas with nearly bare soil. During this ‘extreme’ weather situation, which occurs regularly under Namibian climate conditions, the rangeland vegetation may be more vulnerable to grazing and trampling effects by livestock, and high stocking densities can well cause long-term changes and degradation. A long-term monitoring would be necessary, in order to analyse the reaction and resilience capacity after a drought in highly stocked communal rangelands. The grazing pressure was higher in Okamboro than in Mutompo, as well as the utilization of all natural resources by the inhabitants, because only half of the numbers of people that live in Okamboro live in Mutompo, and the area available per person is much larger (see Table 33, p. 140). In addition, the land use history lasts longer in Okamboro than it does in Mutompo. Livestock, people, as well as the socio-economic backgrounds need to be integrated into these kind of studies, just as the livestock productivity, in order to understand the system on a more holistic, and not only partial level (see chapter 5). However, only when clear grazing gradients persist in more than one occurring good rainy season, this would be a clear evidence for degradation or reduced range conditions (Pickup et al., 1994). In order to prove a long-term degradation from grazing and trampling within zones around the water dam and in the community areas of Okamboro, one has to repeat this transect grazing gradient approach for a period of at least two years with normal rainfall, and also has to analyse the types of grasses in more detail.

Complex computer-based models or expert systems like RAPS (Resources assessment for Pastoral Farming Systems, developed by Harris (2001), for New Zealand) is a mechanistic model and decision-support system (DSS) for assessing forage resources, livestock carrying capacity and development options in complex pastoral systems (Harris, 2000). These models usually combine data and quantitative relationships with rule-based or qualitative inferences. The output is usually a set of options for action with likely benefits and perhaps risks associated with each option (Pearson & Ison, 1987). For complex non-linear dynamic systems, such as the rangeland ecosystems in arid and semi-arid regions, even the chaos theory or fuzzy thinking method could be applied to these systems (Pearson & Ison, 1987). The quality of model output depends on the quality of the input data sets. RAPS need (twice a month) values for land and forage units: the size of the area, the annual dry matter yield, the utilization limits, the herbage quality and quality depreciation rates, and managerial constraints with affect forage availability and time of use. For livestock values needed about: herd and flock composition, profiles for live weight change, changing physiological condition relating pregnancy and lactation, allowance for peculiar environmental conditions, and managerial constraints (Harris, 2000). Other computer-based tools for modelling livestock production on pastures and extensive grasslands are e.g. ‘RANGEPACK HerdEcon’, a dynamic herd or flock model, that is linked to property cash flows, (Australia, developed by Stafford Smith & Foran, 1990a, 1990b); or

GRAZE, a mathematical model that simulates daily performance and interactions associated with beef-forage grazing systems. Accounting for prevailing weather, edaphic conditions and growth status of forage plants (USA); or GRAZFEED, a grazing management tool that predicts cattle and sheep production from available forage and other feeding sources (Australia); all models listed in (Harris, 2000). These models need several data on livestock and rangeland condition, which are difficult to obtain regularly in communal areas. The above-mentioned computer-based models are developed as Decision-Support Systems (DSS) for commercial farmers in the special country or region of the world. Transferring it to other climate zones and edaphic conditions or applying it on communal farming areas, might be very difficult or impossible, due to the differences in climate conditions as well as the differing production objectives of communal livestock.

6.2 LIVESTOCK HUSBANDRY AND NUTRIENT BALANCE

6.2.1 Methodology discussion

Nearly all of the mentioned carrying capacity or grazing capacity calculations was developed for commercial farming systems. Mostly in southern Africa, either carrying capacity models or further developed decision support systems (DSS), have been developed for rangelands with fenced camps, and farming systems with clear economic targets, only one livestock species, and a system which is mainly commercially oriented, which means a very controlled system. Whereas, in communal areas, many farming families use the communal grazing areas for their various livestock species, when there are only few or no fenced areas and the whole area is more or less available for grazing, and a herding of livestock happens only to a limited extent. Communal areas with only one or two water places are not comparable with the camp structure of a commercial farm in Namibia, where water supply reaches each camp. Therefore, it is difficult to estimate the real grazing pressure on the different places used by free roaming livestock on a communal grazing area. However, assuming that livestock use almost the entire communal areas, it would be useful just to have a value of orientation for the carrying capacity or the grazing and browsing capacity, apart from the methodological uncertainties and deficiencies of the capacity formulas. Certainly, a higher pressure occurs near the kraal and the main water place (see chapter 4.3), and also on easily reachable grazing areas, but in turn this depends to a high extent on the topography of the territory, on fenced areas which probably block some livestock routes, and on the grazing orbits of the different livestock species. Theoretically, the entire grazing areas of 3,850 ha in Mutompo, and 5,800 ha in Okamboro, are available for grazing to the free roaming livestock, which is sent into one direction after watering. Every day, a herd of cattle grazes probably only on a small part of the community rangeland, which is one or two square kilometres of size in the WS. The grazing orbit can also be extended to 4 to 6 km during the DS, which is reported in Bayer et al. (1991), another strategy that extends the duration of the grazing period. In order to learn more about the walking orbits and the routes free roaming livestock take for grazing, a GPS tracking (e.g. with self-detecting GPS-collars, see Hendricks et al. (2002), or accompanying of herds and flocks on foot during their daily tour) would be necessary to estimate the real grazing orbit and pressure of the different grazing areas, both the ones close to the homesteads, and the grazing areas in the periphery of the communities.

The progeny history technique (PHT) was widely used in several surveys during the last decade for assessing the animal production and performance in pastoral livestock systems (Kassaye, 1992; Armbruster & Bayer, 1992; and Kaufmann, 1998). Although the method essentially depends on the ability of the pastoralists to know, recall and be willing to tell about the life histories of their animals, the experiences of the investigators were mostly positive and the data obtained was said to be essential for a useful analysis and interpretation. In this study, however, the respondents had problems to remember the life histories of their breeding females and the progeny, thus yielding not necessarily reliable figures of the current herd situation. In fact, the people were patient and willing to answer the questions concerning their cattle herds, but it was apparent that their recalling ability decreased with an increasing of the herd size. Thus, the more animals a livestock owner had, the smaller his interest for the individual animals and its belongings. Although cattle is still part of the people's everyday lives and has a high status in society, the man-animal-relationship is not comparable to camel pastoralists, for example, who value the well-being of their animals higher than that of family members (Kaufmann, 1998). Furthermore, livestock is not the most important matter in Mutompo; cropping on a subsistence level is of first priority to most people. For the Ovaherero people in Okamboro cattle are of high importance, but the inhabitants feel the influences of the modern life. Through their proximity to the urban centers of Okahandja and Windhoek, other job opportunities have appeared and become more important, which has been leading to numerous absentee households. Additionally, a more common access to education has broadened the people's horizons in many respects; hence, livestock does not range in the only and first place in the younger people's minds anymore. Applying once a PHT-approach was not sufficient. In order to obtain reliable figures on the reproductive performances in the communal areas, further observation and recordings through monthly visits need to be undergone and an identification system for the animals, as well as verifiable farmer's records would be conducive.

A full survey of all households within the community was carried out during the field periods of this study. Sometimes, it was difficult to interview the household head or nucleus family members, especially in 'absentee' households, where there live only employees or young herders in the house, and where the actual livestock owners maintain a household in the next urban centre. The knowledge about grazing areas and the livestock as well as its development was sometimes not properly remembered, or the respective young herders were not very enthusiastic on livestock management issues in general. In most cases, an appointment with the household owner personally could complete and clarify the missing topics. In Okamboro, different family members often own parts of the livestock within a kraal of one household, which was not taken into account by this study. A family-herd within a kraal and associated with a household using one fireplace was always related to this household only, as this family and household were considered as one unit. For grazing pressure, this makes no difference, but for ownership analysis, it can indeed make one. It may be that one absentee daughter or other family member owned a large part of the household herd, and this livestock was not mentioned. “How many animals do you have in your kraal/ or at your homestead?” would be a more appropriate question covering the entire household holdings. Nevertheless, the livestock numbers mentioned by the households in our interviews were crosschecked by own observations and by rough estimates, and supplemented with the replicate counting of livestock numbers within the kraals and in the rangelands during the different fieldwork periods.

The problem with obtaining the actual carrying or grazing capacity is having the factors, such as the proper utilization factor or the percentage of utilization, as well as the DMI of the local breeds, measured or estimated most realistically under the local climate and biophysical conditions, and under communally managed farming systems. The challenge is the establishing of an authentic figure on the actual climate and rangeland conditions. Nevertheless, next to the temporary and spatial variability of the rainfall in Namibia, the heterogeneity of natural and biophysical conditions (e.g. soil structure, and topography) of the investigated areas makes it nearly impossible to create an authentic picture without a huge effort. The large workload and high expenses required to carry out a dense net of sampling points in order to cover the heterogeneity prevalent in communal areas, can only be partially justified. A cheaper solution could be using high resolution satellite images[35] in order to differentiate regions with similar values of indices, and combining them with ground-truthing fieldwork for only some vegetation parameters (Palmer, 1999; Ganzin et al. 2003). However, satellite images should not be used without checking the local conditions, when developing a map in which the distributions of bush- and tree-covered areas, as well as open grassland are displayed. The data on the soil condition, as well as the land use

[35] Low resolution satellite images at 1 km resolution were available for a number of years, between 1985 and 2002, providing biomass production over the whole of Namibia (Ganzin, *et al.*, 2003).

intensity is readily available for Namibia (see e.g. Atlas of Namibia Project, 2002, Directorate of Environmental Affairs, Ministry of Environment and Tourism[36]), and could be included as and when necessary. A combination of fieldwork and satellite images could well be an effective method for the future. During a long-term monitoring programme, the small-scale fieldwork could be reduced systematically, if the reaction and variation of the local vegetation to the regionally different rainfall schemes were known. Nevertheless, a dense rainfall monitoring system has to be established, which could be integrated into weather monitoring and may even be used for early-drought-warning. Additionally, a good regional weather forecast, distributed via the regional radio programmes, could help farmers in northern Namibia to decide when to plough and plant their crops best (Hochobeb, 2002). Furthermore, a national land use plan should be developed for Namibia, which would be in the course of applying a land reform. A redistribution of grazing land from commercial to communal farmers requires reliable information on the prices of land, which is related to the agro-ecological zone and the grazing capacity (Ganzin et al., 2003).

The carrying capacity calculations given so far refer only to the grazing capacities derived typically only from the grass and herbage biomass. Nevertheless, browse is also included in forage, and this supplies a considerable part of energy, crude protein and macro-elements required for typical browsers, such as goats, and seasonally also for grazers. In the carrying capacity calculation, as used in this study, the different feeding behaviours of livestock (grazers, and browsers) are considered. The use of grass and herbs biomass and that of leaves and twigs from trees and bushes, as well as the grazing pressure on each of these resources, depend on the number and types of livestock, and on their preferences for the different species (Guevara et al., 1996), as well as on the management practises. Schwartz & Walsh (1991) integrated the feeding behaviour and preferences of different animal species into their calculation of carrying capacity of semi-arid Kenya. The proper use factor (p), also called the permissible off-take, varied for browse and grass resources with the amounts of rainfall (Schwartz & Walsh, 1991). In this study, the proper use factors (p) for grass BM were detected according to Ma (1996), using the grass DM amount as an indicator. For the browsing resources (≤ 1.5 m height) the value 50% and 30% were used for Mutompo and Okamboro correspondingly, according to Schwartz & Walsh (1991), related to the average local rainfall amount. Results from the square meter cages in Okamboro show, that the percentage of utilization of the grass BM is probably much higher (around 73% of the grass biomass), than it was estimated by the mentioned methods according to Ma (1996), probably due to the drought situation. In order to get a more

[36] www.dea.met.gov.na, and http://209.88.21.36/Atlas/Atlas_web.htm.

realistic value, one would have to measure the utilisation factors for browse in field exclosure experiments on a large scale. For the browsing resources, a proper use factor is much more difficult to investigate than for grass BM and for the herbage; no studies were found where this was empirically examined. The other critical point in the estimation of the grazing capacity was that the forage selection was not recognised, but results from other studies (e.g. Ngwa et al., 2000; Hendricks et al., 2002; Rothauge, 2004; Magadzire et al., 2005) have shown, that this is of high importance. Biodiversity of the vegetation enables forage selection by different livestock species. This could enhance the grazing capacity enormously, and it would allow the livestock to utilize different forage niches, either through different feeding behaviours of the species or by the use of the regional fostered key resources, within the communal grazing areas, in times when other forage resources are scarce. Moreover, Rothauge et al. (2004) report that under a high grazing density of 45 kg ha^{-1} in their experiments in central Namibia, a selective behaviour of cattle was suppressed. Together with the theory, that biodiversity enhances the stability and resilience of a rangeland, biodiversity conservation and adapted management of natural resources are of high importance, especially in communal areas, where many poor households highly depend on natural resources and on the rights to use them. Assessing browse as a forage resource, and adding the assumable leaf litter, as well as integrating it into the carrying capacity calculation, will require more research.

A long-term monitoring of rangeland resources and their temporal variability of quantity and quality in semi-arid Namibia is especially necessary in communal areas, with a transect sampling design, similar as it was applied in this study, in order to get a realistic figure about the amount and quality of grazing and browsing resources the year around, but also to cover the spatial heterogeneity and the possible impacts from utilisation on the rangeland resources in communal areas. Considering the entire communal grazing area as a single farm, and pooling the livestock together, seems to be not very realistic. Integrating the grazing orbits within these calculations, or trekking of routes, in order to get an idea of the expansion of the real used area would be a good choice to improve the rangeland assessment, as well as the grazing and browsing capacity calculation. Beside this, the different feeding behaviours of grazers and browsers, as well as local biophysical and socio-economic conditions need to be considered, in order to get a holistic figure of the rangeland conditions within the communally managed grazing areas.

6.2.2 Forage nutrient balance – is the communal rangeland overstocked?

The first hypothesis of chapter 5 (p. 108) was, whether stocking densities of livestock exceed the recommended values, and whether livestock suffer from protein and energy deficit, especially in the DS. When considering the livestock and the communal grazing areas, initially many questions arise. What are appropriate recommended stocking rates or grazing capacities for the semi-arid communal grazing areas in Namibia? And how can they be ascertained and calculated? Are they based on the actual forage resources, which were locally investigated? Moreover, are all forage resources, such as grass, herbs, and browse integrated as well? Secondly, one has to discuss, whether a realistic grazing capacity can be calculated for the communally managed grazing areas in Namibia at all.

Results for the grazing capacity of the communal areas, and their comparison with recommended values indicated that the recommended values have to be considered carefully, if not locally measured, by using an appropriate approach, i.e. separately for commercial and communal farming systems, and regionally measured, not based on a rainfall model solely. The detected grazing and browsing capacity in this study, even if based on a detailed local assessment, can also only give an insight into the analysed season, and they cannot be generalised for all communal areas in Namibia. It is applicable only at the very most for the surroundings of the analysed areas in central and north Namibia, with comparable historical use of these rangelands. Regional weather events, such as a drought situation after a lack of six weeks of rainfall in the Ovitoto region, certainly affect the commercial farms in the Okahandja regions, however, this could theoretically happen during every rainy season.

The two communities had to be examined separately – whereas some aspects were surprisingly similar, such as the proportion of grazers (~75%) and browsers (~25%) of the herds and flocks. They differed considerably, related to their climate and soil conditions, and the resulting vegetation types, and their people, culture, habits, as well as dissimilar socio-economic conditions interrelated to the infrastructure and the access to food and livestock markets. Cattle are of higher importance for the people than small stock, because cattle stand for prestige, especially in Okamboro. The Ovaherero people use the milk of cattle as staple food (sour milk). In Mutompo, cattle are of high importance because the oxen serve as draught animals, pulling the wooden sledges and ploughs, as donkeys or horses are missing. In Okamboro, cars or pickups, as well as horses or donkeys perform the transport task.

While the high stocking densities in Okamboro exceeded or reached most of the recommended values from literature or from the rainfall models, a high potential for the grazing capacity was found for Mutompo. The calculations in this study, which separated the grazing and browsing resources of the grazers and browsers, and considered the DS and the post WS-period, provided a more comprehensive figure. Due to the drought situation in Okamboro, a massive destocking of grazers would have been necessary in the season 2002/2003, yet a strong potential for browsers was detected (the destocking issue is discussed also on p. 79-81). A high potential for all livestock species was found for Mutompo, despite the bush fires, and also despite the relative low rainfall amount of the season 2002/2003. A deficit of protein is expected more likely to occur, rather than a deficit of energy, because the quality of grasses, especially their protein content, decreases quickly to a low level after the seed ripeness. The results of this study show that a high stocking density, such as it was found in Okamboro, undoubtedly has negative influences on the vegetation, even though they are spatially restricted to the village area, or probably occur only on a short-term basis. In addition, the signs of slow long-term changes in species composition, such as a reduction of perennial grasses within the proximity of the water place and settlement, as recognized by the farmers, could be a sign of rangeland degradation. These matters could result in irreversible degradation of the rangelands, especially in years with extreme dry climate conditions, and high stocking rates. Moreover, assuming a low production level, the natural fodder resources of the available grazing area will barely meet the demand of the livestock in a 'normal' rainfall year in Okamboro. In Mutompo, grazing resources are in plentiful supply, regarding the quantity, but the poor soil fertility leads to a deficit of phosphorus and maybe of calcium, and probably leads also to a deficit of even more essential macro- and microelements for animals. The low productivity of cattle in this community can be explained by a mineral deficit on the one hand, which can cause infertility and a disturbance of growth. On the other hand, cows stay within herds for a relatively long period, and thus get quite old, which can also cause lower calving rates. The suppression of the frequent bush fires, e.g. through anti-fire open strip corridors, can be considered as meaningful, whereas for slow fires and windless conditions, small vegetation-free stripes (footpaths) already function well as fire retardants.

In both communities, even if the browsing resources are slightly overestimated, there is a detectable potential for browsers relating to the recorded fodder resources. This is supported by the fact that goats were found to be in good condition during the drought situation in Okamboro, but not the cattle. Keeping more goats, which feed mainly on the bushes and shrubs, either thorny or not, would actually prevent a bush encroachment, and they could also be slaughtered and serve as protein sources for the people. Bloated bellies of young children point at malnourishment in Mutompo, and animals are very seldom slaughtered in this community. Browsing resources are available in great amounts during WS, and also during DS, when farmers additionally use the technique of lopping, which is described as common practise in West African countries. These techniques also make browse available for cattle and sheep, and can be used as supplement feed in times of scarcity. Moreover, only well-adapted breeds of both, goats or cattle, are able to resist a long drought and can regenerate their bodyweight and conditions faster than others after these periods, e.g. by compensatory growth. These are the breeds of best choice under such variable environmental conditions, even though these specific breeds stay behind others in regard of their productivity.

The concept of the livestock carrying capacity is also applied to human beings, and then it is called human carrying capacity, or human support capacity[37]. Values of only population densities per square kilometre are limited considerably, because they do not take into account the agricultural potential of the region, nor the soil quality and climate conditions. This value for human support capacity is based on the demand of calories per adult equivalent, calculated from the average subsistence-based yields from cropping (or the general food availability) (Hopfenberg, 2003). If calculated for a pure extensive pastoral system, the human support capacity is based on the output from livestock production (e.g. energy and protein content of meat, and milk) (FAO, 1991; Upton, 1986). In semi-arid systems of West and East Africa, within extensive grazing systems and a mean annual rainfall of for instance 300 mm, it would support roughly 1.8 people per km^2, or a person would need 56 hectares to meet the daily calories requirement (for meat and milk exclusively; according to Jahnke, 1982). Namibia has an average population density of 2.1 people per km^2 (RoN, 2002). A better measure of population density is the number of persons per million kilocalories of production potential, estimated at the intermediate technology input level for developing countries, such as Namibia. Using this parameter, which is called 'agro-climatic population density' (Matanyaire, 1998), Namibia as a whole is the only country in sub-Saharan Africa that has already reached a very high density of more than 250 persons per million kilocalories of production potential (Binswanger & Pingali (1988), in Matanyaire, 1998), due to its aridity in large parts of the country and in the Namib desert. The 'agro-climatic population density' has been projected that e.g. Botswana would have reached that density by the year 2023, and Zimbabwe by the year 2032. Despite having one of the lowest overall population densities in the world, Namibia suffers from increasing pressure on and consequent risks to its land and water resources. A way out of this situation could be an increase of the agricultural production on the one hand, or on the other hand controlling the population growth, together with a strict

[37] The human support capacity is the maximum level of exploitation of a renewable resource, imposing limits on a specific type of land use that can be sustained without causing irreversible land degradation within a given area (Kessler, 1994).

management towards natural resource and environmental protection, which would also include water saving strategies in the future, in order to sustain livelihoods depending on these resources. The control of the population growth is not really an option for Namibia, but environmental protection, and adopting a responsible attitude to the utilization of natural resources becomes increasingly essential.

6.2.3 Livelihood strategies of communal livestock farmers

Regarding the second hypothesis of chapter 5, that communal livestock farmers tend to maximise their herds for risk minimising, rather than adjusting animal numbers to the existing or expected feed resources on communal rangelands, is of relevance in Namibia just today. Farmers, especially in Mutompo, very seldom sell or slaughter their livestock, unless they are forced to do so, when a drought or a long dry season leads to food insecurity, or the illness of a family member, or other cases of emergency dramatically increase a household's financial needs. Rural people hardly have any cash on hand, because there generally has been no need to, except e.g. to pay the water fee, and maybe for electricity. During normal rainfall years, cropping provided people in Mutompo with staple food on subsistence level, and livestock play a minor role. In Okamboro, people have to buy the staple food in shops or from a mobile seller, and therefore need money to pay for food. Additionally, most children attend the boarding school, for which families also have to pay tuition fees. The demand of money is higher in Okamboro than in Mutompo, in general. However, all inhabitants depend on the natural resources, on the soil for cropping, and on the rangeland as fodder for their livestock. Generally, in Mutompo, crop farming does not provide rural households with a significant cash income. Results of studies on rural livelihoods in the Kavango Region, for example, suggest that although farming is an important direct provider of staple food for many rural households, it makes virtually no contribution to the cash incomes of most households (NPC, 2001). Often, the old age pension funds, if available, meet the total cash demand of a rural household.

The function of livestock as a 'bank account', and as an insurance against crisis, is still relevant in rural areas in Namibia, whereas the trust in the bank system is low, and no effective insurance system actually exists for the rural people. Mogos et al. (2009) carried out a survey with communal and commercial farmers in central Namibia. Their results show, that information about drought insurance is missing, and that education is needed to increase insurance awareness. A drought risk management strategy of livestock farmers in central Namibia are the investment in off-farm acitivities (71.4% of commercial and 92% of communal farmers have off-farm income to support their farming) and the diverstification of farm enterprise (Mogos et al., 2009). The infrastructure is not developed, transaction costs are high, and many rural people live still in absolute poverty. An informal market system is present in the Kavango region; the veterinary cordon fence (see Map 1, p. 21) seriously restricts the EU-meat-market. This cordon fence delimits the veterinary restriction zone towards the north, where such diseases as Foot and Mouth Disease (FMD), Contagious Bovine Pleuropneumonia (CBPP), tuberculosis, and bovine malignant catarrhal fever remain health threats and potential compromises to Namibia's livestock export markets. Thus, trade channels northwards the veterinary cordon fence are oriented towards Angola. In Okamboro, the situation is a bit better. Some farmers are 'rich' compared to the poor farmers within this community, and compared to most of the Mutompo farmers. The infrastructure is much better in the Ovitoto region, and a boarding school is available for most children in Ovitoto. A monthly livestock permit offers local farmers a market opportunity, at which some price transparency exists.

The objective of a communal livestock farmer working under the conditions of an arid or semi-arid land, with uncertain rainfall patterns and frequent droughts, remains to minimise the risk of losing his only productive asset, the livestock, as described in Jones (2003). This objective obviously requires a completely different management strategy, compared to that of a commercial farmer, who owns his farmland and tries to increase the marketable output. For the communal livestock farmer production per hectare is more important than production per head. A livestock owner's combination of objectives tends to be met by the strategy of herd maximisation rather than turnover. Hence, even most of the large herd owners tend to sell only in order to meet cash demands (Sweet & Burke, 2000; Jones, 2003). Since animals can be turned into cash in cases of emergencies, they are important for household security (Byers, 1997). The communal farmers in most parts of Namibia have no accessible investment alternative other than livestock (Jones, 2003). This means that even in good years, after selling excess livestock, there is hardly any other productive investment available than buying livestock again. Livestock has several diverse functions, besides food security and protein supply (meat and milk), such as providing draught power, producing dung, serving as a saving-account and insurance, a social security fund and as proof of social standing (Riethmüller, 2003). It plays an important role in the religion and culture of most Namibians and is an integral part of their social exchange systems, well as the function as a charge in the traditional punishment system; (Irving & Janssen, 1992; Sweet & Burke, 2000; Jones, 2003). For instance, within the Ovaherero population, cattle of the ancestor herd are used in a certain religious belief. Particular animals are milked, but not slaughtered (own observation). One should reappraise the way livestock accumulation is viewed in the development within and research of such societies. 'The desire to defend pastoralists against a charge of irrational, at-all costs accumulation has led to a denial of the 'non-economic' reasons for accumulation' theory of the 'cattle complex' (see

Herskovits, 1926[38], in Sandford, 1983). It must be understood that through social functions, such as partnerships, herding contracts and marriage transactions, the benefit of accumulation is spread far beyond the 'owner of livestock' (Morton & Meadow, 2000).

In Namibia, livestock husbandry in communal areas is subsidised in many ways, such as through the provision of free veterinary services, income tax waivers, rent-free land; and permanent water access (Byers, 1997). These subsidies provide incentives to keep larger herds than otherwise possible, thus leading to more grazing pressure on the land (Krugmann, 2001). In addition to the free governmental extension services, livestock husbandry in communal areas is subsidised also through fodder provisions to bridge severe droughts. These "rescue" operations allow farmers to get through periods of drought without radical destocking; but they have also contributed considerably to rangeland degradation (MAWRD, 1992). Water provision has been one factor, which in turn has led to sedentarisation and the disruption of the large-scale, traditional nomadic and transhumant pastoral movements that once occurred throughout Namibia (Byers, 1997). This contributes to overgrazing, either locally around water points, or even over much larger areas throughout communally managed land. Overall, a breakdown of the traditional, flexible management institutions and practises has taken place, and no modern substitutes, equally adapted to Namibia's arid and variable environment, have replaced those (Byers, 1997). Additionally, a growing population (Kruger & Woehl, 1996), and the desire to invest in animals by those who earn their living from wage employment, are putting more and more pressure on the available land resources (Irving & Janssen, 1992; Jones, 2003; Kressirer & Kruger, 1995). However, a reduction of subsidies was observed in Mutompo, and also in the community of Okamboro. The Namibian government provided diesel supplements for the water pumps of both communities, which has been reduced in a step-by step system during the last years. Before 2001, e.g. Mutompo received 110 litres petroleum monthly for their diesel pump, which was reduced to 50 litres in 2001. Since 2002/2003, the MAWRD has passed over the responsibility for the diesel pumps completely to the inhabitants of these communities. They have to maintain the pumps, and buy and transport the diesel for them by themselves, which can cause problems, due to fact that small-scale subsistence farmers do not have much cash available. Additionally, the transport facilities are very limited and complicated because of the bad and sandy road conditions in Mutompo, as well as the poor infrastructure.

A diversification of income sources, alongside the regular farming activities, is the obvious strategy to secure and improve the livelihoods of farmers of Mutompo, as well as those in

[38] Herskowitz, M.J. (1926): The Cattle Complex in East Africa. American Anthropologist 28: 361-380.

Okamboro. Still, the level of wages in the labour market depends to a high degree on the educational level of the people, which is rather low in most of the rural areas of Namibia. In addition, a stable macroeconomic environment is vital for economic growth and poverty reduction. Despite some positive macroeconomic trends since the early 1990s (for example, a steady reduction of the inflation rate), Namibia's macroeconomic environment cannot yet be considered stable. Yet, as long as no alternative investment opportunities for rural farmers exist, this will inevitably lead to an increase in livestock numbers, as livestock is regarded as a kind of investment and savings instrument, especially for the Ovaherero people. In Okamboro, a diversification of income-sources is quite common, due to the proximity to Okahandja and to the capital Windhoek. Some well-educated people with good jobs, mainly absentees, invest in their livestock in Okamboro, thus increasing the grazing pressure on the communally used land.

6.3 ADAPTED RANGELAND MANAGEMENT OPTIONS FOR COMMUNAL RANGELANDS

The demand for draught oxen seems to drive the livestock husbandry in Mutompo to a high extent, whereas the productivity or rather the milk production, are not of high importance to the livestock farmers. Today, cropping has become more important, and most labour is invested into these farm activities, despite low yields of e.g. millet, and a high risk of total yield failure in years with below-average rainfall. Low crop yields are caused mainly by resource-poor and high-risk farming environment, as well as a lack of access to appropriate production technologies and farm input (Vigne & Whiteside, 1997). Poor access to and availability of credit, markets, rural infrastructure and effective institutions serving smallholders, further contribute to the low levels of agricultural productivity and production (Kressirer & Kruger, 1995; Kruger, 1998). A mean long-term annual rainfall of about 550 mm is the boundary zone, where cropping is sufficient with crops that have a short growing period and adapt to dry lands. Because most farmers are very poor, and previous development projects or governmental services have stopped (for instance, the renting of a tractor for ploughing, or the hiring of a ploughing-service, which normal farmers can afford), today there is a low mechanization level of cropping, normally comprising two oxen and a steel plough. Therefore, cropping requires a lot of work in this region. It would probably be a better option for the people in the inland Kavango region to focus on livestock and milk production, as well as a regular selling of animals, as long as the lack of technology requires massive labour force for cropping, and as long as yields are still low. A small well-managed vegetable garden (fertilized by e.g. using compost or manure) kept near the homestead, could supply the people with fresh vitamin-rich food. Some vegetables are already being planted near the huts or on the fields - this could be intensified – while the labour force for cropping should be reduced. Some fields could also be used to grow fodder plants, with very low input, and this fodder could be stored as buffer for droughts or DS. Regular sales of livestock would provide people with money to buy staple food in shops or elsewhere. This “shift-in-preference-to-livestock”-strategy requires at least an access to and the availability of formal livestock markets, a functioning rural infrastructure, affordable transportation facilities, and a livestock price information system. The development of a public transportation sector, as well as shops in the inland Kavango region, where rural people can buy staple food for reasonable prices, may also support the “shift-in-preference-to-livestock”-strategy. All these improvements and development issues, which lay partly in the responsibility of the government, are also necessary, in order to develop small enterprises or workshops in rural areas, or allow rural people to sell their goods in the urban areas. It could also smoothen the way of finding wage labour, not only in urban areas.

Kakujaha-Matundu (2003) describes the implementation of a grazing scheme within a communal area in an article on the SARDEP project ‘Self-management of communal poof resources among pastoral Ovaherero in semi-arid eastern Namibia’. The overall objective of SARDEP is stated as a reduction of the land degradation caused by human interference in the communal grazing areas of Namibia, and it ensures that communal livestock holders in the program areas apply sustainable and ecological natural resource management practises (MAWRD/GTZ Project Planning Matrix, 1998). The second phase of this project involves the establishment of a grazing scheme. Range management planning takes place, whereby pastoralists in the pilot areas cooperate with the community management committees. In order to start a rangeland rehabilitation and the promotion of sustainable range management the program proposes the following issues: culling of old unproductive cows, selection of superior female replacement, promotion of the use of superior male animals, introduction of mating seasons and implementing an acceptable culling schedule. The purpose behind these production strategies is that superior animals grow faster and thus off-take rises, and the keeping animals on range is reduced to a shorter period. The introduction of mating seasons allows cows to calf during a certain selected season, preferably when fodder is abundant. Cows in good conditions have enough milk for both, their calves and for human consumption or sales. This strategy also has the advantage of economies of scale, since planned mating seasons allow weaners to be sold in bulks (Kakujaha-Matundu, 2003). However, the second phase of this management strategy applied on open ranges was hard to implement. The culling of old unproductive cows was rejected by pastoralists who see the function of old animals as a form of pacifiers of the herd. Older cows, making the herd ‘stick together’, hold different generations of the same ‘family’ together. A disposal of older cows would break this cohesiveness of the herd and make it easier for younger animals to stray. People would have to invest in herding (or group herding) or insert fences in order to control their livestock. This would increase the labour demand for the farmers or their family, and hence increase costs, as additional herders would need to be employed. This has made Ovaherero pastoralists refuse to apply the method, without regarding possible benefits. A herding of about 1,000 cattle on a range would be irrational, as it would lead to more degradation through trampling (Kakujaha-Matundu, 2003).

A similar management approach, such as described above, could be suggested for the Okamboro community, but the farmers, due to similar reasons, would refuse it most likely. For instance, in the Okamboro community, the ancestor cattle herd is very important to the people, as a religious means to communicate with ancestors. These selected animals, which are partly very old, are only milked, but not sold or slaughtered, and even their milk is in some way special. Kakujaha-Matundu (2003) stated that the second phase of the SARDEP-project was a serious case of design failure and not an implementation failure per se. 'Again, foreign aid staff had the vaguest idea about the politicised nature of the environmental issues in the area. On top of that senior local staffs in the agriculture ministry were drawn from the white agricultural sector, without any knowledge of the communal system' (Kakujaha-Matundu, 2003). This clearly points out, how important a holistic approach is, in which not only livestock and the grazing system management are considered, but also the people and their socio-cultural and socio-economic environment. For the development of an effective and adapted livestock management system in communal areas, it is essential to understand the complete system and structure of livestock keeping, and the livelihoods of the communal farmers, and to integrate farmers into the process. More control over livestock and rangeland utilization on a local level requires installation of fences and herding (or group herding) - which causes costs or the investment of valuable time. With uncertain or unapparent benefits, it would be difficult to implement such means. Maybe richer farmers, which tend to go the way of commercialisation with a higher off-take than smaller livestock farmers, would be able to enhance their investments. For instance, a better healthcare of livestock would probably result in better prices on the long run, due to a lower risk for the buyers. It was observed in Okamboro, that richer and higher educated farmers, which were partly absentees, were already investing in superior breeding bulls (e.g. Brahman or Santa Gertrudis) and used fenced camps to control their livestock. The other point is clearly the level of communication and negotiation between farmers within a community in order to agree on resting grazing areas and a rotational grazing scheme, such as it is described for Mutompo. Without strong local institutions and a good relationship among the households and the families within a community, this can be difficult or even impossible. The study of these two communal areas in Namibia did not analyse the intentions or the willingness of the communal livestock farmers to change their range management, in order to prevent rangeland degradation, to enhance livestock productivity, or to earn more money; and most probably, this mindset would differ between a poorer and a better-off livestock farmer.

In the past, transhumance and nomadic movements with stock following rainfall had made it possible to keep large herds. This system of migration of farmers with their herds was well adapted to the prevailing conditions of that time. Today, only the Ovahimba farmers still shift their livestock seasonally between a summer grazing area (hot and wet) and a winter grazing area (cold and dry) (Bollig & Schulte, 1999). In semi-arid rangelands, managers cannot control their changing environment, so they will have to adapt their management quickly, in order to minimise the consequences of unpredictable rainfall variations. For that reason, opportunistic management strategies forming the basis of appropriate rangeland utilization and livestock management in arid and semi-arid rangelands (Kruger, 2001), are suitable strategies. Especially instruments such as drought tracking or seasonal tracking during a long dry season necessitate e.g. the opportunities of fast destocking and restocking of livestock. These strategies require for instance, a good access to livestock markets and price information (also for the export markets) as well as good livestock health services (e.g. regular vaccination, and pest preventions), and the provision of a sufficient health care for communal livestock by the farmers. Additionally, price subsidies, in times of low livestock prices support the selling of animals during a drought or a long dry season, as well as the buying of animals after a drought would be essential. Previous governmental drought relief programmes supporting e.g. the fodder for livestock in a drought, have lead to great increases in livestock numbers. The high mortality of livestock in the past drought years of e.g. 1995/1996, which should be outdated, have regulated the livestock numbers to a low level. It took a long time to regenerate through normal reproduction, and gave resources a rest to regenerate. However, it has impoverished livestock farmers, and made life in this highly variable environment very uncertain and risky. The decline in flexibility, concerning a seasonal movement of animals may also result in a low livestock production and finally, lead to even more severe living conditions for subsistence farmers in the communal areas of Namibia. A well developed bank system which allows savings with good interest rates, and a good infrastructure, are crucial to remove grazing pressure form communal rangelands in the long term, and can probably also contribute to an increase in the living standards of rural people.

The new policy of a loan scheme and land distribution for farmers owning more than 100 cattle (or 150 small stock), is a first step in the right direction, reducing the grazing pressure on communal rangelands. However, such land distribution needs accompaniment, and the ‘new’ commercial livestock farmers need training on how to manage a commercially oriented farm on a long term basis, and there is also a need for credits for further investments, such as for the maintenance of e.g. water pumps and fences, otherwise it will not result in a successful project implementation. Results show, that few better-off farmers keep most of the livestock within communal areas, and they are responsible for most of the grazing pressure. Poorer farmers, which make up the bulk of farmers in the rural areas, still live under poor conditions, are not content, seeing no other way out of poverty than keeping at least a small herd of flock of small stock, and living in a communal area, or merely without any livestock. There are now few other opportunities of earning money with non-farm activities, and in most cases the low education level or high illiteracy rate allow only jobs with low income. Work migration, which splits families, often making life for the remaining family more difficult, especially for women and the elderly, when a head of a household is absent. However, it can be a chance for younger people, who are still without dependants.

For the Sahel, Breman & de Wit (1983) suggested against overexploitation of the grazing areas on a long run, the creation of other possibilities of employment for the livestock farmers, or an improvement of the agricultural production potential by introducing some main nutrients from the outside. Possibilities of nutrient inputs within the system could be the direct use of urea as a source of nitrogen, or the use of protein-rich by-products from fertilized arable land, or the growth of fertilized forage crops, as well as the fertilization of the rangeland (Breman & de Wit, 1983). However, nutrient inputs mean also investments in agricultural activities of communal farmers, which are rare now, due to most households being poor, and they are not one of their first priorities. Manure, as an animal product, was less commonly utilised than expected in the Mutompo community. Few farmers have been reported to use manure as fertiliser in cropping fields or vegetable plantations in unused kraals. The lack of transportation was frequently cited as one of the main factors preventing the widespread use of manure (KFSR/E Working document No. 6, 1995 in Hengua & Bovell, 1997, and Vigne & Whiteside, 1997), and probably also the lack of available labour force. A 1992/93 survey indicated that only 8% of the Kavango respondents regularly used manure (Matanyaire, 1998). Binswanger and Pingali (1988, in Matanyaire, 1998) argued, that an increasing population makes input-intensive techniques cost-effective, and this is clearly the case in the northern communal areas of Namibia (e.g. Ohangwena, Oshana, and Omusati; the former Ovamboland; see Map A 1 in the appendix). Observations in these regions show that farmers bring manure from cattle posts (over 100 km away) for spreading on the crop land (Binswanger and Pingali (1988), in Matanyaire, 1998). However, in the inland Kavango region, which is still able to accommodate a fallow-field-system with new clearing activities of forest when required, there seem to be not any incentives for farmers to adopt land-saving strategies just yet. And as long as cropping yields are low in Mutompo and the practise of fertilizing is not efficient, more and more forest will be cleared, because new fertile areas are required.

A case study, conducted more than 30 years ago, in a less developed rural area of Natal/KwaZulu, Republic of South Africa, revealed that the existing system of land use was not able to provide for the subsistence needs of the people, let alone generate a marketable surplus, and that it was leading to environmental degradation (Erskine, 1988). However, whilst the input of significant capital (e.g. the investment for creating jobs in agriculture) and modern technology could slow down and possibly halt the destruction of the natural resource base, it was not possible to provide a satisfactory standard of living (food plus income) for all the people on the land (Erskine, 1988). In similar rural areas of southern Africa, where there is a land/people relationship of the same order (approximately 1.6 ha per person), the human carrying capacity of the land has already been exceeded to a significant degree (only about 22 % of the people in these areas who want to be employed could under optimal economic conditions earn a worthwhile living) (Erskine, 1988). Obviously, agricultural development alone cannot solve the land pressure problem. These days, the described problems are still eminent in the rural areas of Namibia, and it is not clear, whether the situation in KwaZulu Natal has improved much. Missing job opportunities, both in the agricultural or industrial sector, a low education level of rural people, as well as the absence of a vocational education system in Namibia, finally leads to a continuous poverty of rural households. The creation of alternative job opportunities, interlinked with environmental protection schemes, such as community based tourism projects, or the keeping and hatching of wildlife in a cross-farm-border manner, such as in conservancies, could create jobs for the rural people, and be a feasible solution. Legislation in Namibia (1996) has encouraged communities to diversify land use and livelihoods through the management and utilisation of wildlife (Brown, 2002). To this date, the focus of the conservancy and CBNRM (Community-based Natural Resource Management) initiatives in Namibia has been primarily on the northwest and northeast of the country (2001: 13 conservancies, close to 30,000 people, and 5% of the land mass of Namibia), (Brown, 2002). At present, conservancies have legal stewardship authority over a narrow resources base that includes wildlife (both consumptive and non-consumptive) and tourism, rather than controlling the development of other natural resource based activities. However, it is now recognised that a central feature of the CBNRM approach is that it has the potential to strengthen community rights to manage and benefit from natural resources. Eventually, communal conservancies could become common property management bodies, which are responsible for managing a full portfolio of common resources, including land, rangelands, community forests, fresh water fisheries, and water. Should this scenario evolve, it would create vast new opportunities of income generation activities in the communal areas, and up to almost 24 million hectares (29.2 % of Namibia's landmass, and about 70 % of Namibia's communal lands) could be actually put under some sort of conservancy group management (Brown, 2002).

The need for a land reform process in Namibia is obvious, and it is necessary to make the rights clear and more certain, especially to the communal farmers. The unequal distribution of land, if not resolved in the near future, would lead to conflict, which would destabilise the country and its economy. The lack of secure group tenure, combined with the prevalent weak traditional institutions, do not provide incentives for people to care for the land and invest in its development (NRC, 2002). Additionally, the introduction of a land tax could be used as an instrument to prevent land from non- or under-utilization, which also occurs in Namibia.

Not only in Namibia has the HIV/AIDS epidemic undermined human well-being and economic prosperity, most obviously by reducing the labour force. Furthermore, it has wiped out past investments in education and training, and places a strain on communities and households that need to care for orphaned children, as well as the sick and dying. The impacts of HIV/AIDS negatively affect poverty and household food security, and this can in turn lead to an unsustainable use of resources (Jones, 2003).

Under climate change conditions, there is the possibility that Namibia's climate will become hotter and drier, with increased variability and more frequent and prolonged periods of drought. These conditions will worsen current problems regarding the water management, food production and human health (Jones, 2003). However, du Pisani (2001) found, that the long-term rainfall data for Windhoek, which is on hand for a whole century, shows that there was virtually no trend at all, neither negative, nor positive. Looking at only the last 50 years, the trend may be negative for many places in Namibia. It is a question of the choosing the correct temporal scale which will establish the right perspective.

The aims of finding conjoint solutions for problems with the farmers, without the top-down strategy, by applying participatory approaches (Gonsalves et al., 2005a, 2005b and 2005c; Scoones & Thompson, 1994; Waters-Bayer, 2003), or innovation capacity projects (Waters-Bayer et al., 2006) could fill some gaps regarding a sustainable development. These kinds of projects may result in a more sustainable management, and better living opportunities in rural areas, with adapted and appropriate solutions developed by the farmers themselves, with the help of NGOs and the available networks between research, government and enterprises; on a regional, but also on a national level. In addition, local communal farmer associations could serve as bridges between the different institutions. For instance, the endogenous livestock development (ELD) (Van 't Hooft *et al,* 2005), a people-centred approach that includes both owners and caretakers of animals, proposes an alternative pathway for grazing management interventions. The ELD approach supports husbandry systems based on livestock keepers' own innovative strategies, knowledge and resources (Van 't Hooft *et al,* 2005). In addition, a decentralising of policy institutions, together with the handing over of responsibility for natural resources to the communities, is a key (but complicated) component of equitable and efficient development in Namibia (Blackie, 1999).

7 Summary

This study investigates the livestock and rangeland management of communal farmers in Namibia, in order to understand some links between the socio-economic situation and the economic opportunities of rural people in Namibia. The study was integrated within the framework of the BIOTA Southern Africa Project, aiming at biodiversity monitoring along a rainfall gradient in South Africa and Namibia. Analysing the impacts of land use on natural resources in communal areas was part of the sub-project ‘Socio economic aspects of changes in biodiversity in southern Africa’.

Two locations were selected representing a mixed and a pastoral production system. Mutompo is a community in the north of Namibia, with 14 households, where 197 cattle, 226 goats and 12 sheep grazed in a dry forest region of approximately 3,800 ha. The rainfed cropping of mainly millet is an important activity to produce staple food, basically on a subsistence level. Okamboro, a community located in central Namibia, consisted of 29 households, keeping 941 cattle, 623 goats and 157 sheep on an area of about 5,800 ha in the *Acacia* highlands; where livestock keeping is the most important activity. In order to investigate to which extent land use has an impact on rangelands resources, and to test whether overstocking has caused degradation in the communal areas, a detailed rangeland evaluation, designed with radial transects starting from the central water point, was carried out during the dry and wet seasons in the communities located in central and northern Namibia. The available grazing and browsing resources were quantified and their quality was analysed. Based on these results the grazing capacity of the entire communal areas were estimated, and calculated whether they were overstocked or not. Surveys of all households were conducted in recurrent visits between 2001 and 2003, focussing on livestock as a source of income, on the communal livestock management, the economic strategies and livelihoods of the households. The performance of the livestock was analysed by applying the progeny history technique on 81 cows and 62 does. The software BecVol (Biomass Estimates from Canopy Volume), which is a tool to estimate the browsing resources of shrubs, bushes and trees, was applied to the communal rangelands in Namibia for the first time in the course of this study.

Mixed herds, no herding, no fenced camps, and a main water point as water supply, are evident differences between the two farming systems strongly determining the livestock management. The models and methods to detect the carrying or grazing capacity in southern Africa have not been tailored to communally managed rangelands. The radial transects approach, carried out in the dry and wet seasons, and the integration of the browsing resources, are steps to adapt the method best to the conditions of communal

rangelands in Namibia. The assumption, that communally managed rangelands are usually overstocked, and thus degraded, can only be partly confirmed. Just in some, spatially restricted areas, e.g. the sacrificed zones around the central water points, signs of heavy trampling and grazing were found, but regarding the entire communal rangeland, the natural resources were not degraded. A heavily used sacrificed zone, with bare soil, was found in both communities, and gradients were found for some grass parameters, especially in Okamboro. A heavy impact zone also covered the settled area of Okamboro, whereas in Mutompo, this zone was limited to the area directly surrounding the only water place. The grazing pressure was much higher in Okamboro (42 kg ha^{-1}) than in Mutompo (15 kg ha^{-1}), as well as the utilization of all natural resources by the inhabitants, because twice the number of people that live in Mutompo live in Okamboro, and the area available per household and per animal is much smaller. In addition, the land use history goes back further in Okamboro than it does in Mutompo.

In Okamboro, other signs of long-term high stocking densities were detectable, such as the reduction of the perennial grass species *Stipagrostis uniplumis* (Silky Bushman Gras) within a 1 to 2 kilometre zone around the central water point, and the very sparse vegetation within the village area. A drought situation in Okamboro may overlap with the real rangeland status, resulting in very poor biomass growth, and large areas with nearly bare soil. In Mutompo, the ongoing clearing of dry forest vegetation or shrubs, in order to establish fields for cropping, destroy the vegetation and can reduce the plant biodiversity. Yet, the areas of higher impact are blurred by the patchiness of vegetation, due to an uneven distribution of fertile soil areas, which are oriented along the former sand dune structure. Livestock densities were rather moderate, farmers preferred to graze their livestock within the forest region, because of the shade of the trees and the temporarily available water points. The remoteness of the forest also ensured a protection of the fields from grazing.

Surprisingly, in both communities, despite the different production systems, cattle, which are mainly grazers, covered approximately 88% of the livestock bodyweight. Calculating the capacity of the livestock according to their feeding behaviours (75% grazers and 25% browsers), and assuming that livestock use the entire communal grazing area at once, the communally managed grazing area in Mutompo showed a potential for both, grazers and browsers. During the drought situation in 2002/2003 in Okamboro, browse was still available, but grazers needed to be destocked or moved out to a minimum level, in order to prevent mortality. Following these results, goat keeping should be extended – but goats do not have a prestige function, and only poor farmers keep more goats.

The detected grazing and browsing capacities in this study, even if based on a detailed local assessment, can only give an insight into the analysed region, but they cannot be generalised for all communal areas in Namibia or southern Africa, due to the high temporal and regional rainfall variability.

In Mutompo, livestock keeping was mainly driven by the demand of oxen for ploughing and transport purposes; but livestock productivity was very low, despite adequate forage resources. One reason could be the low nutrient quality of the grass soon after the stage of ripeness, or that cattle get too old in the herds, due to a low turnover rate. In Okamboro, livestock was the main economic activity, even though only few cattle were sold. The Ovaherero are traditional cattle farmers, and besides the high importance for milk production cattle has a cultural-religious meaning. Livestock productivity was moderate or good in Okamboro, and some improved purebred breeding bulls, mainly Brahman, were found. In Okamboro, some absentees and few better-off farmers with larger herds caused most of the grazing pressure on the communal grazing areas, and private fencing was common. In both communities, livestock farmers depended almost exclusively on the grazing and browsing resources of the communal grazing areas. Results from the surveys show that only few animals were sold, even if a regular market took place near Okamboro. The herd size of most small-scale farmers is too small for an efficient marketing. The major income sources were external earnings and old age pensions. Livestock keeping was not market-oriented and the investment in livestock was low. However, in Mutompo, a reduction of livestock numbers by 43% was observed during a period of low millet yield within two years, where probably livestock was sold on informal markets or exchanged in order to secure the food supply of the families. The results point at the multi-functional qualities (prestige, saving, and insurance function) of the livestock in communal areas, which confirm the last hypothesis that the traditional habit of minimizing risks by maximising the herd size is preferred, rather than adjusting livestock numbers to the existing grazing and browsing resources. During severe fodder scarcity due to a drought, better-off farmers were able to transport their cattle further north with a truck.

External factors, such as poor infrastructure, poor formal market access, and the lack of price transparency, as well as missing transportation opportunities, impede the success of livestock marketing especially in Mutompo. Additionally, the veterinary cordon fence blocks the livestock kept in the northern communal areas from participating in the export market. A strong social stratification was detected in both communities. One third of the farmers, mainly better-off households or absentee livestock owners, owned about 83% and 70% of the total livestock in Mutompo and Okamboro, respectively. The poorest households did not own any animals. As unemployment or ‘underemployment’ is threatening communities and alternative job opportunities for on-farm employment are lacking, the future importance of livestock keeping in Namibian villages might increase, rather than decrease. This applies in lesser extent to Mutompo, where the inhabitants make their living mainly on a subsistence level from cropping and livestock. People, who earn wages in the urban centres, reinvest their money into livestock back home. This can still increase the grazing pressure on communally managed land in the future.

In Okamboro, possible solutions to improve the rangeland and livestock management could be a more regular use of rangeland resources in the periphery by herding the herds of several farmers together, or by the establishment of permanent stock posts, where younger cattle and bulls could stay. A combined water- and grazing-fee, thus implementing a fair consumption-dependent payment system with a gradual stepwise increase, paid into a community fund, would give incentives to sell or slaughter some of the livestock. This money could be used to invest in improvements of livestock keeping (e.g. by improving the water facilities and the common health care, or by providing supplement feeding and mineral licks on central places). However, all these measures require cooperation among farmers within a community, and may thus be difficult to implement. The farmers of Mutompo should probably focus more or rather mainly on livestock production, because of the high risks of failure of low crop yields, and the huge workload due to low mechanisation with cropping. The protection of some resting areas – first steps were observed in Mutompo – can provide fodder resources in times of scarcity. A diversification of income sources through other sources of income than livestock, either on-farm or non-farm, is actually not feasible for most farmers. The Affirmative Action Loan Scheme is a resettlement programme that intends to provide communal farmers with more than 150 cattle (or 800 goats or sheep) with a loan and farmland, in order to establish a freehold commercial farm. It targets the reduction of pressure on communally managed resources and is a step in the right direction. Credits granted to poor communal farmers are not yet available, and an accessible and trustful bank system in rural areas, as well as an insurance system for poor families would be essential, in order to create alternative investment opportunities.

A participatory rural development process based on the results of this study may provide local solution. This would be a true alternative to the usual waiting for the improvement of infrastructure, better access to education and livestock markets, provided by the government.

8 Zusammenfassung

Diese Studie untersucht die Tierhaltung und das Weidemanagement von kommunal wirtschaftenden Farmern in Namibia, um Verknüpfungen zwischen der sozioökonomischen Situation und den ökonomischen Möglichkeiten ruraler Haushalte besser verstehen zu können. Diese Studie war in das BIOTA Southern Africa – Projekt eingebunden, welches entlang eines Regenfallgradienten in Südafrika und Namibia die Biodiversität analysierte. Die Analyse der Einflüsse von Landnutzung auf natürliche Ressourcen in kommunal bewirtschafteten Gebieten waren Teile des Subprojektes ‘Socio economic aspects of changes in biodiversity in southern Africa’.

Zwei Standorte wurden ausgewählt, die ein gemischtes Produktionssystem und ein pastorales System repräsentieren. Mutompo, eine der beiden untersuchten Dorfgemeinschaften, liegt im Norden von Namibia und besteht aus 14 Haushalten mit 197 Rindern, 226 Ziegen und 12 Schafen, die in einem Trockenwaldgebiet von circa 3.800 ha weiden. Die Familien versorgen sich in Subsistenz mit Hirseanbau im Regenfeldbau. Okamboro, die zweite Community, liegt in Zentralnamibia. Sie besteht aus 29 Haushalten mit 941 Rindern, 623 Ziegen und 157 Schafen, welche auf einem Gebiet von 5.800 ha im *Acacia* - Hochland leben. Nutztierhaltung ist hier die wichtigste ökonomische Tätigkeit, weil Ackerbau wegen der geringen Regenmengen unmöglich ist. Eine detaillierte Untersuchung der Weideressourcen sollte ermitteln, ob und in welchem Umfang die Landnutzung die Weideressourcen beeinflusst, und ob es durch Übernutzung der kommunalen Weideflächen bereits zur Degradationsprozessen gekommen ist. Die Analyse der Weideressourcen wurde während eines Jahresverlaufs in der Trocken- und in der Regenzeit in den zwei Communities durchgeführt. Die verfügbaren Gras- und Blattfutterressourcen wurden quantifiziert, und deren Qualität ermittelt. Anhand der Ergebnisse aus dieser Weideanalyse konnte die Weidetragfähigkeit beider Communities abgeschätzt werden, und es wurde errechnet, ob diese Flächen zu stark genutzt wurden, oder nicht. Alle Haushalte beider Dörfer wurden anhand semi-strukturierter Fragebögen während mehrmaliger Besuche zwischen 2001 und 2003 interviewt, besonders bezogen auf Nutztiere als mögliche Einkommensquelle, auf das Management der Weiden, und die ökonomischen Strategien und die Quellen für den Lebensunterhalt der Haushalte. Die Produktivität der Nutztiere wurde durch die Analyse der Nachzuchtgeschichte von 81 Kühen und 62 Mutterziegen ermittelt. Die Software BecVol (Blattbiomassenabschätzung vom Kronenvolumen), ein Werkzeug zur Ermittlung der Blatt-Äsungsressourcen von Büschen und Bäumen, ist im Zuge dieser Studie das erste Mal in kommunal bewirtschafteten Gebieten Namibias angewandt worden.

In kommunaler Weidewirtschaft fehlen eingezäunte Camps und Begrenzungen, und die gemischten Herden, welche in der Regel nicht gehütet werden, versorgen sich weitestgehend von einer zentralen Wasserstelle mit Trinkwasser. Diese evidenten Unterschiede zwischen kommunaler und kommerzieller Nutztierhaltung bestimmen das jeweilige Management der Tiere. Die übliche Berechnung der Weidetragfähigkeit ist eine Methode für kommerzielle Viehhaltung im südlichen Afrika, und ist nicht auf kommunal bewirtschaftete Weiden zugeschnitten. Die Evaluierung der Weideressourcen in der Trocken- und Regenzeit fand entlang von jeweils fünf radial angeordneten Transekten statt, ausgehend von der zentralen Wasserstelle. Zusammen mit der Integration von Äsungsressourcen (‚browsing resources') bedeutet das eine Anpassung der Methode an die Bedingungen des kommunalen Weidemanagements in Namibia. Die Annahme, dass kommunale Weiden allgemein überweidet und dadurch degradiert sind, kann nur teilweise bestätigt werden. Bei Einbeziehung der gesamten kommunalen Weideressourcen kann nicht von einer Degradation gesprochen werden. Nur in einigen räumlich begrenzten Zonen, die sogenannten ‚sacrificed zones', z.B. um die Wasserstellen herum, zeigen sich Anzeichen von deutlichen Trittschäden und starker Beweidung durch die Nutztiere. Besonders in Okamboro wurden Gradienten für einige Grasparameter entlang einiger Transekte festgestellt, die auf Schäden durch Landnutzung hinweisen. Eine ausgeprägte Zone mit Anzeichen von starker Nutzung wurde auch im Siedlungsgebiet von Okamboro gefunden, wohingegen in Mutompo diese Zone auf das direkte Umfeld der Wasserstelle begrenzt war. Der Beweidungsdruck in Okamboro (42 kg ha^{-1}) ist um einiges höher als in Mutompo (15 kg ha^{-1}). Dies betrifft auch die Nutzung anderer natürlicher Ressourcen, weil doppelt so viele Einwohner in Okamboro wie in Mutompo wohnen und das Weidegebiet pro Haushalt und pro Nutztier deshalb wesentlich geringer ist. Zusätzlich wurde das kommunale Weideland in Okamboro schon länger in der Vergangenheit genutzt als in Mutompo.

In Okamboro konnten weitere Anzeichen einer anscheinend lang anhaltenden stärkeren Nutzung festgestellt werden. So zum Beispiel die Abnahme von *Stipagrostis uniplumis* (Seidenes Buschman-Gras), einer mehrjährigen Grasart, innerhalb der 1 bis 2 Kilometerzone um die Wasserstelle herum sowie die recht spärliche Vegetation insgesamt im Siedlungsgebiet des Dorfes. Eine Dürre in Okamboro, ausgelöst durch eine Regenpause von sechs Wochen während der Regenzeit, überdeckt möglicherweise den tatsächlichen Zustand der Vegetation. Extrem spärlicher Bewuchs und große Areale gänzlich ohne Bewuchs sind vermutlich eher Folgen der Dürre als der Überweidung. In Mutompo wirkt sich die Rodung der Trockenwaldvegetation für neue Felder vermutlich stärker auf die Flora und deren Biodiversität aus als die Beweidung durch Nutztiere. Jedoch hat auch die unregelmäßige Verteilung der Bodenqualität und Fruchtbarkeit entlang der ehemaligen Dünenstruktur einen großen natürlichen Einfluss auf die Verteilung und den Typus der Vegetation. Die Besatzdichten der Tiere sind hier moderat, und die von den Kleinbauern bevorzugten Weidegebiete liegen im Trockenwaldgebiet, weil es dort schattig ist und es einige temporäre Wasserstellen gibt. Aufgrund der Gefahr von Fraß der Feldfrüchte durch die Nutztiere ist ein möglichst weit entferntes Weiden erwünscht.

Überraschenderweise bilden die Rinder, welche überwiegend als Grasfresser klassifiziert werden, den größten Anteil an den Herden mit circa 88% der Gesamtlebendmasse, und das trotz der unterschiedlichen Betriebssysteme. Wenn das Fressverhalten der Tiere (75 % Grasfresser; 25% Blattfresser) bei den Tragfähigkeitsberechnungen berücksichtigt wird, und angenommen wird, die Tiere würden die gesamte kommunale Weidefläche nutzen, dann kann für Mutompo ein Potential höherer Besatzdichte sowohl für Gras- als auch Blattfresser ermittelt werden. Während der Dürreperiode 2003 in Okamboro bestand ein Potential nur für die Äser, wohingegen die Grassfresser auf ein Minimum der ursprünglichen Anzahl reduziert werden müssten um Mortalität zu verhindern. Anhand dieser Ergebnisse sollte die Ziegenhaltung empfohlen werden – Ziegen haben allerdings keine Prestigefunktion und sind etwas für arme Bauern. Die in dieser Studie ermittelten Grasfresser und Äser (Browser)-Tragfähigkeiten - auch wenn sie auf einer detaillierten lokalen Weideevaluierung beruhen - können nur einen Überblick über die untersuchten Gebiete und Zeitabschnitte geben. Aufgrund der großen temporären als auch der regionale Regenvariabilität können diese Ergebnisse nicht generell auf andere kommunale Gebiete in Namibia oder Südafrika übertragen werden.

In Mutompo wurde die Tierhaltung hauptsächlich angetrieben durch den Bedarf an Ochsen zum Pflügen und für Transportzwecke. Die Produktivität der Rinder war gering, trotz des großen Angebots an natürlichen Futterressourcen. Eine Ursache hierfür könnte der geringe Nährstoffgehalt der Grasvegetation sein, der schon kurz nach der Samenreife gemessen wurde. Oder die Rinder blieben zu lange in den Herden und werden alt angesichts der geringen Umsatzrate. In Okamboro waren die Rinder ökonomisch am wichtigsten, auch wenn anscheinend nur wenige verkauft wurden. Die Ovaherero sind traditionelle Rinderhalter. Neben der hohen Bedeutung der Milch als Nahrungsmittel haben Rinder wichtige kulturelle und religiöse Funktionen. Die Produktivität der Rinder war moderat bis gut. Reinrassige Zuchtbullen (hauptsächlich Brahman) wurden in einigen Herden gehalten. Einige ‚Absentees', so genannte Wochenendbauern, und einige wenige reichere Haushalte waren für den Großteil des Beweidungsdrucks in Okamboro verantwortlich, und das Einzäunen von kommunalem Land war weit verbreitet. In beiden Dorfgemeinschaften waren die Nutztiere fast ausschließlich abhängig von den natürlich vorkommenden Futterressourcen: den Gräsern und Blättern. Laut den Ergebnissen aus den Interviews wurden nur wenige Nutztiere verkauft, auch wenn regelmäßig ein Tiermarkt in der Nähe von Okamboro stattfand. Bei den meisten Kleinbauern war die Herdengröße für eine effiziente Vermarktung zu klein. Die wichtigsten Einnahmequellen waren externe Einkommen und Alterspensionen. Die Nutztierhaltung war meistens nicht marktorientiert, und es wurde wenig in die Tiere investiert. Nichtsdestotrotz wurde in Mutompo innerhalb eines Zeitraums von 2 Jahren eine Reduzierung der Rinderzahlen um 43 % beobachtet, weil die Hirseernten gering ausfielen. Vermutlich wurden Tiere auf dem informellen Markt verkauft oder getauscht, um die Nahrungsmittelversorgung der Familien zu sichern. Insgesamt bestätigen die Ergebnisse die Hypothese, dass die Tiere in den kommunalen Gebieten, besonders die Rinder, multi-funktionelle Qualitäten haben (Prestige, Ersparnisse, und Sicherheit), und noch immer das traditionelle Verhalten überwiegt Risiken zu minimieren. Die Tiere werden nicht verkauft, sondern die Herden werden vergrößert. Somit wird die Herdengröße nicht an die vorhandene verfügbare Futterressourcenmenge angepasst. Während einer Dürre werden die Rinder mit LKWs in Richtung Norden transportiert, was sich nur die reicheren Bauern leisten können.

Externe Faktoren, wie z.B. schlechte Infrastruktur, schlechten Zugang zu Märkten, keine Preistransparenz sowie fehlende Transportmöglichkeiten verhindern die erfolgreiche Vermarktung von Nutztieren, besonders in Mutompo. Zusätzlich dazu blockiert der Veterinärszaun den Exportmarkt für Rindern aus den nördlichen kommunalen Gebieten Namibias. Es wurde eine starke soziale Stratifizierung in beiden Dorfgemeinschaften festgestellt. Ein Drittel der Bauern, hauptsächlich einige reichere und einige ‚Wochenend'-Bauern, besitzen 83% aller Nutztiere in Mutompo; in Okamboro sind es 70%. Die ärmsten Haushalte besitzen keine Nutztiere. Arbeitslosigkeit, aber auch Unterbeschäftigung ist in den kommunalen Gebieten weit verbreitet, und alternative Beschäftigungsmöglichkeiten in Sektoren außerhalb des Agrarbereichs fehlen weitestgehend – dadurch wird die Tierhaltung von Kleinbauern in kommunalen Gebieten in Zukunft eher zunehmen als abnehmen. Das betrifft weniger Mutompo, weil dort der Anbau von Hirse in Jahren mit ausreichendem Regen die Leute mit dem Grundnahrungsmittel versorgt. Personen, die zum Arbeiten in die Städte migriert sind, investieren ihren Verdienst in die Nutztiere in ihrem Heimatdorf. Das wird den Beweidungsdruck in den kommunalen Gebieten in Zukunft noch erhöhen.

Mögliche Lösungs- oder Verbesserungsansätze bezogen auf die Weidenutzung und das Management der Tiere in Okamboro könnte z.B. eine bessere und regelmäßige Nutzung der Peripherie sein, was durch gezieltes Hüten zusammengelegter Herden erreicht werden kann. Oder die Etablierung von permanenten, außerhalb gelegenen Viehstationen, in denen junge Rinder und Bullen gehalten werden, würde den Weidedruck räumlich weiter streuen. Eine kombinierte Wasser- und Beweidungsgebühr, welche allerdings verbrauchsabhängig sein muss und nicht pauschal per Haushalt erhoben wird, würde höhere Anreize zum Verkauf oder zur Schlachtung von Tieren geben. Diese Weide-Wasser-Gebühr sollte schrittweise je nach Viehbesitz ansteigen und in einen kommunalen Fond eingezahlt werden. Dieses Geld könnte für notwendige Investitionen zur Verbesserung der Tierhaltung genutzt werden, wie z.B. die Verbesserung der Wasserversorgung, eine bessere Gesundheitsversorgung und -vorsorge der Tiere, oder das Angebot von Mineral- und Ergänzungsfutter auf zentralen Plätzen. Allerdings benötigen alle diese Maßnahmen einen hohen Grad an Kooperationsbereitschaft unter den Bauern in der Dorfgemeinschaft, und es könnte deshalb Schwierigkeiten bei der Implementierung geben. Die Bauern in Mutompo sollten sich wegen des großen Risikos von geringen Ernten oder sogar Ernteausfällen, und wegen der übermäßig großen Arbeitsbelastung aufgrund der geringen Mechanisierung im Ackerbau, mehr oder ausschließlich auf die Nutztierhaltung konzentrieren. Eine Art Nichtbeweidungsabkommen von bestimmten Flächen, wie es bei den Bauern in Mutompo beobachtet wurde, kann Futterressourcen für das Ende der Regenzeit bereitstellen. Eine Diversifizierung der Einkommensquellen zur Bestreitung des Lebensunterhaltes durch andere als die Tierhaltung, entweder im Agrarbereich oder in einem anderen Sektor, ist für die meisten Leute auf dem Lande nicht möglich. Das ‘Affirmative Action’ Anleiheschema ist ein Umsiedlungsprogramm, welches Farmland und Kredite für kommunale Bauern mit mindestens 150 Rindern (oder 800 Ziegen oder Schafen) zur Verfügung stellt, damit diese eine kommerziell bewirtschaftete Farm aufbauen können. Es zielt auf die Reduzierung des von reicheren Bauern verursachten Nutzungsdruckes auf kommunale Ressourcen, und ist ein Schritt in die richtige Richtung. Kredite werden allerdings nicht für die ärmeren Farmer zur Verfügung gestellt, und ein gut zugängliches und vertrauenswürdiges Bankensystem in ruralen Gebieten wäre notwendig, um alternative Möglichkeiten für Investitionen zu schaffen.

Ein partizipativer Entwicklungsprozess, basierend auf den Ergebnissen dieser Studie, könnte lokal angepasste und umsetzbare Lösungen entstehen lassen. Das wäre eine echte Alternative gegenüber dem passiven Abwarten auf die Verbesserung der Infrastruktur und des Bildungssystems oder dem Zugang zu Märkten, die irgendwann von der Regierung bereitgestellt werden.

9 References

Abel,N. 1997. Mis-measurement of the productivity and sustainability of African communal rangelands: a case study and some principles from Botswana. *Ecological Economics*. 23:113-133.

Abel,N.O.J. and P.M.Blaikie. 1990. Land degradation, stocking rates and conservation policies in the communal rangelands of Botswana and Zimbabwe. *ODI, Natural Resources Perspective*. 29a.

Adams,F., W.Werner, and P.Vale. 1990. The land issue in Namibia: an inquiry. NISER Research Report, 1-186.

Aganga,A.A., T.Adogla-Bessa, U.J.Omphilie, and K.Tshireletso. 2000. Significance of browse in the nutrition of Tswana goats. *Archivos de Zootecnia*. 49:469-480.

Agricultural Bank of Namibia. 2000. Annual Report 2000. Windhoek, Namibia.

Agricultural Bank of Namibia. 2001. Annual Report 2001. Windhoek, Namibia.

Akritas,M.G., S.F.Arnold, and E.Brunner. 1997. Nonparametric Hypotheses and Rank Statistics for Unbalanced Factorial Designs. *Journal of the American Statistical Association*. 92:258-265.

Anonymous. 2004. Mixed systems: Use of crop residues. http://lead.virtualcenter.org/en/dec/toolbox/Mixed1/MSys2crp.htm. 6-9-2004.

ARC (Agricultural Research Council). 1980. The nutritional requirements of ruminant livestock. CABI (Commonwealth Agricultural Bureaux International), Slough, UK. 351 pp.

Armbruster, T. and W. Bayer. 1992. Quick ways to assess animal productivity: Interviewing cows. ILEIA Newsletter, 8 (3).

Ashley,C. 1996. Incentives affection biodiversity conservation and sustainable use: the case of land use options in Namibia. Research discussion paper [13], 1-22. Windhoek, Namibia, Directory of Environmental Affairs, Ministry of Environment and Tourism (MET). Research discussion paper.

Ayantunde,A.A., P.Hiernaux, S.Fernández-Rivera, H.van Keulen, and H.M.J.Udo. 1999. Selective grazing by cattle on spatially and seasonally heterogeneous rangeland in Sahel. *Journal of Arid Environments*. 42:261-279.

Baars,R.M.T. 2002. Rangeland utilization assessment and modelling for grazing and fire management. *Journal of Environmental Management*. 64:377-386.

Baas,S. 1993. Weidepotential und Tragfähigkeit in Zentralsomalia: ein integriertes Evaluierungskonzept zur Bestimmung des Nutzungspotentials für Weidegebiete mit mobiler Tierhaltung (The potential and the carrying capacity of pasture in Central Somalia: an integrative concept for evaluation of use potential of pasture regions with mobile livestock systems). df, 1-312. Berlin, Reimer Verlag.

Barnard,P. and Namibian National Biodiversity Task Force (NNBTF). 1998. Namibian National Biodiversity Programme: Country study. 1-317. Windhoek, Namibia, MET, DEA.

Barret,J.C. 1991. The economic role of cattle in communal farming systems in Zimbabwe. 1-35.

Barton,T., G.Borrini-Feyerabend, A.de Sherbininand, and P.Warren. 1997. *Our People, Our Resources*, IUCN, Gland, Switzerland and Cambridge, UK. http://www.iucn.org/themes/spg/Files/opor/opor.html#contents. 7-10-2004.

Bayer,W. 1988. Ranking of browse species by cattlekeepers in Nigeria. *RRA Notes, IIED London* .4-10.

Bayer,W., M.Metz, J.Sievers, C.Tapscott, and P.Vigne. 1991. Sustainable livestock production in the less developed areas of Namibia. Sector analysis and planning study. Vol.1, 1-157. 1991. GTZ Eschborn.

Bayer,W. and A.Waters-Bayer. 1998. *Forage husbandry*. Macimillian education LTD. London and Basingstoke.

Becker,K., E.Schlecht, C.Hülsebusch, F.Mahler, H.Marschner, and A.Bürkert. 2000. The Influence of livestock mediated nutrient transfers on cropland. Fertility in agro-pastoral land use systems of western Niger. 150-187. University of Hohenheim. Special Research Programme 308.

Behnke,R.H. and N.Abel. 1996. Intensification or overstocking: When are there too many animals? A series of three articles: The quantification of grazing capacity from grazing - and production values for forage species in semi-arid grasslands of southern Africa. *World animal review*. 87.

Behnke,R.H. and C.Kerven. 1994. Redesigning for risk: tracking and buffering environmental variability in Africa's rangelands. ODI, Natural Resources Perspective 1, 1-7.

Behnke,R.H. and I.Scoones. 1993. Rethinking range ecology: Implications for rangeland management in Africa. In R.H.Behnke, I.Scoones, and C.Kerven, editors, *Range ecology at disequilibrium, New models of natural variability and pastoral adaptation in African savannas*. ODI. London. 1-30.

Bessette,G. 2004. Involving the Community: A guide to participatory development communication. http://www.idrc.ca/en/ev-52226-201-1-DO_TOPIC.html, 1-143. Southbound, Penang, Malaysia, and International Development Research Centre, Ottawa, Ontario, Canada. 5-8-2006.

Bester,F.V. and MAWRD. 2003. Grazing Register: Based on the biomass concept. *Spotlight on Agriculture, published by the Ministry of Agriculture, Water and rural Development, Windhoek, Namibia*. 67:1-2.

Bester,F.V. and E.Reed. 1997. Bush encroachment: a thorny problem. *Spotlight on Agriculture, published by the Ministry of Agriculture, Water and rural Development, Windhoek, Namibia*. 1: 1-2.

Bester,F.V., J.A.J.van Eck, and H.Kölling. 1999. The influence of stocking rate on the species composition and grazing capacity of the natural vegetation. In MAWRD, editor, Windhoek. (September 999):238-244.

Bester,J., L.E.Matjuda, J.M.Rust, and H.J.Fourie. 2001. The Nguni: A Case Study. Swaziland workshop on Animal Genetic Resources 2001 (FAO).

Bester,F.V., J.A.J.van Eck, H.Kölling, B.van Rooyen, R.Prinsloo, and MAWRD. 2003. The influence of stocking rate on the grass layer of the Camel Thorn Savanna. *Spotlight on Agriculture, published by the Ministry of Agriculture, Water and rural Development, Windhoek, Namibia*. 66:1-2.

Bille,J.C. 1980. Measuring the primary palatable production of browse plants. In H.N.Le Houérou, editor, *Browse in Africa*. International Livestock Centre for Africa. Addis Ababa, Ethiopia. 185-196.

Binswanger,H., K.Deininger, and G.Feder. 1995. Power, distortions, revolt and reform in Agricultural land relations. Economics Chapter 42. Amsterdam. Handbook of Development.

Binswanger,H. and P.Pingali. 1988. Technology priorities for farming in sub-Saharan Africa. *Research Observer*. 3:81-98.

Blackie,R. 1999. Communities and natural resources: Trends in equitable and efficient use. 29, 1-19. Windhoek, MET. Research Discussion Paper.

Blench,R. and F.Sommer. 1999. Understanding rangeland biodiversity. 1-50. ODI, London.

Bollig,M. and A.Schulte. 1999. Environmental change and pastoral perceptions: Degradation and indigenous knowledge in two African pastoral communities. *Human Ecology*. 27:493-514.

Botha,P. 1981. The effect of selection by sheep, goats and cattle on composition of Mixed Karoo veld (in Afrikaans). D.Sc. Agric. Thesis. Potchefstroom Univesity, South Africa.

Brandt,H. 1980. *Development perspectives for agriculture in an independent Namibia*. In GTZ: Perspectives of independent development in Southern Africa. The case study of Zimbabwe and Namibia. Berlin.

Brand,T.S. 2000. Grazing behaviour and diet selection by Dorper sheep. *Small Ruminant Research.* 36:147-158.

Breman,H. and C.T.de Wit. 1983. Rangeland productivity and exploitation in the Sahel. *Science*. 221:1341-1347.

Briske,D.D., D.Fuhlendorf, and F.E. Smeins. 2003. Vegetation dynamic on rangelands: a critique of the current paradigms. *Journal of Applied Ecology*. 40, 601-614.

Brits,J., M.W.van Rooyen, and N.van Rooyen. 2002. Ecological impact of large herbivores on the woody vegetation at selected watering points on the eastern basaltic soils in the Kruger National Park. *African Journal of Ecology*. 40:53-60.

Brown, C. 2002. Namibia's Natural Resource Sector. A contribution to vision 2030. Special case study: Conservancies and community-based natural resource management (CBNRM) initiatives in Namibia and their contribution to poverty alleviation in rural areas. www.sasusg.net/web/files/papers/Vision%2030%20CBNRM%20case% 20study.pdf. http:// www.sasusg.net/web/files/papers/Vision 2030 CBNRM case study.pdf. 8-17-2005.

Burger,S. 2002. Poisonous plants. *Farmer's Weekly*.32-33.

Burke,A. 2004. Range management systems in arid Namibia - what can livestock numbers tell us? *Journal of Arid Environments*. 59:387-408.

Buß,H.-J. 2005. Land Use Options of Namibian Farms- Optimal Management Strategies Proposed by Bioeconomic Models. PhD-thesis. Agrarökonomische Studien, Band 26, Kiel. Wissenschaftsverlag Vauk.

Byers,B.A. 1997. Environmental threats and opportunities in Namibia: A comprehensive assessment. Research Discussion Paper [21], 1-62. 1997. Windhoek, Namibia, Ministry of Environment and Tourism.

Chambers,J.W., B.Cleveland, B.Kleiner, and P.Tukey. 1983. *Graphical Methods for Data Analysis*. Wadsworth.

Chandler,D.R. 1983. The grazing animal and land pressure in small farming systems: Must ruminant nutrition cerate inevitably confontation between arable land and grazing requirements. *Proceedings Draft Power and Animal Feeding Conference, OD. 1983. Swasiland, CIMMYT.*

Chilonda,P. 2005. Livestock sector brief: Namibia. FAO, AGAL http://www.fao.org/ag/againfo/resources/en/publications/sector_briefs/lsb_NAM.pdf. 15-8-2011.

Chilonda,P. and J.Otte. 2006: Indicators to monitor trends in livestock production at national, regional and international levels. *Livestock Research for Rural Development. Volume 18, Article #117.* http://www.lrrd.org/lrrd18/8/chil18117.htm. 8-8-11.

Cox,J., C.Kerven, W.Werner, and R.H.Behnke. 1998. Privatisation of rangeland resources in Namibia. Project summery Project R6607 Livestock production programme (funded by DFID), 1-2.

de Leeuw,P.N., L.Diarra, and P.Hiernaux. 1993. An analysis of feed demand and supply for pastoral livestock: The Gourma region in Mali. In R.H.Jr.Behnke, I.Scoones, and C.Kerven, editors, *Range ecology at disequilibrium: New models of natural variability and pastoral adaptation in African Savannas*. Overseas Development Institute. London. 136-152.

de Leeuw,P.N. and J.C.Tothill. 1993. The concept of rangeland carrying capacity in Sub-Saharan Africa - myth or reality. In R.H.Behnke, I.Scoones, and C.Kerven, editors, *Range ecology at Disequilibrium: New models of natural variability and pastoral adaptation in African Savannas*. 77-88.

de Pauw,E., M.E.Coetzee, A.J.Calitz, H.Beukes, and C.Vits. 1999. Production of an Agro-Ecological Zones Map of Namibia, Part II. *Agricola*. 10 :33-43.

Dekker,B. and G.N.Smit. 1996. Browse production and leaf phenology of some trees and shrubs in different *Colophospermum mopane* savanna communities. *African Journal of Range & Forage Science*. 13:15-23.

Deniau,L., O.Mukulu, H.Iyambo, and F.Blanc. 1997. Livestock productions in Omusati and Ohangwena regions, Namibia. Windhoek, Namibia.113-131.

DeRamus,H.A. 2004. Grazing management of ruminant animals in sustainable agriculture. *Outlook on AGRICULTURE*. 33:93-100.

Deshmukh,I.K. and M.N.Baig. 1983. The significance of grass mortality in the estimation of primary production of African grasslands. *African Journal of Ecology*. 21:19-23.

Devereux,S. 2001. Social pensions in Namibia and South Africa. IDS Discussion Paper 379, 1-51. Institute of Development Studies.

Diarra,L., P.Hiernaux, and P.N.de Leeuw. 1995. Foraging behaviour of cattle grazing semi-arid rangelands in the Sahel of Mali. In J.Powell, S.Fernández-Rivera, T.O.Williams, and C.Renard, editors, *Livestock and Sustainable Nutrient Cycling in Mixed Farming Systems of sub-Saharan Africa. Volume II: Technical Papers. Proceedings of an International Conference held in Addis Ababa, Ethiopia, 22-26 November 1993.* ILCA (International Livestock Centre for Africa). Addis Ababa, Ethiopia. 101-115.

Dodd,J.L. 1994. Desertification and degradation in Sub-Saharan Africa. *BioScience*. 44:28-33.

Dougill,A. and J.Cox. 1995. Land degradation and grazing in the Kalahari New analysis and alternative perspectives. *Pastoral Development Network*. 38.

Dougill,A. and N.Trodd. 1999. Monitoring and modelling open savannas using multisource information: analyses of Kalahari studies. *Global Ecology and Biogeography*. 8:211-221.

du Peez,C.C. and H.A.Snyman. 2003. Soil organic matter changes following rangeland degradation in semi-arid South Africa. *Proceedings of the VIIth International Rangeland Congress, Durban*.476-478.

du Pisani,A.L. 2000. Evaluation of Seasonal Biomass using NOAA Satellite Imagery, and Field sampling report for the 1999-2000 growing season. Windhoek, MAWRD/GDTA.

du Plessis,W.P. 2000. Effective rainfall defined using measurements of grass growth in the Etosha National Park, Namibia. *Journal of Arid Environment*: 1-20.

du Toit,J.T. 1974. Feeding-height stratification among African browsing ruminants. *African Journal of Ecology*. 28:55-61.

Dube,O.P. and G.Pickup. 2001. Effects of rainfall variability and communal and semi-commercial grazing on land cover in southern African rangelands. *Climate Research*. 17:195-208.

Dube,S., C.Salinas, and O.Mukulu. 2006. The value of trees as fodder for livestock in Northern Namibia. www.foa.org/WAIRDOCS/LEAD/X6109e09E/x6109e0a.htm. 1-9-2004.

Düvel,G.H. 2000. Livestock marketing in Northern Namibia: Cultural versus economic incentives in the marketing of livestock. AIAEE 2000.109-116.

Ellis,J.E. and D.M.Swift. 1988. Stability of African pastoral ecosystems: Alternate paradigms and implicatins for development. *Journal of Range Management*. 41 (6).

Els,J.F., P.T.Jessen, and H.Von Seydlitz. 1999. Strategies for dry season feeding of animals in Namibia. In D.H.Holness (editor). Strategies for dry season feeding of animals in central and southern Africa. Proceedings of a joint ZSAP/FAO Workshop held in Harare, Zimbabwe. 25th – 27th October 1999. 1-6. http://www.fao.org/DOCREP/004/AC152E/AC152E03.htm#ses2.4. 8-9-2004.

Erskine,J.M. 1988. The human carrying capacity of South Africa's less developed areas. A case study from KwaZulu. Paper presented at the Biennial Conference of the Development Society of Southern Africa, University of Durban-Westville; Occasional Paper 17, Institute of Natural Resources, University of Natal, Pietermaritzburg.

Falk,T. 2007. Communal Farmers' Natural Resource Use and Biodiversity Preservation - A New Institutional Economic Analysis from Case Studies in Namibia and South Africa. PhD-thesis, Philipps University Marburg.

FAO. 1991. Guidelines: land evaluation for extensive grazing. 1-158. Rome , FAO. FAO Soils Bulletin 58.

FAO. 1995. Irrigation in Africa in figures - L'irrigation en Afrique en chiffres, Water reports, Namibia. FAO.

FAO. 1998. World reference base for soil resources. World Soil Resources Report No. 84.,1-88. Rome, Italy.

Farm Animal Conservation Trust. 2001. Landrace Breeds: South Africa's Indigenous and Locally Developed Farm Animals, South Africa.

Ffoulkes,D. 1998. Pasture quality and animal requirements (Part 1: Supplementary feeding of grazing livestock in the top end of the NT). *Agnote*. 521:1-5.

Flower,C. and N.von Rooyen. 2001. Kavango farming systems research and extension project: Summary of agroforestry study. *Agricola*. 2001:45-51.

Friedel,M.H. 1991. Range condition assessment and the concept of threshold: A viewpoint. *Journal of Range Management*. 44:422-426.

Friedel,M.H. 1997. Discontinuous change in arid woodland and grassland vegetation along gradients of cattle grazing in central Australia. *Journal of Arid Environment*. 37:145-164.

Fuller,B., S.Nghikembua, and T.F.Irving. 1996. The enclosure of range lands in the eastern Oshikoto region of Namibia. 1-18. Windhoek, Social Sciences Division, Multi-Disciplinary Research Centre, University of Namibia. SSD Research Report 24.

Fusco,M., J.Holechek, A.Tembo, A.Daniel, and Cardenas M. 1995. Grazing influences on watering point vegetation in the Chihuahuan desert. *Journal of Range Management*. 48:32-37.

Ganzin,N., A.Rothauge, M.E.Coetzee, and A.L.du Pisani. 2003. Rangelands resource assessment with satellite imagery: An operational tool for national planning in Namibia. *Proceedings of the VIIth International Rangeland Congress, Durban*. 2013-2015.

Gillet,H. 1986. Desert and Sahel. In G.W.Lawson, editor, *Plant ecology in West Africa*. John Wiley. Chichester. 174-181.

Glatzle,A. 1990. *Weidewirtschaft in den Tropen*. Verlag E. Ulmer. Stuttgart.

Gonsalves,D.J., T.Becker, A.Braun, D.Campilan, H.de Chavez, E.Fajber, M.Kapiri, J.Ricaca-Caminade, and R.Vernooy. 2005a. Participatory Research and

Development for sustainable Agriculture and Natural Resource Management: A Sourcebook. Volume 1: Understanding Participatory Research and Development. 1-272. http://www.idrc.ca/en/ev-73443-201-1-DO_TOPIC.html. 10-8-2007.

Gonsalves,D.J., T.Becker, A.Braun, D.Campilan, H.de Chavez, E.Fajber, M.Kapiri, J.Ricaca-Caminade, and R.Vernooy. 2005b. Participatory Research and Development for sustainable Agriculture and Natural Resource Management: A Sourcebook. Volume 2: Enabling Participatory Research and Development. 1-218. http://www.idrc.ca/en/ev-73444-201-1-DO_TOPIC.html. 10-8-2007.

Gonsalves,J., T.Becker, A.Braun, D.Campilan, H.de Chavez, E.Fajber, M.Kapiri, J.Ricaca-Caminade, and R.Vernooy. 2005c. Participatory Research and Development for sustainable Agriculture and Natural Resource Management: A Sourcebook. Volume 3: Doing Participatory Research and Development. 1-248. http://www.idrc.ca/en/ev-73446-201-1-DO_TOPIC.html. 10-8-2007.

Graz,F.P. 2004. Structure and diversity of the dry woodland savanna of northern Namibia. 1-158. Dissertation. Georg-August-Universtät Göttingen.

Guevara,J.C., O.R.Estevez, and E.R.Torres. 1996. Utilization of the rain-use efficiency factor for determining potential cattle production in the Mendoza plain, Argentina. *Journal of Arid Environment*. 33:347-353.

Gundy,I. 2003. Natural resources in communal rangelands as a key component of rural livelihoods. Durban, South Africa.1609-1619.

Hailwa,J. 1998. Non-wood forest products in Namibia. Directorate of Forestry, Ministry of Environment and Tourism. Windhoek.

Hardin,G. 1968. The tragedy of the commons. Science 162.1243-1248.

Harris,P.S. 2000. Modelling grassland and livestock resources for development planning. *Grassland resource assessment for pastoral systems*. FAO Plant production and protection paper 162, Chapter 5. http://www.fao.org/DOCREP/003/X9137E/x9137e00.htm. 9-8-2004.

Harrison,Y.A. and C.M.Shackleton. 1999. Resilience of South African communal grazing lands after the removal of high grazing pressure. *Land Degradation & Development*. 10:225-239.

Hassan,W.A. 2000. Biological productivity of sheep and goats under agro-silvo-pastoral systems in the Zamfara Reserve in north-western Nigeria. University Giessen.

Hendricks,H.H., P.A.Novellie, W.J.Bond, and J.J.Midgley. 2002. Diet selection of goats in the communally grazed Richtersveld National Park. *African Journal of Range & Forage Science*. 19:1-11.

Hengua,A. and R.Bovell. 1997. Communal livestock in Okavango: A literature review. KFSR/E Livestock review, 1-28. KFSR/E working document 22.

Hiernaux,P. 1980. Inventory of the browse potential of bushes, tress and shrubs in an areas of the Sahel in Mali: Method and initial results. In H.N.Le Houérou, editor, *Browse in Africa*. International Livestock Centre for Africa. Addis Ababa, Ethiopia. 197-203.

Hochobeb,B.N. 2002. Reliance of rural communities in Namibia on long-term weather forecasts and development of effective communication tools and products to transfer the seasonal forecast information for the rainy season from the Namibia Metrological Services to these communities. Namibian Institute of Health and Safety CC (REG. NO. 98/1308).

Holling,C.S. 1973. Resilience and stability of ecological systems. *Annual Review of Ecological Systems*. 4:1-23.

Hopfenberg,R. 2003. Human support capacity is determined by food availability. *Population and Environment*. 25.

Humphrey,L.R. 1991. *Tropical pasture utilization*. Cambridge University Press. Cambridge.

Huntley,B.J. 1982. Southern African Savannas. In B.J.Huntley and B.H.Walker, editors, *Ecology of Tropical Savannas*. SpriBillings,W.D.; Golley,F.; Lange,O.L.; Olson,J.S.; Remmert,H.nger-Verlag. Berlin, Heidelberg, New York. 101-119.

IFAD, 1992: Namibia: Northern livestock improvement project. A socio-economic and production systems diagnostic study, IFAD, Rome

Illius,A.W., J.F.Derry, and I.J.Gordon. 1998. Evaluation of strategies for tracking climatic variation in semi-arid grazing systems. *Agricultural Systems*. 57:381-398.

Imbamba,S.K. 2003. A case study in land degradation and human vulnerability in the drylands of northern Namibia. htto://africa.unep.net/casestudies/pdf/ land_degradation_nNamibia.pdf, 1-30. UNEP. 15-3-2005.

Irving,T.F. and S.Janssen. 1992. Sustainable livestock production in the less developed areas of Namibia. Environmental assessment study and identification of pilot areas for Hereroland and Namaland. Vol. 2. Windhoek, Namibia, UNAM Multi-disciplinary Research and Consultancy Centre (MRC).

Jahnke,H.E. 1982. *Livestock production systems and livestock development in tropical Africa*. Kieler Wissenschaftsverlag Vauk. Kiel.

James,C.D., J.Landsberg, and S.R.Morton. 1999. Provision of watering points in the Australian arid zone: a review of effects on biota. *Journal of Arid Environments*. 41:87-121.

Jeltsch,F., T.Stephan, S.J.Milton, W.R.J.Dean, and N.van Rooyen. 1996. Verbuschungsdynamik an Wasserstellen in der südlichen Kalahari - ein räumliches Simulationsmodel. *Verhandlungen der Gesellschaft für Ökologie*. Band 26:435-442.

Jeltsch,J., N.van Rooyen, G.E.Weber, W.R.J.Dean, and S.J.Milton. 1999. Piosphere, grazing and shrub encroachment in the semi-arid southern Kalahari. *VIth International Rangeland Congress Proceedings*. Vol 1:533-535.

Jones,B.T.B. 2003. Selected natural resource management and limited rural development assessment. USAID/Namibia. 1-90.

Jones.B.T.B. and D.S.Cownie. 2001. Socio-ecological survey report for the Kavango region. Results of a socio-ecological survey carried out in the Kavango region, Namibia, May to August 2001. Windhoek, Namibia.

Joubert,D.F. and A.Rothauge. 2001. A preliminary state-and-transition model for managers of semi-arid rangeland in central Namibia. Poster.

Kakujaha-Matundu,O. 2003. Self-management of common pool resources among pastoral Ovaherero in semi-arid eastern Namibia. The Hague, The Netherlands, Institute of Social Studies (ISS).

Kamupingene,G.T. and A.L.Abate. 2004. Nutritive value of goat diets in Okondjatu communal area of east-central Namibia. *South African Journal of Animal Science*. 34 (Supplement 1).

Kassaye, H. 1992. Interviewing cows. RRA Notes 15, pp. 52-53

Katjiua,M. and D.Ward. 2007. Pastoralists perceptions' and realities of vegetation change and browse consumption in the northern Kalahari, Namibia. *Journal of Arid Environments*. 69, 716-730.

Kaufmann,B. 1998. Analysis of pastoral camel husbandry in northern Kenya. Weikersheim, Germany, Margraf. Tropical Agricultural Series, Hohenheim.

Kempf,J. 2000. Klimageomorphologische Studien in zentral-Namibia: ein Beitrag zur Morpho-, Pedo- und Ökogenese. 1-548. University Würzburg.

Kennedy,A.D. 2003. Stability and resilience of South African savanna grasslands to drought. www.britischecologicalsocietey.org/articles/grants/reports/1614, 1-6.

Kessler,J.J. 1994. Usefulness of the human carrying capacity in assessing ecological sustainability of land-use in semi-arid regions. *Agriculture, Ecosystems and Environment*. 48:273-284.

Keya,G.A. 1998. Herbaceous layer production and utilization by herbivores under different ecological conditions in an arid savanna of Kenya. *Agriculture, Ecosystems and Environment*. 69:55-67.

Keyler,S. 1995. Economics of the pearl millet subsector in northern Namibia. A summary of baseline data. ICRISAT Working Paper 95/3. Windhoek.

King,J.M. 1983. *Livestock water needs in pastoral Africa in relation to climate and forage*. ILCA, Addis Ababa, Ethiopia.

Kirchgessner,M. 1997. *Tierernährung*. DLG Verlag Frankfurt/Main.

Knemeyer,J.L. 1985. Untersuchung über die Nutzung marginaler Standorte in Afrika durch eine Bewirtschaftung von Wildtieren - dargestellt am Beispiel von Nordwest Namibia, (Investigation on the use of marginal regions in Africa for wildlife management – an example from north-western Namibia). 1-250. Justus-Liebig-Universiät Giessen.

Kott,R. 2004. Nutrition Part 1 - Section 5 to 7. Montana Farm Flock Sheep Production Handbook. http://animalrangeextension.montana.edu/Articles/Sheep/Flock%20Handbook/Nutrition-1.htm [1].

Kressirer,R.F. and A.S.Kruger. 1995. On-farm research in animal production and range management in the communal areas of Namibia - one way how to look at it. Windhoek, Namibia. Proc. 6th AGRISON Congress, September 1995.

Kruger,A.S. 1998. The influence of stocking rate and cattle type on veld and animal performance in the camel thorn savanna of Namibia. M.Sc. thesis, University of Pretoria, South Africa. 172.

Kruger,A.S. 2001. Towards sustainable range management and livestock production. In J.C.Fitter, R.F.Kressirer, T.Kroll, A.S.Kruger, N.P.K.Neumann, and W.Werner, editors, *Coping in a fragile environment, the SARDEP experience. The Sustainable and Range Development Programme (SARDEP) in the communal areas of Namibia*. MAWRD. Windhoek, Namibia. 89-106.

Kruger,A.S. and N.F.G.Rethman. 1999. The influence of stocking rate and cattle type on the condition of the herbaceous layer in the camel thorn savanna of Namibia. *VIth International Rangeland Congress Proceedings*. Vol. 1:488-489.

Kruger,A.S. and H.Woehl. 1996. The challenge for Namibia's future: Sustainable land-use under arid and semi-arid conditions. *Entwicklung + ländlicher Raum*. 4:16-20.

Krugmann,H. 2001. Fundamental issues and the threats to sustainable development in Namibia. *DEA Research Discussion Paper*. 26:1-37.

Kuiper,S.M. and M.E.Meadows. 2002. Sustainability of livestock farming in the communal lands of southern Namibia. *Land Degradation & Development*. 13:1-15.

Kutuahupira,J.T., H.D.Mouton, and M.E.Coetzee. 2001. Soil Survey of Sonop Research Station. *Agricola*. 2001:69-74.

Landau, S., A.Perevoltotsky, D.Bonfil, D.Barkai and N.Silanikove. 2000. Utilization of low quality resources by small ruminants in Mediterranean agro-pastoral systems: the case of browse and aftermath cereal stubble. *Livestock Production Science*. 64:39-49.

Landsberg,J., C.D.James, S.R.Morton, W.J.Müller, and J.Strol. 2003. Abundance and composition of plant species along grazing gradients in Australian rangelands. *Journal of Applied Ecology*. 40:1008-1024.

Lange,F. 2003. The productive performance of cattle in two communal areas of Namibia. within the framework of BIOTA Southern Africa, integrated in sub-project S11 Socio economic aspects of changes in biodiversity in southern Africa. 1-40, unpublished.

Lange,R.T. 1969. The piosphere: Sheep track and dung patterns. *Journal of Range Management*. 22:396-400.

Le Houérou,H.N. 1980. The role of browse in the Sahelian and Sudanian zones. In H.N.Le Houérou, editor, *Browse in Africa*. International Livestock Centre for Africa. Addis Ababa, Ethiopia. 83-100.

Le Houérou,H.N. 1984. Rain use efficiency: a unifying concept in arid-and ecology. *Journal of Arid Environments*. 7:213-247.

Le Houérou,H.N. 1989. *The grazing land ecosystems of the African Sahel*. Springer-Verlag. Berlin, Heidelberg, New York.

Le Houérou,H.N., R.L.Bingham, and W.Skerbek. 1988. Relationship between the variability of primary production and variability of annual precipitation in world arid lands." *Journal of Arid Environments*. 15:1-18.

Le Houérou,H.N. and C.H.Hoste. 1977. Rangeland production and annual rainfall relation in the Mediterranean basin and in the African Sahelo-sudanian zone. *Journal of Range Management*. 30:181-188.

Legel,S. 1990. Ernährung Schafe und Ziegen. In S.Legel, editor, *Nutztiere der Tropen und Subtropen, Bd. 2: Büffel, Kamele, Schafe Ziegen, Wildtiere*. S. Hirzel Verlag. Stuttgart, Leipzig. 306-469.

Leggett,K., J.Fennessy, and S.Schneider. 2003a. Does land use matter in an arid Environment? A case study from the Hoanib River catchment, north-western Namibia. Journal of Arid Environments. 53:529-543.

Leggett,K., J.Fennessy, and S.Schneider. 2003b. Seasonal vegetation changes in the Hoanib River catchment, north-western Namibia: a study of a non-equilibrium system. Journal of Arid Environments. 53:99-113.

Lewis,J.G. 1975.A comparative study of the activity of some indigenous East African ungulates and conventional stock under domestication. Ph.D. thesis London University.

Light,D., N.G.Buck, and L.L.Lethola. 1982. The reproductive performance, mothering ability and productivity of crossbreds and Tswana beef cows in Botswana. *Animal Production* . 35:421-426.

Lind,M., Rasmussem.K., H.Adriansen, and A.Ka. 2003. Estimating vegetative productivity gradients around watering points in the rangelands of Northern Senegal based on NOAA AVHRR data. *Danish Journal of Geography*. 103:1-15.

Ma,K. 1996. Die Futterressourcen Ningxias und ihre Nutzung. PhD-thesis. 1-190. University Giessen.

Magadzire,Z., I.J.Gordon, and A.W.Illius. 2005. Foraging strategies of cattle and goats during the late-wet and dry seasons in Southern Zimbabwe. 127-128. http://www.lpp.uk.com/media/default.asp?step=3&code=R6984&sf=2. 17-09-2006.

Maggs,G.L., P.Graven, and H.H.Kohlberg. 1998. Plant species richness, endemism, and genetic resources in Namibia. *Biodiverstiy and Consevation*. 7:435-446.

Mahanjana,A.M. and P.B.Cronje. 2000. Factors affection goat production in a communal farming system in the Eastern Cape region of South Africa. South African Journal of Animal Science. 30:149-154.

Makhabu,S.W., B.Marotsi, and J.Perkins. 2002. Vegetation gradients around artificial water points in the Central Kalahari Game Reserve of Botswana. *African Journal of Ecology*. 40:103-109.

Malan,J. 1998. *Die Völker Namibias*. Göttingen, Windhoek.

Masunda,B. 2002a. Home-made multi-nutrient blocks for improved ruminant performance in the communal areas. *Spotlight on Agriculture*. 60:1-2.

Masunda,B. 2002b. The effects of rangeland resting on biomass production, species composition and soil characteristics in a resting camp in Okongo. Proceeding of the reporting conference, Swakopmund, Namibia.

Matanyaire,C.M. 1998. Sustainability of pearl millet (*Pennisetum glaucum*) productivity in northern Namibia: current situation and challenges. *South African Journal of Science*. 94:157-165.

Maurer,U. 1996. Nutzungspotential und Landdegradation im semi-ariden Namibia. Ein Betrag zur Desertifikationsforschung. Der Tropenlandwirt [Beiheft Nr. 55], 1-195.

McDonagh,J.F. and A.E.M.Hillyer. 2003. Grain legumes in pearl millet systems in northern Namibia: an assessment of potential nitrogen contribution. *Expl. Agriculture*. 39:349-362.

Mendelsohn,J. and S.el Obeid. 2003. Sand and Water: A profile of the Kavango region. Cape Town, David Philip Publisher.

Mendelsohn,J., A.Jarvis, C.Roberts, and T.Robertson. Atlas of Namibia. 2002. Cape Town, David Philip Publisher.

Mendelsohn,J. 2006. Farming system in Namibia. With major contributions by S. el Obeid, N. de Klerk and P. Vigne. Chapter 3: The natural environment: http://www.the-eis.com/data/literature/Farming%20systems%20in%20Namibia%20Part%202.pdf. 5-8-2011.

Milton,S.J. and M.T.Hoffman. 1994. The application of state-and-transition models to rangeland research and management in arid succulent and semi-arid grassy Karoo, South Africa. *African Journal of Forage Science*. 11:18-26.

Ministry of Agriculture, Water and rural Development (MAWRD). 1992. Socio-economic survey of southern communal areas. 1-98. Windhoek, Namibia.

Ministry of Agriculture, Water and rural Development (MAWRD), and International Service for National Agricultural Research (ISNAR). 1993. *Review of the agricultural research system of Namibia*. The Hague, Netherlands.

Minson,D.J. 1981. Nutritional differences between tropical and temperate pastures. In F.H.W.Morley and .A.Neimann-Sorensen and D.E.Tribe, editors, *Grazing Animals. World Animal Sciences Series*. Elsevier. Amsterdam. 143-157.

Mogos, Y.T. and L.Kafidii. 2009: Risk management strategies of cattle farmers in Namibia: Case study from Omaheke and Otjozondjupa regions. *Journal of Agriculture Extension and Rural Development.* Vol.1 (2):63-70.

Moleele,N.M. 1998. Encroacher woody plant browse as feed for cattle. Cattle diet composition for three seasons at Olifants Drift, south-eastern Botswana. *Journal of Arid Environment*. 40:255-268.

Moleele,N.M. and J.S.Perkins. 1998. Encroachment woody plant species and boreholes: is cattle density the main driving factor in the Olifants Drift communal grazing lands, south-eastern Botswana. *Journal of Arid Environment*. 40:245-253.

Moleele,N.M., S.Ringrose, W.Matheson, and C.Vanderpost. 2002. More woody plants? The status of bush encroachment in Botswana's grazing areas. *Journal of Environmental Management*. 64:3-11.

Mortimore,M. 1998. *Roots in the African dust*. Cambridge University Press. Cambridge.

Morton,J. and N.Meadow. 2000. Pastoralism and sustainable livelihoods: an emerging agenda. National Resource Institute, Social Science Dept., UK.(www.nri.org) Policy Series No. 11, 1-50.

Mphinyane,W.N. 2001. Influence of livestock grazing within piospheres under free range and controlled conditions in Botswana.

Mphinyane,W.N. and N.F.G.Rethman. 2003. Influence of livestock grazing within piospheres on soil nutrients distribution and forage quality in the Kalahari Sandveld. *Proceedings of the VIIth International Rangeland Congress, Durban*.378-381.

Mwangala,S. 2003. On wet-spells in Namibia during the month of April with special reference to the wet spell of mid-April 2003. www.meteona.com. 18-10-2005.

Mwendera,E.J., M.A.Mohammed Saleem, and Z.Woldu. 1997. Vegetation response to cattle grazing in the Ethiopian highlands. *Agriculture, Ecosystems and Environment*. 64:43-51.

Ndikumana,J., J.Stuth, R.Kamidi, S.Ossiya, R.Marambi , and P.Hamlet. 2000. Effects of the 1995–97 drought and the 1997–98 El Niño rains and the responses of pastoralists and livestock. ILRI Project Report A-AARNET (ASARECA-Animal Agriculture Research Network), Nairobi Kenya. http://www.cgiar.org/ilri/info/databases.cfm; http://www.asareca.org/Networks/ARNDOC.htm, 1-124.

Ngwa,A.T., D.K.Pone, and J.M.Mafeni. 2000. Feed selection and dietary preferences of forage by small ruminants grazing natural pastures in the Sahelian zone of Cameroon. *Animal Feed Science Technology*. 88:253-266.

Nicholson,S.E. 2001. "Climate and evnironmental change in Africa during the last two centuries." *Climate Research*. 17:123-144.

NOLIDEP. 1996. Preliminary Site Surveys. Northern Region Livestock Development Programme, Ministry of Agriculture, Water and Rural Development (MAWRD). Windhoek, Namibia.

NRC. 1981. Nutrient requirements of domestic animals, number 15: Nutrient requirements of goats: Angora, dairy, and meant goats in temperate and tropical countries. *National Academic Press.* Washington, D.C.

NRC. 1987. Predicting Feed Intake of Food-Producing Animals Board on Agriculture *(BOA)*. *National academic press*, openbook.

NRC. 1996. Nutrient requirements of beef cattle. *National Academic Press*. Washington, D.C.

O'Connor,T.G. 1994. Composition and population responses of an African savanna grassland to rainfall and grazing. *Journal of Applied Ecology*. 31:155-171.

Oba,G. and E.Post. 1999. Browse production and offtake by free-ranging goats in an arid zone, Kenya. *Journal of Arid Environments*. 43:183-195.

Oba,G., E.Post, N.C.Stenseth, and W.J.Lusigi. 2000. The role of small ruminants in arid zone environments: A review of research perspectives. *Annals of Arid Zone*. 39:305-332.

Omphilie,U.J., A.A.Aganga, and B.Malamba. 2003. Diets and forage preference of communally grazed range goats in an *Acacia*-bush savanna in Southeast Botswana. *Proceeding of the VIIth International Rangeland Congress, Durban*. 1301-1305.

Osborn,T.G., J.G.Wood, and T.B.Paltridge. 1932. On the growth and reaction to grazing of the perennial saltbush (*Atriplex versicarium*). An ecological study of the biotic factor. *Proceedings of the Linnean Society of New South Wales*. 57:377-402.

Otte,M.J. and P.Chilonda. 2002. Cattle and small ruminant production systems in sub-Saharan Africa - A systematic review. FAO. http://www.fao.org/ag/againfo/resources/en/publications/agapubs/AGAL-Y4176E.pdf , 1-98.

Owen-Smith,N. 1982. Factors influencing the consumption of plant products by large herbivores. In B.J.Huntley and B.H.Walker, editors, *Ecological Studies 42: Ecology of tropical savannas*. Springer Verlag. Berlin, Heidelberg, New York. 360-404.

Palmer,A.R. 1999. Grazing capacity information system (GCIS). 1-19. Grahamstown, Agricultural Research Council.

Pearson,C.J. and R.L.Ison. 1987. *Agronomy of grassland systems*. Cambridge University Press. Cambridge.

Peel,M.J.S., H.Biggs, and P.J.K.Zacharias. 1999. The evolving use of stocking rate indices currently based on animal number and type in semi-arid heterogeneous landscapes and complex land use systems. *African Journal of Range & Forage Science*. 15:117-127.

Peet,R.K. 1974. The measurement of species diversity. *Annual Reviews Ecological Systems*. 5:285-307.

Pellew,R.A. 1980. The production and consumption of *Acacia* browse and its potential for animal protein production. In H.N.Le Houérou, editor, *Browse in Africa*. International Livestock Centre for Africa. Addis Ababa, Ethiopia. 223-231.

Pickup,G., G.N.Bastin, and V.H.Chewings. 1994. Remote-sensing-based condition assessment for nonequilibrium rangelands under large-scale commercial grazing. *Ecological Applications*. 4 :497-517.

Pickup,G., G.N.Bastin, and V.H.Chewings. 1998. Identifying trends in land degradation in non-equilibrium rangelands. *Journal of Applied Ecology*. 35:365-377.

Powell,J.M. 1985. Yield of sorghum and millet and stover consumption by livestock in the subhumid zone of Nigeria. *Tropical Agriculture*. 62:77-81.

Preston,T.R. 1986. Better utilization of crop residues and by-products in animal feeding: research guidelines 2. A practical manual for research workers. FAO ANIMAL PRODUCTION AND HEALTH PAPER 50/2.

Ranvig,H. and H.H.Hansen. 1999. Goat grazing and crop livestock interactions in rural areas in Zimbabwe. http://www.husdyr.kvl.dk/htm/hhh/ENRECA/ZIM.PDF. 20-1-2004

Riethmüller,P. 2003. The social impact of livestock: A developing country perspective. *Animal Science Journal*. 74:245-253.

Robertson,M. 1998. Land degradation, the 'New' Rangeland Ecology and the implications for Namibia. Windhoek, Namibia, Desert Research Foundation of Namibia.

RoN. 1991. National conference on Land Reform and the Land Question. Vol. 1. 1991. Windhoek, Namibia, Office of the Prime Minister.

RoN. 2001. Population and housing census: Preliminary report. 1-46. 2002. Windhoek, Namibia, Census Office.

Rothauge,A., A.L.Abate, and G.N.Smit. 2004. Stocking rate of free-ranging beef cattle affects their diet selection. *Agricola*. 14:33-36.

Rutherford,M.C. 1978. Primary production ecology in Southern Africa. In M.J.A.Werger, editor, *Biogeography and ecology of southern Africa*. Junk. The Hague.

Rutherford,M.C. 1980. Annual plant production-precipitation relations in arid and semi-arid regions. *South African Journal of Science*. 76:53-56.

Rutherford,M.C. 1982. Woody plant biomass distribution in *Burkea africana* Savannas. In B.J.Huntley and B.H.Walker, editors, *Ecological Studies 42: Ecology of tropical savannas*. Springer Verlag. Berlin, Heidelberg, New York. 120-141.

Saleem,M.A.M. 1998. Nutrient balance patterns in African livestock systems. *Agriculture, Ecosystems and Environment*. 71:241-254.

Sandford,S. 1983. Management of pastoral development in the Third World. London, Oversea Development Institute (ODI).

Sandford,S. 1993. Improving the efficiency of opportunism: new directions for pastoral development. In R.H.Behnke, I.Scoones, and C.Kerven, editors, *Range ecology at disequilibrium, New models of natural variability and pastoral adaptation in African savannas*. ODI. London. 174-182.

Schmidt,A.G., G.K.Theron, and W.van Hoven. 1995. A comparison of some methods used to estimate the grazing capacity of a game ranch in Northern Province, South Africa. *Koedoe*. 38:123-128.

Schoeman,S.J. 1989. Recent research into the production potential of indigenous cattle with special reference to the Sanga. *South African Journal of Animal Science*. 19:55-61.

Scholes,J.R. 1986. A guide to bush clearing in the Eastern Transvaal Lowveld. Johannesburg, Resource Ecology Group, University of the Witwatersrand.

Scholtz,M.M., L.Berg, D.J.Bosman, and C.Alberts. 2000. *Beef breeding in South Africa*. Animal improvement institute, ARC. Pretoria.

Schwartz,H.-J. and M.Walsh. 1991. Range unit inventory. In H.-J.Schwartz , S.Shaabani, and D.Walther, editors, *Range Management Handbook of Kenya*. Ministry of Livestock Development (MOLD). Nairobi. 74-110.

Scoones,I. 1995a. Exploiting heterogeneity: habitat use by cattle in dryland Zimbabwe. *Journal of Arid Environments*. 29:221-237.

Scoones,I. 1995b. New directions in pastoral development in Africa. In I.Scoones, editor, *Living with uncertainty, New directions in pastoral development in Africa*. International Institute for Environment and Development 1995. London. 1-36.

Scoones,I. and K.Wilson. 1989. Households, lineage groups and ecological dynamics issues for livestock research and development in Zimbabwe's communal land. In B.Cousins, editor, *People, land and livestock: Proceedings of a workshop on the socio-economic dimensions of livestock production in the communal lands of Zimbabwe.*

Scoones,I. and J.Thompson. 1994. Beyond farmer first. Rural people's knowledge, agricultural research and extension practice. Reprinted 2000, London, UK, *International Institute for Environment and Devlopment.* 1-301.

Shackleton,C.M. 2000. Comparison of plant diversity in protected and communal lands in the Bushbuckridge lowveld savanna, South Africa. *Biological Conservation*. 94: 273-285.

Shackleton,S.E., C.M.Shackleton, and B.Cousins. 1999. The economic value of land and natural resources to rural livelihoods. Case studies from South Africa. 1. *Paper presented at the Land and Agrarian Reform Conference, 26th - 28th July 1999.*

Shannon,E.E. and W.Weaver. 1949. *The Mathematical Theory of Communication*. University Illionois Press. Urbana, Illinois.

Silanikove,N. 2000. The physiological basis of adaptation in goats to harsh environments. Small Ruminant Research. 35:181-193.

Siulapwa,N.J. and H.Simukoko. 2000. Status of crop residues and agro-industrial by-products as supplementary animals feed in Zambia - a review. http://bij.hosting.kun.nl/esap/ZAMB/ZAMB7/General/cropsZambia.html . 6-9-2004.

Smit,G.N. 1996. BecVol: Biomass Estimates form Canopy VOLume (version 2)- Users guide. [2]. Bloemfontein, South Africa., University of the Free State, unpublished manual.

Smit,G.N. 1999. *Guide to the Acacias of South Africa*. Briza Publication. Pretoria.

Smit,G.N. 2004. An approach to tree thinning to structure southern African savannas for long-term restoration from bush encroachment. *Journal of Environmental Management*. 71:179-191.

Smit,G.N. and J.S.Swart. 1994. Influence of leguminous and non-leguminous woody plants on the herbaceous layer and soil under varying competition regimes in Mixed Bushveld. *African Journal of Range Forage Science*. 11:27-33.

Smit,G.N. and N.F.G.Rethman. 2000. The influence of tree thinning on the soil water in a semi-arid savanna of southern Africa. *Journal of Arid Environments*. 44:41-59.

Snyman,H.A. and I.B.Oosthuizen. 1999. Rangeland and soil condition: their effects on productivity in a semi-arid climate in South Africa. 211-212.

Squires,V.R. 1982. Dietary overlap between sheep, cattle, and goats when grazing in common. *Journal of Range Management*. 35:116-119.

Strohbach,B.J. and M.M.Strohbach. 2004. An annotated plant species list for Mile 46 LDC and surrounding area in central Kavango, Namibia, with some notes on species diversity. *Dinteria*. 29:55-78.

Strohbach,B.J. and J.Luther-Mosebach. 2010. Woodland savanna, Mutompo, Vaskular plants. In Jürgens,N., D.H.Haarmeyer, J.Luther-Mosebach, J.Dengler, M.Finckh and U.Schmiedel (eds). Biodiversity in southern Africa 1: Patterns at local scale – the BIOTA observatories. Göttingen-Windhoek: Klaus Hess Publisher. 102-106.

Subbarao,K. Namibia`s social safety net: Issues and options for reform. http://papers.ssrn.com/sol3/papers.cfm?abstract_id=569223 World Bank Policy Research Working Paper No. 1996, 1. 1998. The World Bank. 15-3-2004.

Sullivan,S. 1999. The impact of people and livestock on topographically diverse open wood- and shrub-land in arid north-west Namibia. *Global Ecology and Biogeography*. 8:257-277.

Sullivan,S. and R.Rhode. 2002. On non-equilibrium in arid and semi-arid grazing systems. *Journal of Biogeography*. 29:1595-1618.

Swanepoel,J. 2002. Sandveld Research Station. *Spotlight on Agriculture*. 54.

Sweet,J. 1998a. A rainfall model for estimating carrying capacity. *NOLIDEP (Northern Region Development Project, Republic of Namibia, MAWRD*.1-4.

Sweet,J. 1998b.Livestock - coping with drought: Namibia - a case study. Eastbourne, UK. This paper was presented for the Grassland Group of the Crop and Grassland Service (AGPC) of the FAO for the FAO/AGAP electronic conference on Livestock - Coping with Drought.

Sweet,J. and A.Burke. 2000. Country pasture/forage resources profiles: Namibia. http://www.fao.org/ag/agp/agpc/doc/counprof/namibia.htm.

t' Mannetje,L. and R.M.Jones. 2000. Grassland vegetation and its measurement. *Field and laboratory methods for grassland and annual production research* . CAP International. 1-8.

Tapia Garcia,C. 2004. Land reform in Namibia: economic versus socio-political rationale. Groppo, P. 2004/2 [Land reform: land settlements and cooperatives]. FAO.

Tapscott,C. and L.Hangula. 1994. Fencing of communal range land in northern Namibia: Social and ecological implications. 1-15. Windhoek, Social Sciences Division, Multi-Disciplinary Research Centre, University of Namibia. SSD Discussion paper No. 6

Thalen,D.C.P. 1979. *Ecology and utilization of desert shrub rangeland in Iraq*. Dr. W.Junk B.V. The Haque.

The World Bank. 2000. World Development Report 2000/200. Attacking Poverty. http://worldbank.org/poverty/wdrpoverty/report. Oxford University Press, New York.

Tilman,D. and J.A.Downing. 1994. Biodiversity and stability in grasslands. *Nature*. 367:363-365.

Todd,S.W. 2006. Gradients in vegetation cover, structure and species richness of Nama-Karoo shrublands in relation to distance from livestock watering points. *Journal of Applied Ecology*. 43:293-304.

Tolsma,D.J., W.H.O.Ernst, and R.A.Verwey. 1987. Nutrients in soil and vegetation around two artificial waterpoints in eastern Botswana. *Journal of Applied Ecology*. 24:991-1000.

Topps,J.H. 1997. Nutritive value of indigenous browse in Africa in relation to the needs of wild ungulates. *Animal Feed Science Technology*. 69:143-154.

Toulmin,C. 1993. Tracking through drought: options for destocking and restocking. In R.H.Behnke, I.Scoones, and C.Kerven, editors, *Range ecology at disequilibrium, New models of natural variability and pastoral adaptation in African savannas*. ODI. London. 95-115.

Trollope,W.S.W. 1982. Ecological effect of fire in South African savannas. In B.J.Huntley and B.H.Walker, editors, *Ecology of Tropical Savannas*. Hunger-Verlag. Berlin Heidelberg New York. 292-306.

Twine,W. 2003. Changing socio-economic factors influence vegetation change in the communal rangelands of the south African lowveld. *Proceedings of the VIIth International Rangeland Congress*, Durban, South Africa. 289-295.

van den Bosch,S., J.C.Guevara, F.M.Tacchini, and O.R.Estevez. 1997. Nutrient content of browse species in the arid rangelands of the Mendoza plain, Argentina. *Journal of Arid Environment*. 37:285-298.

van der Merwe,P.S. and S.J.Schoeman. 1995. Effect of early calving of Simmentaler heifers under an extensive management system. *South African Journal of Animal Science*. 25:36-39.

van Essen,L.D., J.du P.Bothma, N.van Rooyen, and W.S.W.Trollope. 2002. Assessment of the woody vegetation of Ol Choro Oioura, Masai Mara, Kenya. *African Journal of Ecology*. 40:76-83.

van't Hooft,K., D.Millar and S.Django. 2005. Endogenous Livestock Development Report from a workshop in Cameroon. Compas Magazin, Oct. 2005.

Vetter,S. and W.J.Bond. 1999. What are the costs of environmental degradation to communal livestock farmers? *Proceedings of the VIth International Rangeland Congress.* Vol.1: 537-541.

Vigne,P. and M.Whiteside. 1997. Encouraging sustainable smallholder agriculture in Namibia. 1-59. Environment and development consultancy Ltd. Agricultural Services Reform in Southern Africa.

Vogel, M. 2006. Erfassung von Vegetationsveränderungen in Namibia mit Hilfe von Fernerkundungs-Change-Detection-Verfahren, unter Berücksichtigung rezenter Niederschlagsereignisse. PhD-thesis, University Würzburg.

Wagner,G. 1957. *A study of Okahandja District (South West Africa)*. The Government Printer, Pretoria.1-100.

Walker,B.H. 1980. A review of browse and its role in livestock production in southern Africa. Le Houérou, H. N. Browse in Africa: The current state of knowledge, 7-24. Addis Ababa, Ethiopia, International livestock centre for Africa.

Walker,B.H. and I.Noy-Meir. 1982. Aspects of the stability and resilience of savanna ecosystems . In B.J.Huntley and B.H.Walker, editors, *Ecological Studies 42: Ecology of tropical savannas*. Springer Verlag. Berlin, Heidelberg, New York. 556-590.

Walter,H. 1939. Grassland, Savanne und Busch der ariden Teile Afrikas in ihrer ökologischen Bedingtheit. *Jahrbuch wissenschaftlicher Botanik*. 87:750-860.

Walter,H. 1954. Le facteur eau dans les regions arides et sa signification pour l'organisation des communautés végétales dans les contress subtropicales. *in Coll.Intern.du CNRS Vol.59, 236pp.: Les Divisions Ecologiques du Monde, Paris:CNRS*.27-39.

Walter,H. 1973. *Ecology of tropical and subtropical vegetation*. Oliver and Boyd. Edinburgh.

Ward,D., B.T.Ngairorue, J.Kathena, R.Samuels, and Y.Ofran. 1998. Land degradation is not a necessary outcome of communal pastoralism in arid Namibia. *Journal of Arid Environment*. 40:357-371.

Ward,D. and B.T.Ngairorue. 2000. Are Namibia`s grasslands desertifying? *Journal of Range Management*. 53:138-144.

Ward,D., D.Saltz, and B.T.Ngairorue. 2004. Spatio-temporal rainfall variation and stock management in arid Namibia. *Journal of Range Management*. 57:130-140.

Waters-Bayer,A. 2003. Local-level socio-institutional issues and capacity building in pastoral community devlopment. Göttingen, ETC Ecoculture. 1-65.

Waters-Bayer,A., L.van Veldhuizen, M.Wongtschowski and C.Wettasinha. 2006. Recognising and enhancing local innovation processes. http://www.prolinnova.net/workingpaper.php [Invited lead paper, Innovation Africa Symposium, 21-23 November 2006, Kampala, Uganda. Prolinnova WORKING PAPER 13.

Werner,W. 2003. Land reform in Namibia: Motor of Obstacle of Democratic Development. Paper presented at a Meeting on Land Reform in Southern Africa: Motor of Obstacle of Democratic Developmen; held under the auspices of the Friedrich Ebert Foundation. Berlin, 28 May 2003.1-18.

Westoby,M., B.H.Walker, and I.Noy-Meir. 1989. Opportunistic management for rangelands not at equilibrium. *Journal of Range Management*. 42:266-274.

Wijngaarden,W.v. 1985. Elephants, trees, grass, grazers; relationship between climate, soils, vegetation and large herbivores in a semi-arid savanna ecosystem (Tsavo, Kenya). 159 pp. Wageningen.

Wilson,R.T. 1986. Cattle husbandry in the agro-pastoral system. *World animal review*. 58:25-30.

Wylie,B., J.Harrington, R.Pieper, A.Maman, and I.Denda. 1988. Pasture Assessment Early Warning System. Integrated Livestock Production Project. Niamey, Government of Niger and Tufts University /USAID /New Mexico State University.

Yaron,G., G.Janssen, and U.Maamberua. 1992. *Rural development in the Okavango region of Namibia: an assessment of needs, opportunities and constraints*. Gamsberg Macmillian Publisher Ltd; NISER and Oxfam Canada. Windhoek, Namibia.

Young,B.A. and J.L.Corbett. 1972. Maintenance energy requirement of grazing sheep in relation to herbage availability. 1. Calorimetric estimates. *Aust.J.Agric.Res.* 23:57-76.

Zeidler,J., S.Hanrahan, and M.Scholes. 2002. Land-use intensity affects range condition in arid to semi-arid Namibia. *Journal of Arid Environment*. 52:389-403.

Zimmermann,I., F.P.Graz, N.N.T.Imasiku, N.D.Muroua, M.M.Sibalantani, and C.S.Sikopo. 2001. Quantified range condition assessment of open Camel thorn savanna along a degradation gradient. *African Journal of Forage Science*. 18:116.

Zimmermann,I. 2002. Degradation gradient as a basis for monitoring the ephemeral Omatako floodplains of central Namibia. www.ees.ufl.edu/homepp/brown/hoorc/docs/5%20Papers%20&%20Paper%20Abstracts/ Zimmerman%204.3.doc Okavango delta wetland conference, Maun, Botswana, 246-264. Polytechnic of Namibia, Windhoek, Namibia.

Zimmermann,I., D.F.Joubert, and P.Graz. 2003. Proposed ground monitoring of bush thickening in Namibia. *Proceedings of the VIIth International Rangeland Congress, Durban.* 793-795.

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Table A 1: Development of livestock numbers and stocking density in the Kavango

Year	Source	No. of Cattle	No. of Goats	No. of Sheep	Total number cattle, goats, sheep (no.)	Total body-weight (kg)	Stocking density (kg/ha)
1987	Adams, 1990	78,867	3,076	4,510	106,453	20,544,330	4.24
1988	Yaron, 1992	79,867	23	123	80,013	19,971,130	4.12
1990	Yaron, 1992	88,000	30,000	91	118,091	22,902,730	4.72
1991	Yaron, 1992	91,454	31,085	70	122,609	23,798,150	4.91
1996	DVS, in Hengua & Bovell, 1997	98,775	40,442	128	139,345	25,910,850	5.34
2000	official data, DVS	199,500	160,600	900	361,000	54,720,000	11.29

Sources: DVS - Directorate of Veterinary Services. Cattle: 250 k bodyweight, small stock: 30 kg bodyweight, Size of the Kavango region: 4,848,300 ha

Table A 2: Development of livestock numbers in the Ovitoto-Reserve

Year	Cattle	Goats	Sheep	Donkeys	Horses	total	Stocking density (kg/ha), without horses and donkeys
1943	4,643	7,399	708	368	231	15,292	33.02
1948	8,431	8,827	997	817	253	21,273	56.48
1954	12,652	12,565	1,107	396	356	29,030	62.13
		Small stock					
1989	10,321	5,689				16,010	45.23
1994	12303	9708				22,011	55.50
1995	7473	15577				23,050	38.93
1996	7897	9525				17,422	37.40
1997	7058	95				7,153	28.89
1998	7568	954				8,522	31.43
1999	9394	5972				15,366	41.60
2000	10841	7078				17,919	48.11

Sources: 1943 – 1954: Wagner, 1957; 1989: Adams et al., 1990; 1994-2000: Veterinarian office Okahandja.

Table A 3: Differences of vegetation parameters between inside and outside fenced areas (camps) in Okamboro

	Inside mean	Outside mean	Differ-ences of means	SE of differ-ences	T-value	df	Error prob-ability
Grass biomass DS 2002 (g m^{-2})	8.61	8.65	0.039	2.98	0.013	91	0.993
Grass biomass WS 2002/3 (g m^{-2})	0.31	1.51	1.196	0.55	2.177	75	0.343
Ground cover DS 2002 (%)	6.91	7.36	0.450	1.93	0.232	19	0.819
Ground cover WS 2002/3 (%)	11.33	11.09	-0.240	2.49	-0.098	14	0.923
No. of grass species DS 2002 (n)	3.08	2.67	-0.417	0.53	-0.792	17	0.819
No. of grass species WS 2002/3 (n)	2.83	2.68	-0.157	0.63	-0.249	6	0.923
Grass biodiversity index (H) DS 2002	0.52	0.72	0.20	0.10	1.919	15	0.074
Grass biodiversity index (H) WS 2002/3	0.06	0.13	0.079	0.08	0.993	78	0.324
Grass Evenness index (E_H) DS 2002	0.44	0.59	1.149	0.07	2.031	15	0.060
Grass Evenness index (E_H) DS 2003	0.36	0.43	0.073	0.14	0.513	23	0.613
Height of trees and bushes (m)	1.43	1.67	0.24	0.21	1.10	17	0.288
Diameter of crowns (m)	1.53	2.06	0.53	0.28	1.929	33	0.062
Density of trees and bushes (no. ha^{-1})	1518.40	1504.94	-13.46	370.02	-0.036	11	0.972
Leaf mass (kg) per ha	1210.95	1441.83	230.9	272.92	0.846	15	0.410
Browse leaf mass (kg) per ha	646.61	673.61	26.61	164.77	0.162	15	0.874

Table A 4: Grass parameters of the single transects Mutompo

Transect number of Mutompo	T 1 Mean	T1 SE	T2 Mean	T2 SE	T3 Mean	T3 SE	T4 Mean	T4 SE	T5 Mean	T5 SE	Total Mean	Total SE	n
n per transect (grass parameter)	10		8		13		5		20				
Mean grass biomass DS 2002 ($g\ m^{-2}$)	90.83	11.88	39.34	5.54	69.78	10.03	30.90	5.84	37.31	9.77	57.75	5.38	50
Mean grass biomass WS 2002/3 ($g\ m^{-2}$)	94.65	17.41	63.31	18.92	105.39	14.92	97.78	68.68	90.48	10.76	91.53	8.97	52
Mean grass ground cover DS 2002 (%)	22.78	2.65	18.08	2.42	21.36	2.53	19.00	4.00	11.75	3.91	17.74	1.59	53
Mean grass ground cover WS 2002/3 (%)	28.00	2.81	19.00	3.83	33.00	8.83	22.50	2.50	22.06	2.47	25.02	2.27	48
Mean number of grass species DS (no.)	3.56	0.69	1.91	0.29	3.67	0.33	1.80	0.20	2.00	0.32	2.69	0.24	39
Mean number of grass species WS (no.)	3.73	0.33	2.13	0.40	3.00	0.25	1.40	0.25	3.59	0.29	3.06	0.17	54
Mean grass biodiversity index (H) WS	0.84	0.09	0.40	0.15	0.66	0.10	0.16	0.14	0.75	0.09	0.63	0.05	54
Mean of grass Evenness index (E_H) WS	0.64	0.05	0.62	0.17	0.61	0.07	0.59	0.41	0.57	0.06	0.60	0.04	45
n per transect (grass nutrients)	6-9		4-8		8-13		0-5		5-16				
Crude protein (CP) DS 2002 (%)	2.85	0.25	4.18	0.42	3.16	0.28	-	-	3.52	0.04	3.40	0.19	20
Crude protein (CP) WS 2002/3 (%)	3.80	0.28	4.88	0.66	4.15	0.22	6.04	0.82	2.93	0.21	4.00	0.20	53
Crude fibre (CF) DS 2002 (%)	35.02	0.83	37.48	1.43	37.17	0.46	-	-	37.84	0.78	36.86	0.47	20
Crude fibre (CF) WS 2002/3 (%)	42.39	0.57	42.52	1.30	43.11	0.85	37.94	0.75	42.55	0.68	42.29	0.42	51
Phosphorus total (P) DS 2002 (%)	0.03	0.00	0.04	0.01	0.02	0.00	-	-	0.03	0.00	0.002	0.01	20
Phosphorus total (P) WS 2002/3 (%)	0.05	0.01	0.02	0.00	0.02	0.00	0.03	0.00	0.02	0.00	0.03	0.00	43
Calcium (Ca) DS 2002 (%)	0.16	0.03	0.29	0.04	0.33	0.04	0.25	0.05	0.24	0.03	0.25	0.02	20
Ash content DS 2002 (%)	4.17	0.20	3.67	0.35	3.90	0.26	-	-	3.88	0.51	3.90	0.16	20
Ash content WS 2002/3 (%)	4.61	0.46	3.52	0.22	3.88	0.12	-	-	-	-	4.403	0.21	43
ME DS, ($MJ\ kg^{-1}$)	11.88	0.03	11.95	0.05	11.93	0.04	-	-	11.90	0.08	11.93	0.11	20
ME WS ($MJ\ kg^{-1}$)	6.89	0.28	6.46	0.28	6.57	0.24	7.63	0.36	6.62	0.19	6.74	0.79	43
ME I^{+} DS, ($MJ\ kg^{-1}$)	12.19	0.00	12.29	0.13	12.18	0.00	-	-	12.17	0.01	12.18	0.01	20
ME I^{+} WS, ($MJ\ kg^{-1}$)	12.13	0.02	12.15	0.02	12.13	0.01	12.16	0.01	12.13	0.00	12.14	0.02	44

ME - results from laboratories. $^{+}$ Formula used: ME I = 12.47 – 0.00686*crude fibre + 0.00388*crude protein - 0.01335*ash (according to Kirchgessner, 1997).

Table A 5: Grass parameters of the the single transects of Okamboro

Transect number of Okamboro	T 1 Mean	T1 SE	T2 Mean	T2 SE	T3 Mean	T3 SE	T4 Mea	T4 SE	T5 Mean	T5 SE	Total mean	SE	n
n per transect (grass parameter)	14		19		15		15		12		(75)		
Mean grass biomass DS 2002 (g m^{-2})	10.32	2.42	7.53	3.47	17.94	4.10	2.46	0.88	1.83	0.91	8.64	1.48	93
Mean grass biomass WS 2002/3 (g m^{-2})	1.11	0.39	1.59	0.80	2.03	1.44	0.99	0.39	0.11	0.11	1.32	0.46	77
Mean grass ground cover DS 2002 (%)	6.08	0.70	5.08	1.64	11.07	1.87	4.67	1.21	14.60	4.71	7.28	0.88	63
Mean grass ground cover WS 2002/3 (%)	9.80	1.57	15.07	1.85	11.59	2.33	5.91	1.81	15.00	5.00	11.13	1.07	54
Mean number of grass species DS (no.)	3.44	0.30	3.38	0.53	3.06	0.38	2.67	0.62	2.00	1.00	2.75	0.21	63
Mean number of grass species WS (no.)	2.26	0.29	2.05	0.43	2.09	0.32	2.91	0.32	3.00	-	2.70	0.18	40
Mean grass biodiversity index (H) DS 2002	0.68	0.05	0.59	0.08	0.80	0.27	0.97	-	0.00	-	0.64	0.05	27
Mean grass biodiversity index (H) WS 2002/3	0.19	0.23	0.19	0.32	0.07	0.19	0.09	0.17	-	-	0.12	0.23	80
Mean of grass Evenness index (E_H) DS 2002	0.56	0.04	0.50	0.08	0.52	0.14	0.70	-	0.00	-	0.54	0.04	26
Mean of grass Evenness index (E_H) WS	0.44	0.07	0.58	0.06	0.58	0.23	0.24	0.08	0.00	-	0.42	0.04	25
n per transect (grass nutrients)	0		4		7		0		1		(12)		
Crude protein (CP) DS 2002 (%)	-	-	2.88	0.13	2.44	0.31	-	-	2.30	-	2.58	0.19	12
Crude fibre (CF) DS 2002 (%)	-	-	36.68	0.78	37.96	0.65	-	-	39.2	-	37.63	0.49	12
Phosphorus total (P) DS 2002 (%)	-	-	0.12	0.02	0.11	0.01	-	-	0.06	-	0.12	0.01	12
Ash content DS 2002 (%)	-	-	6.75	0.65	6.30	0.36	-	-	3.80	-	6.42	0.31	12
ME DS 2002 (MJ kg^{-1})	-	-	11.50	0.00	11.57	0.06	-	-	11.90	-	11.58	0.05	12
ME I DS 2002 $^{+}$ (MJ kg^{-1})	-	-	12.14	0.01	12.14	0.01	-	-	12.61	-	12.14	0.00	12

$^{+}$ Formula used for metabolisable energy I: ME I = 12.47 – 0.00686*crude fibre + 0.00388*crude protein - 0.01335*ash (according to Kirchgessner, 1997).

Table A 6: BecVol-regression analysis for different trees species for calculation of leaf volume and leaf mass

Species	L mass/ volume	n	r²	a	b
Normal plants					
Compretum apiculatum	L mass L volume	30	0.936 0.933	-6.66795 -5.73831	0.862375 0.855550
Grewia species	L mass L volume	15	0.804 0.844	-3.58694 -4.39578	0.670455 0.792703
Terminalia sericea	L mass L volume	27	0.822 0.853	-5.27024 -4.39578	0.781664 0.792703
General: microphyllous[1]	L mass L volume	101	0.886 0.898	-3-88021 -2.93340	0.708109 0.696712
General: broad- leaved	L mass L volume	105	0.903 0.897	-5.44972 -4.68022	0.789596 0.791964
Coppiced plants					
Acacia erubescens	L mass L volume	27	0.960 0.958	-5.93298 -4.96379	0.854976 0.836859
Compretum apiculatum	L mass L volume	26	0.911 0.911	-4.26560 -3.46766	0.699236 0.701416
General: microphyllous[1]	L mass L volume	75	0.801 0.816	-6.65355 -5.4836	0.873145 0.845745
General: broad- leaved	L mass L volume	86	0.873 0.900	-3.80039 -3.15416	0.707427 0.710263

Source: Smit, 1996; regression equation: ln y = a + bx; for all equations $p < 0.001$.
[1] e.g. *Acacia* species.

Table A 7: Medians and means of the grass parameters of the distance classes

Distance class	1	1	1	2	2	2	3	3	3	4	4	4
	Median	Mean	SE of mean	Median	Mean	SE of mean	Median	Mean	SE of mean	Median	Mean	SE of mean
Mutompo												
Grass biomass DS 2002 (g m^{-2})	42.05	48.51	6.66	58.90	63.25	10.36	68.80	68.86	16.61	74.70	64.70	19.42
Grass biomass WS 2002/3 (g m^{-2})	43.20	66.75	20.34	129.75	111.59	10.97	114.3	102.8	12.91	65.40	65.23	4.71
Grass ground cover WS 2002/3 (%)	15.0	17.76	2.31	30.00	30.29	1.69	30.00	38.50	7.19	10.00	12.50	2.50
Number of grass species DS 02(no.)	2.00	1.76	0.161	3.50	3.57	0.47	3.50	3.33	.049	2.50	2.50	0.50
Number of grass species WS 02/03 (no.)	2.00	2.21	0.24	3.00	3.37	0.29	3.50	3.92	0.29	3.00	3.00	0.41
Grass biodiversity index (H) WS 2002/3	0.41	0.35	0.07	0.82	0.76	0.08	0.82	0.86	0.12	0.72	0.71	0.15
Grass Evenness index (E_H) WS 2002/3	0.44	0.45	0.09	0.71	0.67	0.04	0.72	0.65	0.07	0.65	0.64	0.06
Crude protein WS 2002/3 (%)	4.84	4.83	0.40	3.66	3.94	0.29	3.09	3.25	0.27	3.19	3.06	0.59
Crude fibre WS 2002/3 (%)	39.82	39.91	0.68	43.71	43.04	0.67	43.86	43.51	0.52	44.20	43.88	1.19
ME I DS 02 (MJ kg^{-1})	12.17	12.17	0.005	12.19	12.19	0.004	12.19	12.18	0.005	12.18	12.18	0.000
ME I WS 02/03 (MJ kg^{-1})	12.14	12.14	0.007	12.13	12.14	0.003	12.14	12.14	0.004	12.12	12.12	0.009
Okamboro												
Mean grass biomass DS 02 (g m^{-2})	0.00	3.24	0.91	2.90	6.43	2.21	6.65	11.76	3.04	44.0	42.61	7.17
Mean grass biomass WS 02/03 (g m^{-2})	0.00	0.22	0.09	0.00	0.42	0.18	1.80	3.71	1.83	1.60	2.32	1.28
Mean number of grass species DS (no.)	3.00	2.41	0.37	3.00	2.33	0.40	4.00	3.91	0.29	3.00	3.13	0.30
Mean grass biodiversity index (H) WS 2002/3	0.00	0.03	0.02	0.00	0.12	0.05	0.33	0.35	0.08	0.00	0.15	0.10
Ash content DS 2002 (%)	/	/	/	7.90	7.90	/	6.90	6.87	0.15	6.00	6.09	0.23
ME DS 2002 (MJ kg^{-1})	/	/	/	11.30	11.30	/	11.50	11.50	0.00	11.60	11.60	0.04

Table A 8: Effects of distance classes (d), transects (t), and their interaction (t*d) on grass parameters

Model	Mutompo d	Mutompo t	Mutompo t * d	Mutompo Test-type; R and adj-R	Okamboro d	Okamboro t	Okamboro t * d	Okamboro Test-type; R and adj-R
	ANOVA F-values				ANOVA F-values			
Grass biomass DS 2002 (Mut-sqrt-trans-formation, Ok-ln)	2.7°	8.6 ***	ns	ANOVA (0.587; adj 0.422)	9.4***	2.8*	2.6*	ANOVA (0.620; adj 0.500)
Grass biomass WS 2002/3 (Ok-ln-transformation)	ns	ns	3.1*	(SAS, nhV) (0.560; adj 0.414)	4.4*	ns	ns	ANOVA (0.543; adj 0.269)
Ground cover DS 2002 (ln-transformed)	ns	7.4***	3.1*	(SAS Rank-AV) (0.569; adj 0374)	ns	ns	3.3**	(SAS, nhV) (0.534; adj 0.350)
Ground cover WS 2002/3 (sqrt-transformed)	14.1***	ns	7.1***	(SAS, nhV) (0.731; adj 0.625)	ns	3.51*	ns	ANOVA (0.498; adj 0.294)
No. of grass species DS 2002 (Ok ln-transformed)	3.1*	ns	ns	ANOVA (0624; adj 0443)	3.1***	ns	ns	(SAS Rank-AV) (0.274; adj 0.061)
No. of grass species WS 2002/3 (sqrt-transformed)	4.1*	12.7***	4.3**	(SAS, nhV) (0.628; adj 0507)	ns	ns	ns	ANOVA (0.355; adj. 0.032)
Shannon index DS 2002	no data	no data	no data		ns	ns	ns	ANOVA (0.353 adj 0.094)
Shannon index WS 2002/3 (sqrt-tranformed)	3.0*	6.6***	2.8*	ANOVA (0.636; adj 0.514)	10.5***	3.3*	4.7***	(SAS Rank-AV) (0.544; adj 0.450)
Evenness index DS 2002	no data	no data	no data		ns	ns	ns	ANOVA (0.057; adj -0.273)
Evenness index WS 2002/3	3.0*	ns	ns	(SAS, nhV (0.236; adj -0.051)	ns	ns	ns	ANOVA (0.566; adj 0.200)

d = distance classes – km groups of distances; t – transect, SAS rank-ANOVA and SAS non-homogeneous variances (nhV) in grey rows are often imprecisely and unreliable, due to less than 7 cases per distance class. R and adj = adjusted R - coefficient of determination. Distance classes: class 1 = 0 ≤ 1km; class 2 = 1 ≤ 2 km; class 3 = 2 ≤ 3 km; class 4 > 3 km. Transformation: sqrt – square root; ln – logarithmic. Significance levels: *** = p ≤ 0.001; ** = p ≤ 0.01; * = p ≤ 0.05; ° = p ≤ 0.1; ns - not significant (p> 0.1).

Table A 9: Significant effects of distance classes, transects and their interaction on grass parameters

	Mutompo			Okamboro		
	Distance classes (d)	Transect (t)	t * d	Distance classes (d)	Transect (t)	t * d
Grass biomass DS 2002	°	***		***	*	*
Grass biomass WS 2002/03			*	*		
Ground cover DS 2002		***	*			**
Ground cover WS 2002/03	***		***		*	
No. of grass species DS 2002	*			***		
No. of grass species WS 2002/03	*	***	**			
Shannon index (H) WS 2002/3	*	***	*	***	*	***
Evenness index (E_H) WS 2002/03	*					

Distance classes: class 1 = 0 ≤1 km; class 2 = 1 ≤ 2 km; class 3 = 2 ≤ 3 km; class 4 > 3 km. t – Transect; d – distance classes; DS – dry season, WS – wet season. Significance level: *** = p ≤ 0.001; ** = p ≤ 0.01; * = p ≤ 0.05; ° = p ≤ 0.10; empty cells = p > 0.10.

Table A 10: Effects of distance classes (d), transects (t), and their interaction (t*d) on nutrients of grass samples

Model	**Mutompo** d	t	t * d	Test-type; R; (adj-R)	**Okamboro** d	t	t * d	Test-type; R; (adj-R)
	ANOVA - F-values + sign. Median test – χ^2 values				ANOVA - F-values + sign. Median test – χ^2 values			
Crude protein WS 2002/3 (%)	11.2**	19.2***	/	Median, 0.545 (0.393)		no data		
Crude fibre WS 2002/3 (%)	5.9**	3.7**	ns	ANOVA 0.550 (0.251)		no data		
Phosphorus total WS 2002/3 (%)	ns	16.4**	/	Median, 0.779 (0.680)		no data		
Ash DS 2002 (%)	ns	ns	ns	Median, 0.429 (0.073)	8.9*	15.58**	ns	ANOVA 0.918 (0.849)
ME DS 2002 (MJ/ kg)	ns	ns	/	Median, 0.480 (0.109)	ns	4.95°	ns	Median 0.878 (0.777)
ME WS 2002/3 (MJ/ kg)	ns	5.4**	ns	ANOVA 0.471 (0.241)		no data		
ME I+ DS 2002 (MJ/kg)	7.9*	ns	/	Median, 0.500 (0.142)	ns	ns	ns	ANOVA 0.515 (0.112)
ME I+ WS 2002/3 (MJ/kg)	16.9***	ns	/	Median, 0.356 (0.136)		no data		

d = distance classes – km groups of distances; t – transect. ; R and adj-R (adjusted R) - coefficient of determination. ANOVA - univariate analysis of variances; Median – nonparametric Median-test of main effects. + Formula used: ME I = 12.47 – 0.00686*crude fibre + 0.00388*crude protein - 0.01335*ash. Distance classes: class 1 = 0 ≤ 1 km; class 2 = 1.01 ≤ 2 km; class 3 = 2.01 ≤ 3 km; class 4 > 3.01 km. Transformation: sqrt – square root; ln – logarithmic. Significance levels: *** = p ≤ 0.001; ** = p ≤ 0.01; * = p ≤ 0.05; ° = p ≤ 0.1; ns - not significant (p > 0.1).

Table A 11: Browse parameters of the single transects

Transect number	T 1 Mean	T1 SE	T2 Mean	T2 SE	T3 Mean	T3 SE	T4 Mean	T4 SE	T5 Mean	T5 SE	Total Mean	Median	Total S SD
Mutompo													
Height of tress and bushes (m)	0.839	0.04	1.22	0.03	1.17	0.05	1.96	0.06	1.37	0.04	1.40	1.38	0.57
Canopy diameter (m)	0.72	0.04	0.84	0.03	0.88	0.04	1.56	0.05	0.96	0.03	1.04	0.95	0.45
Density (n ha^{-1})	3,495.0	759.1	4,577.7	520.0	3,007.7	387.0	3,883.3	330.8	3,082.4	376.9	3,471.8	3,050	1,689
Leaf volume (m^3 ha^{-1})	2,408.8	990.3	3,684.7	628.9	3,927.7	1,150.3	8,279.0	1,853	3,802.5	748.4	4,047.8	2,963	3,639
Leaf biomass (kg ha^{-1})	1,142.3	455.0	1,838.0	317.7	1,832.6	509.0	4,059	905.0	1,822.0	370.7	1,947.6	1,448	1,732
Browse leaf biomass (height ≤ 1.50 m; in kg ha^{-1})	464.1	89.0	1142.2	180.4	630.0	128.8	2032.9	406.7	911.8	223.8	923.8	625	808
Okamboro													
Height of tress and bushes (m)	1.30	0.06	1.40	0.06	1.20	0.04	1.33	0.04	1.41	0.05	1.64	1.49	0.90
Canopy diameter (m)	1.39	0.07	1.55	0.07	1.25	0.05	1.55	0.06	1.39	0.06	2.00	1.63	1.64
Density (n ha^{-1})	578.40	230.4	1,107.1	181.9	1,750.0	235.76	1,727.50	221.2	1,907.9	275.4	1,503.6	1,350	1,080
Leaf volume (m^3 ha^{-1})	1,070.0	200.7	2,534.7	345.2	2,532.1	241.3	4,019.7	771.4	3,702.1	361.4	2,938.8	2,495	2,175
Leaf biomass (kg ha^{-1})	501.4	93.5	1,206.1	163.4	1,232.8	117.8	1,969.2	376.9	1,791.9	177.3	1,422.5	1,202	1,061
Browse leaf biomass (height ≤ 1.50 m; in kg ha^{-1})	253.6	41.2	461.8	79.7	615.7	110.8	986.1	153.5	848.9	184.7	668.2	512	613

Results rest upon the analysis of total 3,992 bushes and trees in Mutompo and 3,071 bushes and trees in Okamboro.

Table A 12 Medians and means of the browse parameters of the distance classes

Distance class	1	1	1	2	2	2	3	3	3	4	4	4
	Median	Mean	SE of mean	Median	Mean	SE of mean	Median	Mean	SE of mean	Median	Mean	SE of mean
Mutompo												
Density (n ha^{-1})	4550	4476	329.8	2750	3135	376.8	2075	2270	343.2	2775	2888	614.9
Canopy diameter (m)	1.08	1.12	0.10	0.89	0.99	0.10	0.77	0.99	0.16	0.96	0.94	0.19
Leaf volume (m^3 ha^{-1})	4687	4865	758.3	2573	3951	965.2	1473	2693	903.4	3058	3629	1040.1
Leaf BM (kg ha^{-1})	2369	2389	365.9	1229	1874	450.6	713	1278	436.2	1458	674	461.9
Browse leaf BM (kg ha^{-1})	1251	1301	164.4	566	836	206.0	404	464	137.9	483	531	135.9
Tree and bush height (m)	1.51	1.41	0.13	1.26	1.35	0.12	1.27	1.48	0.22	1.27	1.37	0.22
Okamboro												
Density (n ha^{-1})	850	1260	160.2	170	1542	230.2	1750	1926	265.3	1450	1672	318.3
Canopy diameter (m)	1.72	2.23	0.33	1.91	2.15	0.27	1.58	1.61	0.12	1.32	1.38	0.14
Leaf volume (m^3 ha^{-1})	2238	2626	387.1	3073	3300	349.1	354	3418	509.7	2252	2501	441.9
Leaf BM (kg ha^{-1})	1050	1275	190.1	1490	1582	168.0	1628	1667	248.8	1104	1208	204.0
Browse leaf BM (kg ha^{-1})	291	468	83.7	781	751	110.5	859	751	181.3	600	556	65.7
Tree and bush height (m)	1.50	1.66	0.171	1.52	1.81	0.19	1.51	1.53	0.09	1.38	1.38	0.13

Table A 13: Effects of distance classes (d), transects (t), and their interaction (t*d) on bush and tree parameters and browsing resources

Community	Mutompo				Okamboro			
Model	d	t	t * d	Test-type; R; adj-R	d	t	t * d	Test-type; R, adj-R
	F-value				F-value			
Leaf biomass per ha (kg ha^{-1}); (Mut sqrt; Ok ln transformed)	3.61*	ns	2.42*	SAS Rank-AV (0.350; adj. 0.144)	5.02 **	12.50 ***	2.27*	SAS Rank-AV (0.453; adj 0.327)
Browse leaf biomass per ha (kg ha^{-1}); (Mut ln; Ok sqrt transformed)	6.61 ***	7.07 ***	ns	ANOVA (0.619; adj 0.280)	9.72 ***	9.51 ***	2.21 *	SAS Rank-AV (0.473; adj 0.15)
Density (n ha-1); (sqrt transformed)	3.85 *	ns	3.01*	ANOVA (0.530; adj. 0.382)	2.97*	4.92 ***	1.99*	ANOVA (0419; adj. 0.286
Tree/bush height (m); (Mut ln, Ok sqrt transformed)	ns	16.18 ***	15.51 ***	SAS Rank-AV (0.392; adj 0.199)	ns	ns	2.34*	SAS Rank-AV (0.115; adj -0.086)
Canopy diameter (m); (Mut sqrt, Ok ln transformed)	ns	10.08 ***	5.50 ***	SAS Rank-AV (0.285; adj 0.058)	ns	ns	3.68 ***	SAS Rank-AV (0.125; adj -0.074)
Leaf volume per ha; (Mut ln, Ok sqrt transformed)	4.39 **	3.12*	2.53*	SAS Rank-AV (0.370; adj 0.171)	3.32*	17.61 ***	2.62 **	SAS Rank-AV (0.418; adj 0.285)

d - distance classes – km grouped distances; t – transect; R and adj (adjusted R) - coefficient of determination. Distance classes: class 1 = 0 ≤1 km; class 2 = 1.01 ≤ 2 km; class 3 = 2.01 ≤ 3 km; class 4 > 3.01 km. Significance levels: *** = p ≤ 0.001; ** = p ≤ 0.01; * = p ≤ 0.05; ns - not significant (p > 0.05). Transformation: sqrt – square root; ln – logarithmic.

Table A 14: Spearman-rank-correlation of vegetation parameters as related to distance

Parameter	Mutompo	n	Okamboro	n
Grass biomass DS 2002	ns	50	0.450***	93
Grass biomass WS 2002/3	0.342*	52	0.387***	77
Ground cover DS 2002	ns	53	0.629***	63
Ground cover WS 2002/3	0.407**	48	ns	54
No. of grass species DS 2002	0.532***	39	ns	63
No. of grass species WS 2/3	0.436***	54	ns	40
Shannon Index (H) WS 2002/3	0.433***	54	0.393***	80
Crude protein (%) DS 2002	ns	20	-0.728*	11
Crude protein (%) WS 2002/3	-0.461**	53	no data	
Crude fibre (%) WS 2002/3	0.491***	51	no data	
Ash (%) DS 2002	ns	20	-0.699*	11
Ash (%) WS 2002/3	-0.537***	43	no data	
Browse leaf mass per ha	-0.501***	55	0.369***	92
Density of trees and bushes	-0.514***	55	0.257*	92
Leaf volume	-0.238*	55	ns	92

Significance level: *** = p ≤ 0.001; ** = p ≤ 0.01; * = p ≤ 0.05; ns – not significant = p> 0.05.

Table A 15: Theoretic carrying capacity recommendations (Sweet, 1998a)

	Mean rainfall[1] (mm)	Presumed rainfall values (Kempf, 2000)[2] (mm)	Actual rainfall season 2001/02 (mm)	CC based on mean rainfall[3] ($kg\ ha^{-1}$)	CC based on presumed values[3] ($kg\ ha^{-1}$)	CC based on actual rainfall[3] ($kg\ ha^{-1}$)
Mutompo	550	509	428	101.4	117.3	98.7
Okamboro	350	290	248	51.6	66.8	57.2
Calculated with correction factors (see):						
Mutompo	sandy soil			78.0	90.2	75.9
Okamboro	slopes, moderate stony, range condition poor			32.3	41.8	35.7

CC - carrying capacity; BM – biomass. The recommended carrying capacity is calculated with a biomass intake rate of 2.5% per kg live bodyweight, and with rain use efficiency (RUE) of 3 kg DM ha^{-1} mm^{-1} $year^{-1}$. [1] Mean rainfall according to Mendelsohn et al. (2002), see also Table 4, p. 22. [2] For details see Table 34, p. 142). [3] Values calculated with the estimated rainfall variability, for Mutompo: 20%, and for Okamboro: 35%.

Table A 16: Bodyweights of current livestock

	Mutompo Number (n)	BW/ head (kg)	Total BW (kg)	Share of total BW (%)	Okamboro Number (n)	BW/ head (kg)	Total BW (kg)	Share of total BW (%)
Oxen	46	400	18,400		6	540	3,240	
Bulls	11	350	3,850		22	540	11,880	
Cows or heifers	103	250	25,750		482	330	159,060	
Calves	37	80	2,960		431	90	38,790	
Sum of cattle, and % of total livestock	197		50,960	88.1	941		212,970	87.5
Goat castrates	5	40	200		1	45	45	
Bucks	20	36	712		42	42	1,760	
Does	160	31	4,896		475	37	17,528	
Kids	41	10	410		105	10	1,050	
Sum of goats, and % of total livestock	226		6,218	10.8	623		20,382	8.4
Sheep castrates	0	40	0		0	40	0	
Rams	2	35	70		14	35	490	
Does	8	35	280		134	35	4,690	
Lambs	2	10	20		9	10	90	
Sum of sheep, and % of total livestock	12		370	0.6	157		5,270	2.1
Donkeys + horses (D+H), and %	2	140	280.0	0.5	19	250	4,750	2.0
Total (no. and kg BW)	437		57,828		1,740		243,372	
Total converted to LSU (450 kg BW)			129				541	

Table A 17: Daily intake rates differentiated by grazer and browser

	Mutompo	%	BW (kg)	Okamboro	%	BW (kg)
Percentage of BW, and BW grazer [#]		74.7	43,209		76.2	185,457
Percentage of BW, and BW browser [##]		25.3	14,619		23.8	57,916
Daily intake rate: 2.5 % of total BW per day		Daily Intake rate (kg)			Daily intake rate (kg)	
Grazer [#]			1,080			4,636
Browser [##]			365			1,448
Total			1,446			6,084

[#] Grazer: 80 % cattle and sheep + 30% goats + donkeys + horses. [##] Browser: 70% goats + 20% cattle + 20% sheep.

Table A 18: Daily energy and protein requirement of livestock

	Mutompo			ME requirement	CP requirement	Okamboro			ME requirement	CP requirement
	No.	%	Head (n) or BW (kg)	ME (kJ)	CP (kg)	No.	%	Head (n) or BW (kg)	ME (kJ)	CP (kg)
Oxen	46	23	400	2,032,496	16.83	6	1	540	332,027	2.75
Bulls	11	6	350	439,714	3.64	22	2	540	1,217,433	10.08
Cows or heifers	103	52	250	3,199,036	26.49	482	51	330	18,435,692	152.64
Calves	37	19	80	488,929	4.05	431	46	90	6,221,371	51.51
Sum of cattle	197			6,160,177	51.00	941			26,206,523	216.97
Goat castrates	5	2	40	33,719	0.33	1	0	45	7,367	0.07
Bucks	20	9	36	123,590	1.21	42	7	42	293,275	2.87
Does	160	71	31	882,626	8.64	475	76	37	3,015,291	29.51
Kids	41	18	10	97,757	0.96	105	17	10	250,354	2.45
Sum of goats	226			1,137,693	11.14	623			3,566,288	34.91
Sheep castrates	0	0	40	0	0.00	0	0	40	0	0.00
Rams	2	17	35	11,195	0.14	14	9	35	78,366	0.95
Does	8	67	35	44,781	0.55	134	85	35	750,076	9.14
Lambs	2	17	10	4,375	0.05	9	6	10	19,688	0.24
Sum of sheep	12			60,351	0.74	157			848,130	10.33
Donkeys+ horses (D+H)	2		140	39,154	0.33	19		250	574,584	4.89
Total (no. and maintenance metabolism requirement)	437			7,397,374	63.21	1,740			31,195,525	267.10
BW grazer #			57,828	5,356,883	45.06			243,372	23,288,193	197.20
BW browser ##				2,040,491	18.14				7,907,332	69.90
Sum total				7,397,374	63.21				31,195,525	267.10

BW – body weight; ME – metabolisable energy; CP – crude protein. # Grazer: 80 % cattle and sheep + 30% goats + donkeys + horses. ## Browser: 70% goats + 20% cattle + 20% sheep.

Table A 19: Daily energy and protein requirement of livestock separated for grazer and browser

	Mutompo BW (kg)	Energy requirement ME (kJ)	Protein requirement TP (kg)	**Okamboro** BW (kg)	Energy requirement ME (kJ)	Protein requirement TP (kg)
Sum total (see Table A 18)		7,397,374	63.21		31,195,525	267.10
	50% of energy requirement	3,698,687		50% of energy requirment	15,597,762	
Total daily requirement of livestock (kg)		11,096,061	63.21		46,793,287	267.10
Total requirement per year (kJ or kg)	(incl. + 50% energy for activity)	4,050,062,387	23,070	(incl. + 50% energy for activity)	17,079,549,666	97,490
Daily requirement per kg BW of current livestock	(57,828)	191.88	0.00109	(243,372.3)	192.27	0.0011
Total daily requirment grazer (incl. plus 50% for energy)		8,035,325	45.1		34,932,289	197.2
Total requirment per year grazer (incl. plus 50% of energy for activity)		2,932,893,684	16,448.2		12,750,285,478	71,979
Grazer daily per kg BW	(43,209)	185.96	0.00104	(185,385)	188.36	0.001063
Total daily requirment browser (incl. plus 50% of energy for activity))		3,060,736	18.1		11,860,998	69.9
Total requirment per year browser (incl. plus 50% of energy for activity)		1,117,168,703	6,621.9		4,329,264,188	25,512
Browser per kg BW	(14,619)	209.37	0.0012	(57,916)	204.80	0.0012

Plus 50% of energy requirment was considered for walking and grazing in semi-arid rangeland in Mutompo and Okamboro.
Donkeys and horses were treated like cattle.

Table A 20: Cycle sector sizes of transect model

Distance from water point (= radius) (km)	Size of cycle sector (m²)	Size of inner cycle size (m²)	Covered areas by each cycle sector (m²)	(ha)
1	3,141,593	0	3,141,593	314
2	12,566,371	3,141,593	9,424,778	942
3	28,274,334	12,566,371	15,707,963	1,571
4	50,265,482	28,274,334	21,991,149	2,199
5	78,539,816	50,265,482	28,274,334	2,827

Table A 21: Grass and herb availability and its metabolisable energy and crude protein content

Community	Measured or plus herbs	Month	Scale	Grass/herb biomass (kg)	Metabolisable energy (MJ)	Crude protein (kg)
Mutompo	Total measured	Oct. 02	total	3,210,449	39,098,216	103,087
	Total measured	Oct. 02	per ha	834.3	12.2	26.8
	Total measured	May 03	total	3,785,848	45,968,994	132,986
	Total measured	May 03	per ha	983.8	12.1	34.6
	100% incl. herbs	Oct. 02	total	3,839,697	46,761,466	123,292
	100% incl. herbs	Oct. 02	per ha	997.8	12,152.1	32.0
	100% incl. herbs	May 03	total	4,490,016	54,519,227	157,721
	100% incl. herbs	May 03	per ha	1,166.8	14,168.2	41.0
Okamboro	Total measured	Oct. 02	total	1,885,740	22,873,797	49,894
	Total measured	Oct. 02	per ha	324.7	12.1	8.6
	Total measured	May 03	total	104,881	1,272,725	8,915
	Total measured	May 03	per ha	18.1	12.1	1.5
	100% incl. herbs	Oct. 02	total	2,255,345	27,357,061	59,673
	100% incl. herbs	Oct. 02	per ha	388.3	4,710.2	10.3
	100% incl. herbs	May 03	total	124,388	1,509,452	10,573
	100% incl. herbs	May 03	per ha	21.4	259.9	1.8

Herbs: plus 19.6% for Oct. 2002-values (rest of the DS), and plus 18.6% for May 2003-values (post WS-period), according to Knemeyer, 1985). Seasonal grass biomass was defined as 82.2% in WS and 32.1% in DS (according to Knemeyer, 1985). Size of grazing areas for Mutompo: 3,848 ha, for Okamboro: 5,808 ha.

Table A 22: Calculated total available browse biomass and its metabolisable energy and crude protein content

Community	Season	Scale	Browse biomass (kg)[1]	Metabolisable energy (MJ)	Crude protein (kg)
Mutompo	DS-month	total	2,467,642	34,546,988	296,117
	DS-month	per ha	641	8,978	77
	post WS-months	total	6,215,724	87,020,136	870,201
	post WS-months	per ha	1,615	22,614	226
Okamboro	DS-month	total	3,257,203	45,600,842	228,004
	DS-month	per ha	561	7,851	39
	post WS-months	total	8,204,542	114,863,588	984,545
	post WS-months	per ha	1,413	19,777	170

[1] Results from software package BecVol (Smit, 1996), calculated for distance classes and cycle sector areas (see Table A 20). DS values are 39.7% of the post WS values, according to Knemeyer (1985). The hectare-values in this table can differ from the mean values per ha shown in Tab. 17 (p. 84), and in Table A 12, because they are calculated based on the means for the distance classes in the cycle sector model.

Table A 23: Potential stocking rates and percentage of utilized forage resources for grazers and browsers

	Mutompo						Okamboro					
	Supply of forage (kg)	Potential stocking (kg ha^{-1})	Rest of DS (%)	Supply of forage (kg)	Potential stocking (kg ha^{-1})	Post WS-period (%)	Supply of forage (kg)	Potential stocking (kg ha^{-1})	Rest of DS (%)	Supply of forage (kg)	Potential stocking (kg ha^{-1})	Post WS-period (%)
	DS: Oct 2002	90 days	forage utilized	WS: May 2003	243 days	forage uilized	DS: Oct 2002	90 days	forage utilized	WS-drought: May 2003	243 days	forage utilized
Proper use factor (p)	**45% of grass/herbs**						**30 % of grass/herbs**					
BM (kg)	1,727,864	200	5.6	2,020,507	86	13.0	676,604	52	61.7	37,316	0	3,032
ME (MJ)	21,042,660	327	3.4	24,533,652	141	8.0	8,207,118	83	38.3	452,836	0	1,882
CP (kg)	55,481	154	7.7	70,975	73	16.2	17,902	0.0	102.3	3,172	0	1,559
Proper use factor (p)	**50% of browse up to 1.5 m height**						**30 % of browse up to 1.5 m height**					
BM (kg)	1,233,821	143	2.7	3,107,862	133	2.9	977,161	74	13.3	2,461,363	70	14.4
ME (MJ)	17,273,494	246	1.4	43,510,068	229	1.5	13,680,253	131	7.3	34,459,076	122	7.8
CP (kg)	148,059	345	1.0	435,101	373	0.9	68,401	108	8.4	295,364	173	5.2

In these calculations, grazing resources were assumed to be utlized by grazers' only, browsing resources by browsers' only. BM – biomass, ME – metabolisable energy, CP – crude protein, p – proper use factor, DS – 3 dry season months; post WS-period – 8 after wet season months.

Table A 24: Potential stocking rates during study period

Type		Current BW (kg); no. of animals (n)	Season	Share of resources utilzed[1] (%), (limitations in parenthesis)	Additional potential of stocking (kg BW and no.)	Potential 100% (kg BW and no.)	Max. potential stocking level (kg ha^{-1})
Mutompo							
Grazer	BW	43,371	Rest of DS	7.7 (CP)	40,031	83,402	21.7
Grazer	no.	237	Rest of DS	7.7 (CP)	219	456	
Grazer	BW	43,371	Post WS-period	16.2 (CP)	36,345	79,716	20.7
Grazer	no.	237	Post WS-period	16.2 (CP)	199	436	
Browser	BW	14,457	Rest of DS	2.7 (BM)	14,067	28,524	7.4
Browser	no.	200	Rest of DS	2.7 (BM)	195	395	
Browser	BW	14,457	Post WS-period	2.9 (BM)	14,038	28,495	7.4
Browser	no.	200	Post WS-period	2.9 (BM)	194	394	
total	BW	57,828	Rest of DS		54,098	111,926	29.1#
total	no.	437	Rest of DS		413	850	
total	BW	57,828	Post WS-period		50,383	108,211	28.1##
total	no.	437	Post WS-period		393	830#	
Okamboro							
Grazer	BW	184,963	Rest of DS	102.3 (CP)	0	0	0
Grazer	no.	1,084	Rest of DS	102.3 (CP)	0	0	0
Grazer	BW	184,963	Post WS-period	3,032 (BM)	0	0	0
Grazer	no.	1,084	Post WS-period	3,032 (BM)	0	0	0
Browser	BW	58,409	Rest of DS	13.3 (BM)	50,641	109,050	18.8
Browser	no.	656	Rest of DS	13.3 (BM)	569	1,225	
Browser	BW	58,409	Post WS-period	14.4 (BM)	49,998	108,408	18.7
Browser	no.	656	Post WS-period	14.4(BM)	562	1,218	
total	BW	243,372	Rest of DS		50,641	109,050	18.8###
total	no.	1,740	Rest of DS		569	1,225	
total	BW	243,372	Post WS-period		49,998	108,408	18.7###
total	no.	1,740	Post WS-period		562	1,218	

[1]Selection of highest values of utilization from calculations for biomass, energy and protein availabilities; DS – 3 dry season months; post WS-period – 8 after wet season months; BM – standing biomass; CP – crude protein. # From this value 25.4% have to be browsers ## From this value 26.3% have to be browsers. ## From this value 100% have to be browsers. Current stocking density: Mutompo: 11.2 kg ha^{-1} grazer, 3.8 kg ha^{-1} browser; Okamboro: 31.9 kg ha^{-1} grazer, 10.0 kg ha^{-1} browser.

Table A 25: P and Ca requirements of current livestock

	P (kg) per 3 month	P (kg) per 8 month	Ca (kg) per 3 month	Ca (kg) per 8 month
Mutompo				
Cattle (129 animals)	107.5	290.1	143.3	386.9
Goats (226 animals)	42.7	115.3	6.01	164.8
Sheep (12 animals)	2.6	7.0	2.7	7.3
Total	152.8	412.5	207.0	558.9
Grazers	114.6	309.4	155.3	419.2
Browsers	38.2	103.1	51.8	139.7
Okamboro				
Cattle (960 animals)	518.4	1399.7	691.2	1866.2
Goats (623 animals)	117.7	317.9	168.2	454.2
Sheep (157 animals)	33.9	91.6	35.3	95.4
Total	670.1	1809.2	894.7	2415.8
Grazers	25.8	69.6	26.8	72.5
Browsers	8.1	22.0	8.5	22.9

Table A 26: P and Ca utilization by livestock referred to total available fodder during DS and WS

		Total BM (kg)	% P in grass and brow-se	Sum P (kg)	P-de-mand of live-stock (kg)	P- used (%)	% Ca in grass and brow-se	Sum Ca (kg)	Ca-dema nd of live-stock (kg)	Ca-used (%)
Mutompo										
DS PU 45-50	Grass	1,727,864	0.026	449	114.6	25.5	0.252	4,354	155.3	3.6
	Browse	1,233,685	0.23	2,838	38.2	1,4	0.76	9,377	51.8	0.6
	Total	2,961685		3,287	152,8	4.7		13,731	207.0	1.5
WS PU 45-50	Grass	2,020,507	0.028	566	309.4	54.7	0.252	5,092	419.2	8.2
	Browse	3,107,862	0.61	18,958	103.1	0.5	0.48	14,918	139.7	0.9
	Total	5,128,369		19,524	412.5	2.11		20.009	558.9	2.8
Okamboro										
DS PU 30-30	Grass	676,604	0.117	792	25.8	3.3	0.34	2,300	26.8	1.2
	Browse	977,161	0.32	3,127	8.1	0.3	0.61	5,961	8.5	0.1
	Total	1,653,765		3,919	33,9	0.8		8,261	35,3	0.4
PU WS 30-30	Grass	37,316	0.117	45	69.6	**155.4**	0.34	127	72.5	57.0
	Browse	2,461,363	0.41	10,092	22.0	0.2	0.49	12,061	22.9	0.2
	Total	2,498,679		10,136	91,6	0.9		12,188	95.4	0.8

PU- utilization rate. Percentage of P and Ca content in vegetation, according to Knemeyer (1985). A stable daily intake rate of 2.5% of live body weight in the DS-period and in the post WS-period was applied. Cattle: 8.8 kg DM intake per day. Goats: 1.0 kg DM intake per day. Sheep: 1.5 kg DM intake per day. Requirements: cattle – 8.0 g P/day, and 11.0 g Ca/day on moderate production level. Goats – 2.1 g P per day, and 3.0 g Ca per day on maintenance level. Sheep – 2.4 g P per day, and 2.5 g Ca per day on maintenance level.

Table A 27: Significant Spearman-rank-correlations between determinants of farmers' preferences of grazing areas and vegetation parameters

	Mutompo			Okamboro	
	n	Preference cropping season[1]	Preference non-cropping season[2]	n	Preference
	(R; significance)			(R; significance)	
Grass biomass Oct. 2002	50	ns	ns	90	0.239*
Grass biomass May 2003	52	0.460**	0.460**	77	0.402***
Ground cover Oct. 2002	53	-0.313*	-0.313*	63	0.396**
Ground cover May 2003	48	0.584**	0.584**	54	ns
No. of grass species Oct. 2002	39	0.688**	0.688**	63	0.257*
No. of grass species May 2003	54	0.612**	0.612**	40	0.356*
Grass Shannon index Oct. 2003	54	0.448**	0.448**	80	0.442***
Crude protein May 2003	53	-0.468***	-0.468***	0	no data
Crude fibre May 2003	51	0.305*	0.305*	0	no data
Phosphorus total May 2003	43	-0.526***	-0.526***	0	no data
Mean bush and tree density	55	-0.471***	-0.480***	92	ns
Mean leaf biomass per ha	55	ns	ns	92	0.218*
Mean browse leaf biomass per hectare	55	-0.414**	-0.400**	92	0.398***
Mean leaf volume per ha	55	ns	ns	92	0.215*

[1]Cropping season corresponds with WS; [2]non-cropping season corresponds with DS. The other parameters were tested also, when data were available, but without significant results.

Table A 28: Sex ratios of livestock

Community	Livestock species	Sex ratio: male : female[1]
Mutompo	Cattle	55 : 50
	Goats	16 : 50
	Sheep	25 : 50
Okamboro	Cattle	6 : 50
	Goats	9 : 50
	Sheep	10 : 50

[1] Calculated only for the adult animals.

Table A 29: Significant results of configuration frequency analysis of off-take of calves

Communitiy	Configuration	n	Z-value	p	Trend
Mutompo	121	20	2.76	0.003	Male calves stay in the herd.
Okamboro	211	65	5.70	0.000	Female calves stay in the herd.
Okamboro	222	45	7.59	0.000	Male calves were sold.

For the determination of trends within the off take performance of calves between the two villages, a configuration frequency analysis was conducted with the combination of the following three characters: 1.) village [1 = Mutompo; 2 = Okamboro], 2.) sex of the calf [1 = female; 2 = male], and 3.) disposition of the calf [1 = in herd; 2 = sold]. Within the possible 12 configurations of characters the three trends were significant $\alpha = 0.004$ ($\alpha = 0.05/12$). Conducted by F. Lange, 2003; unpublished.

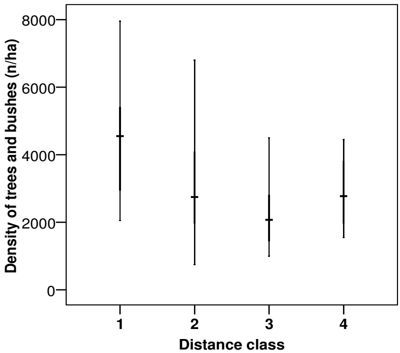

Figure A 1: Density of trees and bushes for distance classes in Mutompo

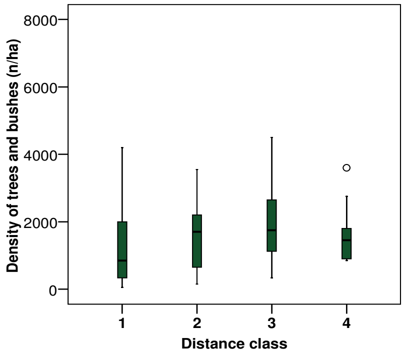

Figure A 2: Density of trees and bushes for distance classes in Okamboro
(o = outlier value)

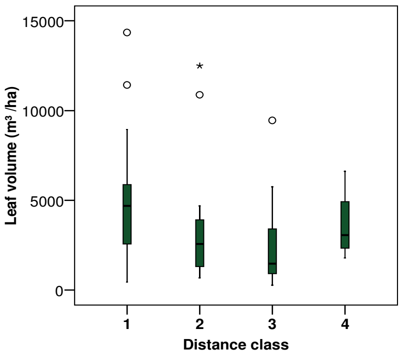

Figure A 3: Leaf volume of trees and bushes for distance classes in Mutompo
(o = outlier value; * = extreme value)

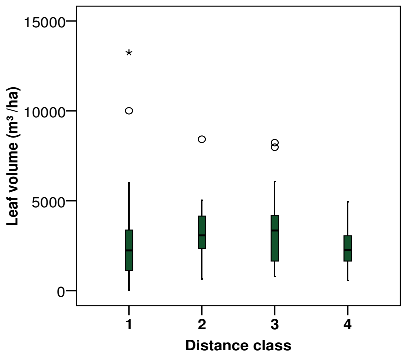

Figure A 4: Leaf volume of trees and bushes for distance classes in Okamboro
(o = outlier value; * = extreme value)

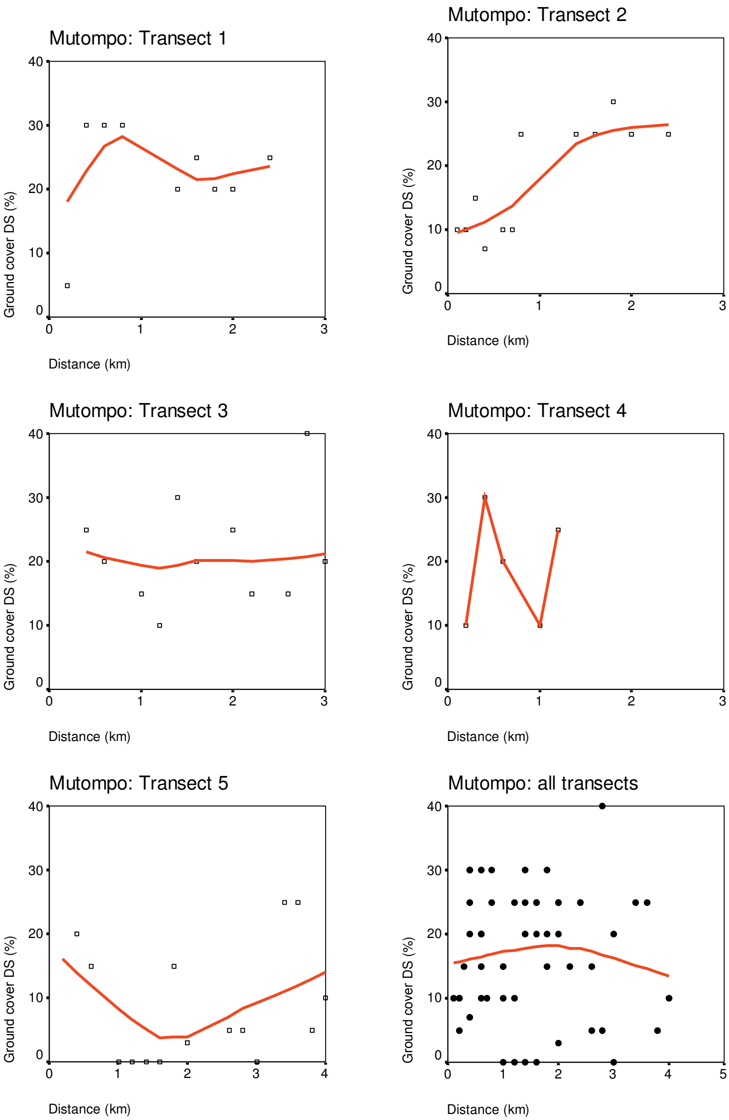

Figure A 5 / 1-6: Spatial distribution of ground cover per transect in studied DS in Mutompo

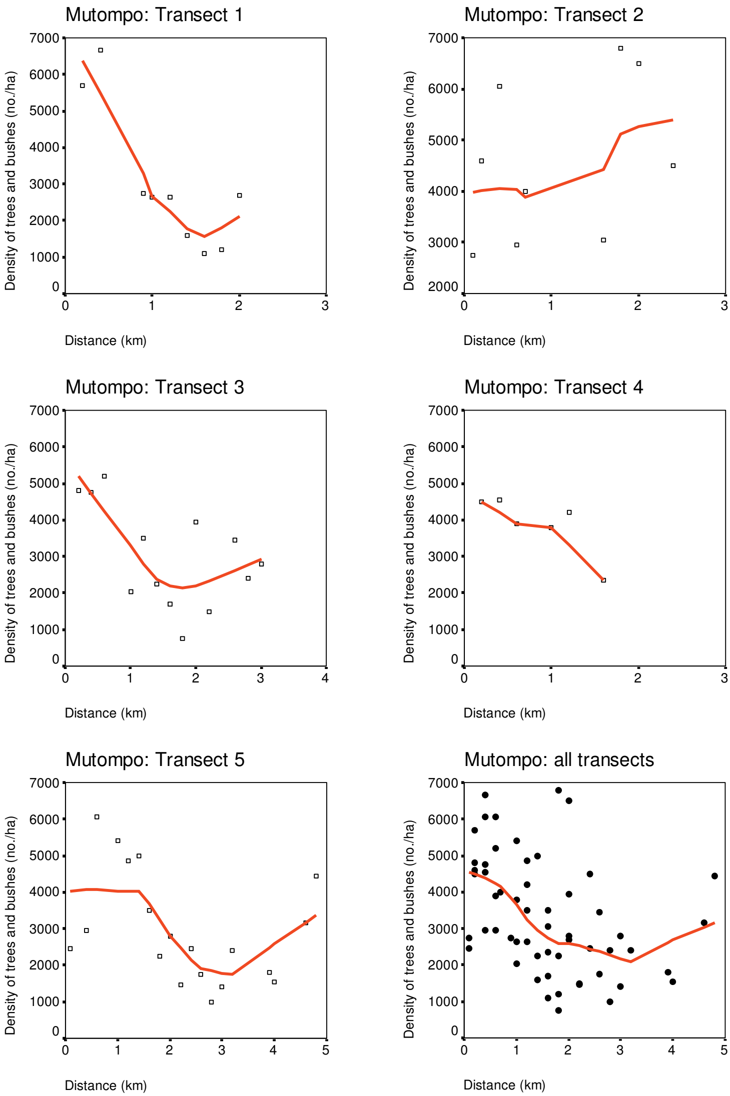

Figure A 6 / 1-6: Spatial distribution of density of trees and bushes per transect in Mutompo

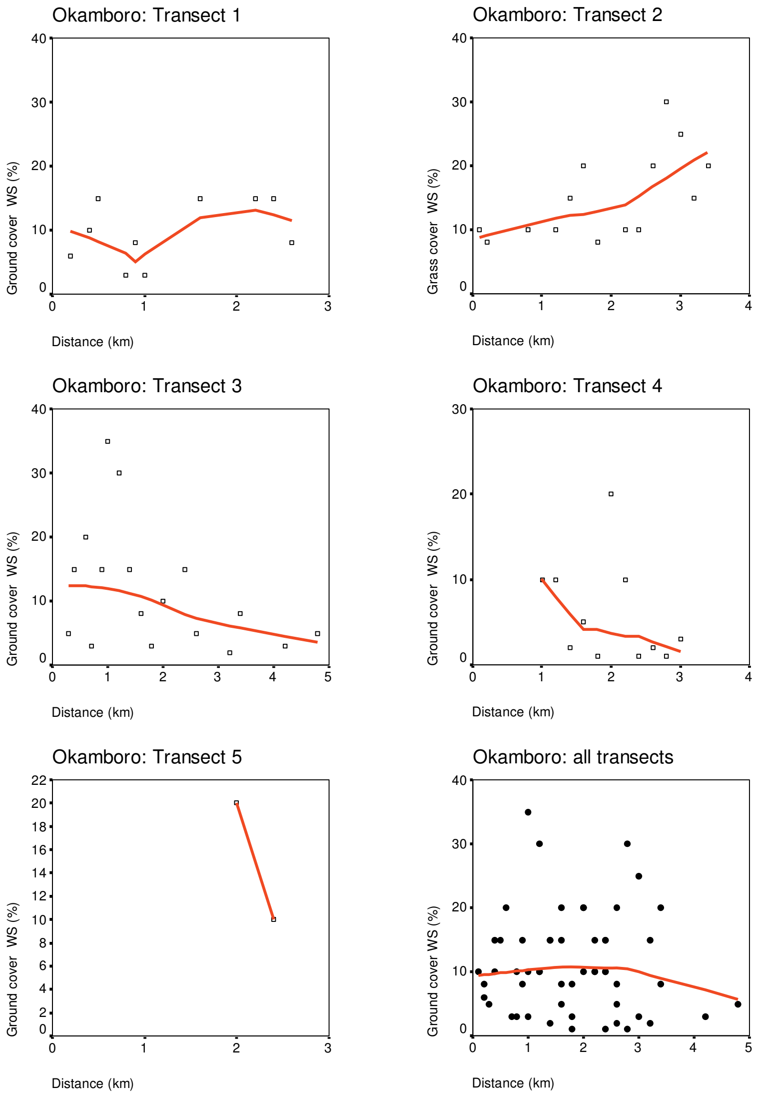

Figure A 7 / 1-6: Spatial distribution of ground cover per transect in studied DS in Okamboro

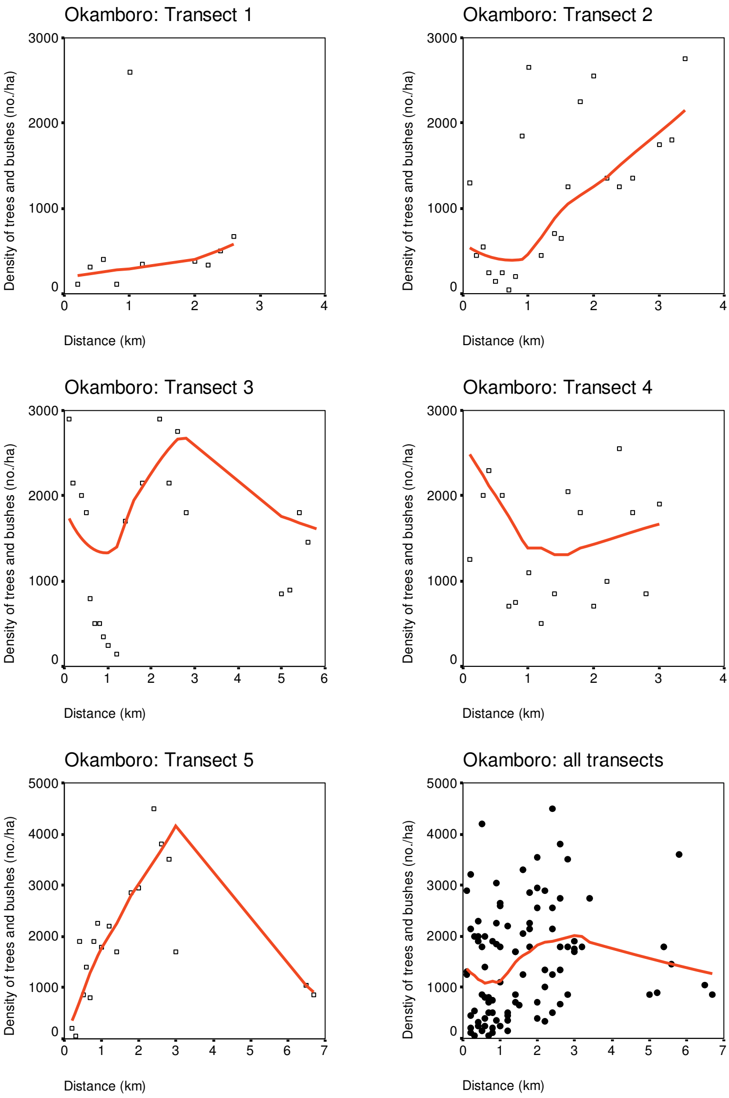

Figure A 8 / 1-6: Spatial distribution of density of trees and bushes per transect in Okamboro

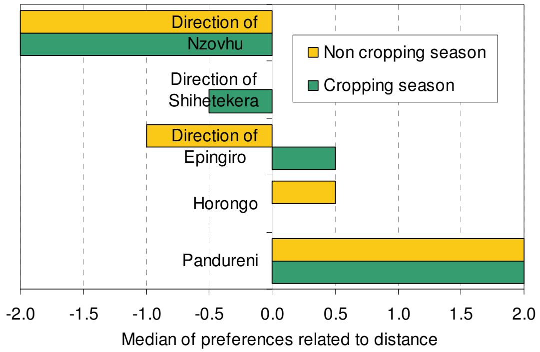

Figure A 9: Preference related to distance in Mutompo
(n=7; -2 = very far, 2 = very close)

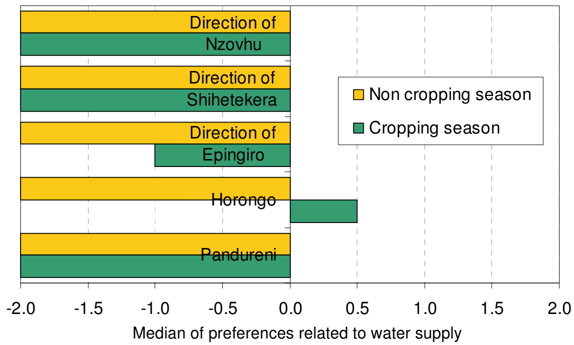

Figure A 10: Preference related to water supply in Mutompo
(n=7; -2 = little water, 2 = very much water)

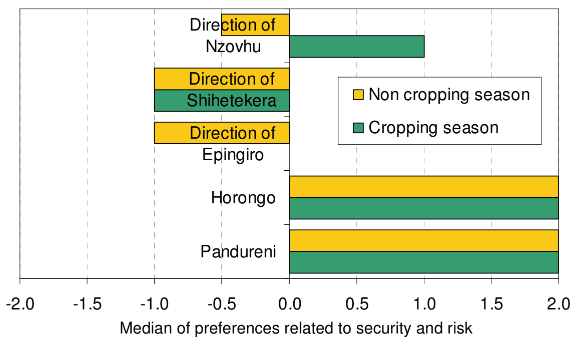

Figure A 11: Preference related to security and risk and in Mutompo
(n=7; -2= very many risks, 2 = no risks at all)

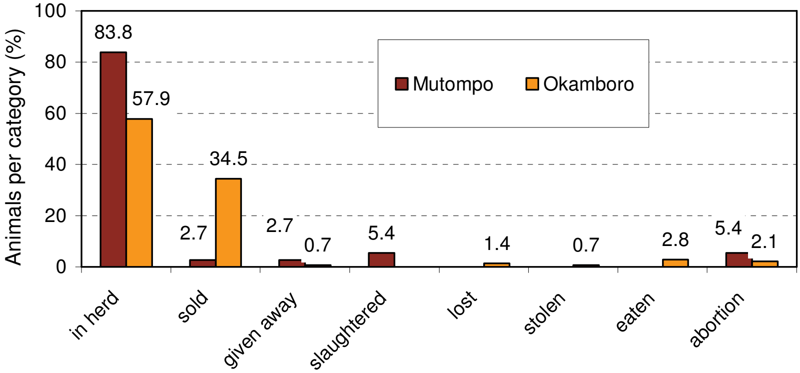

Figure A 12: Disposition of evaluated calves
(Compiled by F. Lange, 2003; unpublished)

Map A 1: Regional districts, towns and main road system of Namibia

(Sources: Mendelsohn et al., 2002, electronic version. District borders: grey lines; towns: yellow dots; main streets: red lines),

Qu 1: Rangeland assessment sheet

Rangeland assessment

Community:	Date:
Nr. of photo:	Nr. of transect:
GPS reading of transect point: Altitude: º ‘ ´´ S º ‘ ´´ E	Observer: Accuracy of GPS: WGS 84
Main vegetation type:	Direction of transect from central:
Distance from water: km Distance from next fence: km	Remarks:
Disturbances: Road: cultivated land: old land: heavily grazed: fire: garden: Plantation/field: cleared: eroded:: others:	Livestock signs: Grazing O Trampling O Dung O Others:
Soil type: Litter: O yes O no	

Habitat description:

Flat 0 - 1° (0-2%)	Gently undulating 1 - 3° (2-5%)	Undulating 3 - 6° (5-10%)	Rolling 6 - 9° (10-15%)	Moderately steep 9 - 17° (15-30%)	Steep 17 - 30° (30-60%)	Very steep > 30° (>60 %)

Erosion:

none	Wind erosion	Wind deposition	Shifting sand	Sheet erosion	Rill erosion	Gully erosion	Deposition by water
slight							
moderate							
severe							
extreme							

Surface Crusting:

None	Weak (soft or slightly hard, <0.5 cm thick)	Moderate (soft or slightly hard, >0.5 cm thick, or hard <0.5 cm)	Strong (hard crust >0.5 cm)	Clay bubbles (Schaumböden) present

Vegetation structure(rough classification) :

Th: High tree >20m Tt: Tall tree 10 – 20m Ts: Small tree 5 –1 0m Tl: Low tree 2- 5m
Sh: High shrub 2 –5 m St: Tall shrub 1 – 2m Ss: Small shrub 0.5 – 1 m Sl: Low shrub <50cm

	Total	Trees	Shrubs >1m	Trees and shrubs	Shrubs <1m	Grasses	Herbs
Average height							
Total canopy cover							
Greeness [%]							
Vegetation structure:							

Biomass (rough classification):

1.00 m² area	Total	Grasses	Herbs	Others
Biomass [g]				

Aspect:

North
NW NE
West o East
SW SE
South

Species composition:

Th: High tree >20m Tt: Tall tree 10 – 20m Ts: Small tree 5 –1 0m Tl: Low tree 2- 5m
Sh: High shrub 2 –5 m St: Tall shrub 1 – 2m Ss: Small shrub 0.5 – 1 m Sl: Low shrub <50cm, Hl: low herbs; G:grass; H: herbs

Abundance: rare (r) occasional (+) common (1) Abundant (2) Dominat (3 &4)

Description of plant: | Annual = A | Perennial = P

No.	Species/provisional name	Biomass [g]	Abundance by growth form (r, 1, 2, 3, 4)									
			Grass	Herbs	Sl	Ss	St	Sh	Tl	Ts	Tt	Th
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15												
	Total cover:											

No.	Trees and bushes Species/provisional name	Numbers	BecVol-measurements					
			Height of trees or bushes [m]	Height maximum canopy diameter	Height of first leaves [m]	Maximum canopy diameter [m]		Base diameter at hight C [m]
			A	B [m]	C	D 1	D 2	E
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
	Total number:							

Qu 2 Basic household questionnaire

<table>
<tr><td colspan="3">Village:</td><td colspan="2">No:

(Version 31. July 2001)</td></tr>
<tr><td colspan="2">Date:</td><td>Duration of interview:</td><td colspan="2" rowspan="2">Interviewer:</td></tr>
<tr><td colspan="2" rowspan="2">Rapport:</td><td>Translator:</td></tr>
<tr><td colspan="3">Remarks/characteristics:</td></tr>
<tr><td>No.</td><td colspan="3">Persons, who are present during this Interviews</td><td>Percentage of talking</td></tr>
<tr><td></td><td colspan="3"></td><td></td></tr>
</table>

Modul 1: Household/family structure

	Names	Sex/ Age	Legal status*	Education *(standard or grade)*	permanent = p; non permanent = np	Since when do you live in this village?	remarks
Household head							
Wife/ Husband							
1							
2							
3							
4							
5							
6							
7							

* Legal status: 1 = single; 2 = married; 3 = divorced; 4 = widowed, 5 = other (specify)

Modul 2: Sources of income and transfer of money

Q2:From which sources do you make your living?(in cash or in kind)
Q3:How important are the following income sources for you?

Livestock production (1 to 5)	
Other self employment (1 to 5)	
Permanent work (1 to 5)	
Casual work (1 to 5)	
Remittance / private transfers (1 to 5)	
Pension (1 to 5)	
Other state transfers (1 to 5)	
Others:	

1 = absolutely unimportant; 2 = unimportant; 3 medium important; 4 important; 5 very important

Q4:Do you give money/goods to other persons?
Q5:To whom (family members, other relatives, friends, others)?
Q6:Where did you learn how to do your job?

	Q6a: how long? how often?	Q6b: related to?(1= livestock production; 2= crop production; 3 =other self employment; 4 = salaried employment)	Q6c: where?
learned from community members or relatives			
working experience on private enterprises			
formal vocal training			
special trainings (e.g. from extension workers) related to livestock keeping, crop production or other ways of working			
others:			

Modul 3: Livestock

Q7: Do you or other household members own livestock? (yes / no)
Q8: Where do you or other household members keep the animals?
(community land; private farm; other communal area; compound;
others:____

Q9: Do you take care for the animals of other owners? (yes / no)
Q10: Who are the owners and where are they?
Q11: when did you start livestock keeping (yr)
Q12: with how many animals male female

Q13: where did you get them from
purchase gift inherited others

Q14: If you stopped with livestock production, when and why?

animal species	cattle	goats	sheep	others:
Q15: breed				
Q16: male				
Q17: female				
Q18: young stock				
Q19: Reproduction				
Q20: young born last year				

animal species	cattle			goats			sheep			others:		
Q21: Use: Sales/ consumption (month of use) / other use (gift, pledging, share-arrangements)	S	C	O	S	C	O	S	C	O	S	C	O
Q22: number last year												
Q23: animal category												

Q24: Losses: last year/last season				
Q25: Reasons for losses:				
Q26: carnivores				
Q27: thieves				
Q28 diseases				
Q29: others				
use of returns Q30: education				
Q31: health				
Q32: investment (specify!!)				

Q33: food/clothing				
Q34: other				
Remarks:				
Q35: How many animals do you need to make a living?				
Q36: Where do you sell your animals?				
Inputs (per year or per season, specify)	cattle	goats	sheep	others:
Q37: Feed: how much?				
Q38: feed type				
Q39: veterinary products				
Q40: type				
salt / minerals Q41: how much?				
Q42: type				
Q43: herding/labour				
Q44: types				
Q45: other inputs				

Q46: Was the last year a good one, a bad one, and reasons?

Q47: Did livestock die due to thirst or famished sometimes? (yes / no)

When yes, when last time (last serve drought)? When the last time before?

Q48:Year of serve drought	Q49: How many animals die?	Q50: How many animals did you own/have before the drought?

Modul 4: Crop production (only for Mutompo)

	Q51: own land (ha):	Q52: rented (ha): Q53: rent/ha:
fields (n)		
Paddock		
Q54: When was the land acquired? Q55: from where Q56: price		
Q57: fencing?		
Q58: If you stopped crop production, when and why?		
Q59: mixed/single cropping (clarify if the concept of mixed cropping is known) (e.g. maize, sorghum, millet, groundnuts, cowpea, lucerne, vegetables)		

Q60: Crop												
Q61: ha (clarify: ha or acres)												
Q62: variety (modern - hybrid – local)												
Q63: kg seed												
Q64: origin of seed												
Q65: yield												
Q66: Use: Sales/ consumption / other use (gift)	S	C	O	S	C	O	S	C	O	S	C	O
Q67: quantity												
Q68: Price, when sold												
Q69: consumption of harvest (months)												
Use of returns Q70: education												
Q71: Health												
Q72: Investment (specify !)												
Q73: food/clothing												
Q74: Other												
Inputs												
Q75: fertiliser												
Q76: fertiliser type												
Q77 : Costs												
Q78: Other												
Pesticides												
Q79: Type												
Q80: Costs												
Drought power												
Q81: animal - motor												
Q82: Costs												
labour												
Q83: hired - family												
Q84: Costs												
Land												
Q85: Acres rented												

Q86: Was the last year a good one or a bad one, reasons?
Q87: Where do you sell crop products?

Qu 3: Progeny History Technique (PHT) - questionnaire

PROGENY HISTORY QUESTIONNAIRE - CATTLE

Village:	*Date:*	*Questionnaire No.:*	Function of the interviewed person: Herder Owner Else

Could you give the names of your breeding females?

_______________ _______________ _______________ _______________

_______________ _______________ _______________ _______________

Questions concerning the mother cow:

Q1: What is the name of this cow? ____

Q2: Was she born in your herd or did you get her from anywhere else? born in herd aquired

Q3: If born in herd, when was she born? (give date as year/event/month) year__________ season________

Q4: If acquired, when did you get her? (give date as year/event/month) year__________ season________

- did you buy her, get her as maal or as dowry? buy maal dowry
- from where did you get her (region, town)? _____________________________
- how old was she at that time? _____________________________
- why did you get/buy her? ____

Q5: What breed or type is this cow? pure crossbred Africander Sanga Brahman Simmen.

Q6: Does the cow have any problems like
udder abnormalities
mastitis
poor milk let-down or
anything else? __________________________________

Q7: How many calves did this cow deliver up to now? (the complete number, alive as well as dead ones)

no.:____________ names: ____

Q8: Did the cow have any abortions? yes no

If yes, how many and when? ____

Were those early or late abortions? early late

Q9: Did this cow have difficult births? yes no

Q10: Did this cow ever show difficulties to conceive? (Is it difficult to get her pregnant?) yes no

If yes, what do you think was the reason?

Q11: Is the cow now pregnant and since how many months, or is she lactating? pregnant lactating

since_______

BCS: ______ **Weight:** _______ kg **RL:** _______ cm **SIL:** _______cm **CC:** __________cm

No. of hornrings: ______________ dentition: ___________________________________

Questions concerning the calves of that cow: (to be asked for all calves, not only the ones which are still alive)

Q1: What is the name of this calf?

Q2: When was this calf born? (give date as year/event/month)

Q3: Which was the sex of this calf?

Q4: What breed is this calf?

Q5: How long did you milk the female during this lactation (months)?

Q6: Did the calf survive until weaning?

If not, when died (give date as year/event/month) or how old was it when it died?

What was the cause of its death?

Q7: Where is the calf now? (in your herd, sold, given away (maal, dowry), died after weaning)

Q8: If disposed, when disposed (give date as year/event/month) or how old was the calf when you disposed it and why?

First calf

1. name: ______________________
2. born: year__________________ season_______________________
3. sex: female male
4. breed: pure crossbred Africander Sanga Brahman Simmen.
5. lactation length: ______________________months
6. survived until weaning: yes no
7. died, when and why____
   predators diseases drought nutritional accident else (too small etc.)___________
8. where is the calf now: herd sold given away (maal, dowry) died after weaning
   disposed, why:____

BCS: ______ **Weight:** _______ kg **RL:** _______ cm **SIL:** _______cm **CC:** _________cm

Second calf

1. name: ______________________
2. born: year__________________ season_______________________
3. sex: female male
4. breed: pure crossbred Africander Sanga Brahman Simmen.
5. lactation length: ______________________months
6. survived until weaning: yes no
7. died, when and why____
8. predators diseases drought nutritional accident else (too small etc.)
9. where is the calf now: herd sold given away (maal, dowry) died after weaning
   disposed, why:____

BCS: **Weight:** **kg** **RL:** **cm** **SIL:** **cm** **CC:** **cm**

Third calf…etc.

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Eidesstattliche Erklärung

Ich erkläre: Ich habe die vorgelegte Dissertation selbständig und ohne unerlaubte fremde Hilfe und nur mit den Hilfen angefertigt, die ich in der Dissertation angegeben habe. Alle Textstellen, die wörtlich oder sinngemäß aus veröffentlichten Schriften entnommen sind, und alle Angaben, die auf mündlichen Auskünften beruhen, sind als solche kenntlich gemacht. Bei den von mir durchgeführten und in der Dissertation erwähnten Untersuchungen habe ich die Grundsätze guter wissenschaftlicher Praxis, wie sie in der Satzung der Justus-Liebig-Universität Gießen zur Sicherung guter wissenschaftlicher Praxis niedergelegt sind, eingehalten.

Dransfeld, den 19.09.2011

Unterschrift: ....