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CHANGING GRAZING SYSTEMS IN CENTRAL NORTH NAMIBIA

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ABSTRACT

Current and historical livestock movement patterns are explored in a semi-arid communal environment in central–north Namibia, placed in context of increasing population, large-scale enclosures, increased water supply and changing vegetation. Farmer's knowledge of movements, rangeland potential, vegetation condition and plant indicators was gathered and analysed with various methods such as Canonical Correspondence Analysis (CCA). Local rangeland units were mapped with Landsat TM imagery and analysed with a Geographical Information System (GIS). The data suggest that good grazing was previously maintained by low herbivore pressure and frequent fires in a management regime controlled by hunter-gatherers and limited permanent water supply.

Population increase in settled areas starts migration to more fertile land units in previous prime grazing areas causing a conflict between grazing and cropping and a decrease in grazing condition triggering further migration and need for new water supply. Recent large-scale enclosures are targeting predominantly more fertile land units with the most palatable perennial grass species and water, causing further conflict for communal farmers.

Having reached the frontier of the traditional land there is no space for further expansion, resulting in the need to adapt to uncertainty with annual grasses more dependent on rainfall. Livestock movement patterns have changed drastically for large herd owners from transhumance and migration to largely permanent cattle posts. Small herd owners face increasing longer movements between **kraals**, water points, depending on less suitable and decreased unfenced grazing lands. Copyright © 2006 John Wiley & Sons, Ltd.

KEY WORDS: livestock movements; indigenous knowledge; rangeland condition; canonical correspondence analysis; migration; Namibia

INTRODUCTION

Half of sub-Saharan Africa is semi-arid or arid, receiving less than 800 mm of rain annually on average with rainfall showing high spatiotemporal variability (Middleton and Thomas, 1997). Livestock are very important agronomically, economically and culturally to rural producers in these areas (Blench, 2004). The spatial distribution of livestock, affected by changing management practices, is a major factor determining anthropogenic changes in savanna ecologies (Scoones, 1993). Due to sensitivity of the mostly poorly structured soils to trampling and of annual-dominated vegetation to defoliation (Hiernaux and Turner, 1996), the seasonal pattern of grazing pressure across agropastoral landscapes is a key factor behind land deterioration (Turner and Hiernaux, 2002).

Understanding spatiotemporal distributions of livestock and of the factors influencing these distributions is necessary for evaluating sustainability of both grazing and agricultural systems (Scoones, 1995). Fine-scaled information on livestock activities is still limited in semi-arid Africa (Turner and Hiernaux, 2002).

A first objective of this paper is to reach a greater understanding of the grazing component of the current agropastoral landscape in central north Namibia through translating local producers' detailed but non-Cartesian accounts on rangeland condition, use, management and especially livestock movements to the quantitative

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extraction measures on a Cartesian plane required by resource scientists. It is accepted that such translations are very much needed in rural Africa where land use patterns diverge greatly from western agricultural and ranching systems (Turner and Hiernaux, 2002). At the same time local perceptions are amplified by conventional resource assessments to allow comparison and verification following the Indigenous Land Units (ILU) approach developed by Verlinden and Dayot (2005).

A second objective of this paper is to investigate the current livestock movement patterns, and put these in the perspective of historical patterns and the environmental changes. Transhumance patterns are considered to be a typical feature of livestock management but they are suggested to have changed over the years as a result of dynamic processes in the environment, including increasing settlement (Verlinden and Dayot, 2005), enclosure (Marsh and Seely, 1992; Tapscott and Hangula, 1994; Fuller *et al*., 1996; Kerven, 1997), water supply (Mendelsohn *et al*., 2000) and changing vegetation (Verlinden and Dayot, 2005). These processes and their effects are insufficiently understood, but the hypothesis in this study is that the grazing options have been seriously restricted over time.

The area is subject to a much debated process of large-scale privatisation of range resources, mainly by enclosure of open access and common property land, possibly forcing herders to make further adjustments as elsewhere in the Kalahari (Perkins, 1996). Several authors working in arid to semi-arid areas suggest that where pastoralists are able to maintain their activities on a large spatial scale by migrating to areas where key rich resources can be exploited, negative effects of grazing on plant biodiversity do not develop (Sinclair and Fryxell, 1985; Ellis and Swift, 1988; Behnke and Abel, 1996). This may hold in areas where livestock have been present for a long time and where no vast changes in water supply have occurred. In large portions of the study area livestock rearing is a relatively recent phenomenon because of previous lack of water. In a similar area just north of the present study, but with less influence of enclosures, oral history suggests vast changes in grass cover and woody plant cover have occurred over the past few decades (Verlinden and Dayot, 2005). The pressure on land for grazing, already high in the mid 1990s (Fuller *et al*., 1996; Kerven, 1997; Strohbach, 2000a), was considered to be critical in 2004 even in the most remote areas (NASSP, 2004), possibly preventing required livestock mobility in view of uncertainty in semi-arid environments (Scoones, 1995; Southgate and Hulme, 2000). The paper therefore describes a grazing system in a critical stage in a rapidly changing semi-arid environment and discusses the various grazing strategies that have modified over time.

METHODS

Study Area

Namibia is mostly arid to semi-arid, rainfall is highly seasonal and occurs almost entirely as a single wet season in summer. In the wetter areas the rainy season extends from October/November to April, but in the drier areas in the west the season starts later and is shorter. The bulk of the rain falls between the months of January and March. Less than 1 per cent of total precipitation is recorded in the June to September winter period. The median rainfall for the semi-arid study area of about 19 425 km^2 is around 400 mm, decreasing towards the west (Hutchinson, 1995). Soils are mainly arenosols, poor in nitrogen and phosphorus, especially in the inverted dune system of the eastern dry Kalahari woodlands. These woodlands are dominated by *Burkea africana* and are semideciduous. In the western part, the Cuvelai basin, there are drainage lines called **oshanas** with clay soils (Figure 1). The landscape there is a mixture between saline solonetz soils, cambisols and arenosols with a hard pan at varying depth (Mendelsohn *et al*., 2000).

Despite having one of the lowest overall population densities in the world (the 1·9 million people (2001) live at an average density of about two persons per square kilometre), Namibia suffers increasing pressure on, and consequent risks to, its land and water resources. Regionally, there are large variations in population density, with heavy concentrations reaching 100 persons per square kilometre in parts of the northern communal areas, including the western Cuvelai part of the study area (Figure 1). To the east of the Cuvelai the population density decreases sharply to less than one person per square kilometre in the eastern dry Kalahari woodland portion of the study area and to similar low densities in the open saline grasslands (**Ombuga**) to the south.

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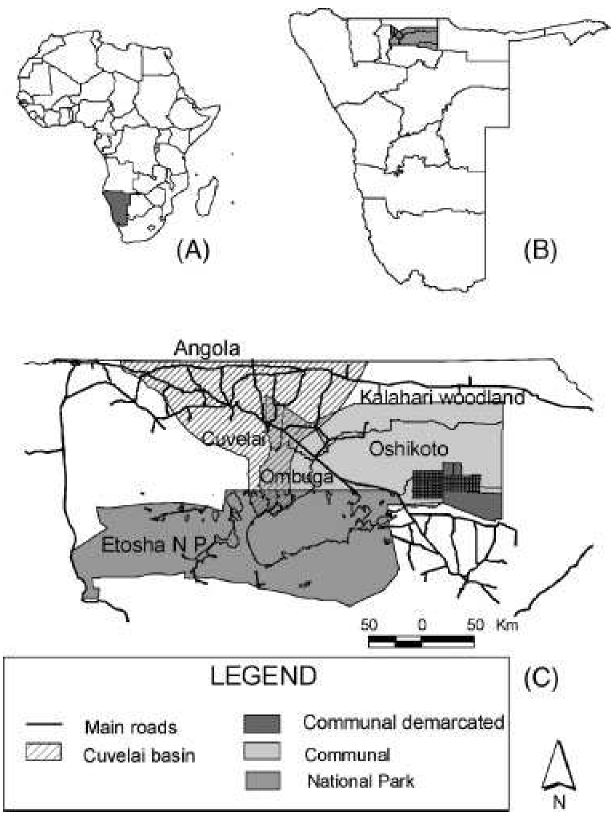

Figure 1. The map in (A) shows the location of Namibia in Africa, in (B) the location of the study area in Namibia and (C) shows the main tenure systems in the study area Oshikoto with some main landscape features referred to in the text

In Namibia there are three broad categories of land tenure. Approximately 44 per cent of the Country is farmland with freehold tenure, 41 per cent is used as communal areas, and the remaining 15 per cent is state land including conservation areas. The entire study area is communal land, some of it consisting of demarcated farms (Mangetti + quarantine camp), but borders with Etosha National Park and freehold farmland to the south. The traditional or communal farming sector is subsistence-based and labour-intensive, with limited use of technology and external inputs. In the communal areas there are user rights rather than ownership rights, and only the cropping areas are normally allocated to individual households, while the grazing areas tend to be shared by members of a community. Although all land in the study area is communal, in this paper the farmers who keep livestock on unenclosed areas are considered 'communal farmers', while the farmers in the demarcated farms are considered 'commercial ranchers'. The large enclosures are called 'informal' fences as opposed to the fences of the demarcated farms, the farmers in these large enclosures are also considered 'commercial ranchers'.

Livestock are important in the livelihoods of the people in the area (Siiskonen, 1990; Marsh and Seely, 1992; Kreike, 1994; Erkkilä, 2001). Traditionally, cattle not land constitute the most important economic factor, because they are inheritable property and land is not. The importance of cattle now is both traditional and modern economic with mainly informal marketing and low off-take rates of around 1·7 per cent compared to 18·8 per cent for the entire country (Mendelsohn *et al*., 2000; NASSP, 2005a).

History of Livestock Movements

The traditional movement pattern before the advent of boreholes and pipelines in the 1970s was that cattle remain close to the homestead, but outside the crop fields, when grass and water were sufficient to feed the animals, from

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the beginning of the rainy season around October until the beginning of the dry season in May. After harvesting is completed, livestock eat the remaining stalks of Pearl millet on the fields, afterwards they would be brought to the cattle posts located outside settled areas. Cattle were kept at different cattle posts to spread risk of drought and disease and also to hide wealth. Cattle post herders looked after different peoples' cattle and received every third calf as compensation from each cattle owner (Williams, 1991).

More recent accounts state that the majority of the cattle remained long in the cattle post areas. Once the rainy season begins, some of the milk cows would be brought back to the villages, provided there is sufficient grazing, so that families can have the benefit of the milk (Kreike, 1994; Kerven, 1997). Plough oxen must also be returned to the villages as cultivation takes place at this time. The bulk of the oxen and milk cows remained at the cattle posts and returned only briefly to the villages for the time of harvest from April to July (Kerven, 1997). How far away and how long cattle were herded at cattle posts depended not only on the grazing quality (around the homesteads and at the cattle posts) but also on the water supply and the availability of labour (Kerven, 1997). Around a homestead there is a reserved piece of land that is not cultivated, called the **ekove** (Kreike, 1994). These **ekove** are increasing in size as they become more important as a grazing reserve in emergencies (NASSP, 2005b).

The central Cuvelai had historically seasonal potable water available during the wet season with well water becoming increasingly saline during the dry season. The amount was also limited and water-levels were (and still are in some villages without pipeline water) used to decide when, who and how many cattle should leave for the cattle posts, well water being prioritised for human consumption. In central Oshikoto more wells with potable water could be found but eastern Oshikoto has fewer pans and traditional wells. Even fewer are found around the Mangetti area and these areas were not available for grazing due to shortage of water supply before the advent of deep borehole technology.

Tapscott and Hangula (1994) suggest that a form of transhumance (**ohambo**) was being practiced in the Ondonga Kingdom (largely in Oshikoto) in the 19th century, indicating that land shortage around the settled area was then already a problem. After the rinderpest pandemic at the end of the 19th century pressure on the land was greatly reduced (Erkkilä and Siiskonen, 1992). This changed rapidly as Estermann (1976) indicated that uninhabited zones between tribes had largely been settled in the 1950s. Oral history collected in this study is in agreement with Kreike (1994) that central and eastern Oshikoto was used for a long time for establishing cattle posts. Increasingly graziers have been attracted to this forested area, following water development programmes since the 1970s. This culminated in the 1990s following a drought in 1992 with a major programme of borehole installation in eastern Oshikoto, initiated by the Namibian Government as part of drought relief measures (Kerven, 1997).

The establishment of Etosha National Park disrupted the seasonal movement to the permanent water points in the south and this was exacerbated by the establishment in 1969 of a veterinary cordon fence south of the survey area. Encroachment by large fencing of farms on the eastern dry season pasture area began in the 1970s with the establishment of the Mangetti block, an area with few, if any, traditional wells. In the late-1970s the first local businessman managed to acquire the rights to fence communal grazing land (Tapscott and Hangula, 1994).

New boreholes since the 1970s and especially after the drought of the early-1990s have attracted the attention of others who saw an opportunity to open up commercial ranches by privatising the rangeland around boreholes. This started competition for grazing and water between mobile, subsistence-oriented livestock owners and town-based commercialising ranch-owners and this process is suggested as having a major influence on availability of land for grazing by communal farmers (Marsh and Seely, 1992; Fuller *et al*., 1996; Kerven, 1997), although only limited information on the extent of enclosures was available. Enclosed fenced land prevents access to grazing for all other communal farmers and results in less grazing land available for these farmers (Thomas *et al*., 2000).

Large areas with limited water supply were not grazed by livestock but visited by hunters and hunter-gatherers historically, resulting in an ecosystem with low herbivore pressure characterised by low woody cover due to frequent fires. These areas were called **Ombuwa** (open land) and according to oral history just north of the present study area have with increased grazing changed gradually into **Ongoya** (meaning one cannot pass) (Verlinden and Dayot, 2005). Decreasing grass cover and increasing shrub cover are well-known changes in the environment as a result of heavy grazing and decreased fire frequencies (Downing, 1978). It is unknown to what extent these modifications of the vegetation affect livestock and the grazing systems used, but studies in similar environments

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suggest significant decreases in stocking rates of over 50 per cent (Dean and Macdonald, 1994). It is therefore necessary to assess grazing condition next to grazing potential.

Interviews

In contrast to the official view, many pastoralist societies have developed elaborate systems to assess range condition and trends (Oba and Kotile, 2001).

Verlinden and Dayot (2000, 2005) found that Owambo agropastoralists in north central Namibia use a classification of ILUs having distinct hydrological properties, elevation, vegetation and some soil properties like depth of hard pan. The ILUs are identified on the basis of plant indicators, elevation and soil. With specific relevance to grazing, different ILUs have different seasonal qualities and potentials and livestock, especially cattle, are reportedly moving between them depending on where green grasses appear first after rains, where most palatable plants (including browse) are found at particular times of the year and where grasses are most nutritious (Verlinden and Dayot, 2005). Verlinden *et al*. (2006) suggested that presence and abundance of a few specific ILUs could be crucial because they are reported to contain the most palatable grasses and/or best browse. This shows the importance of incorporating Indigenous Technical Knowledge (ITK) on the ILUs in understanding local use of rangeland (Thomas and Twyman, 2004). In addition, local movement routes and herding practices can be explained by the pattern of ILUs in the grazing system (Oba and Kotile, 2001).

Data were collected during two field trips at the end of the rainy season, one lasting 2 weeks in March and then one lasting a month in April 2005. Field assistants spent 2 weeks in the field to plan the study with local people. The visit started with a community meeting in a village with a Community-Based Organisation working on resource management. The principal method of investigation during the meetings was open-ended discussions on key topics of the research: potentials and limitations of the main land units available for grazing in the area, indicators used for assessing grazing potential and condition, movements of livestock between seasons and over years and local range and livestock management. After the meeting key informants were asked to join the research team to visit portions of the grazing area to identify and describe the ILUs and to collect a total of 936 ground truthing points for mapping the rangeland. During the field trip additional questions were asked on what was seen and on issues remaining after the community meeting. The next day or days were continued in the same way or the research team went with the local extension technician to visit remaining parts of the area. Ten community meetings with an average attendance of 25 people were held and over 50 different key informants accompanied the field trips.

Mapping of Rangeland

A GIS, Arcview®, was used as a platform for bringing data together where appropriate. In the northern regions, including Oshikoto, participatory GIS information, based on indigenous knowledge on ILUs with assessments of potentials and limitations for grazing and cropping, has been developed and used in a series of Community-Based Natural Resource Management related projects and this has been well received and accepted by the people (Nott *et al*., 2003).

Aerial photographs and available satellite imagery were used as a background to map the ILUs in the GIS. The ground truthing points were overlaid with the imagery and on the basis of visual interpretation of the imagery the rangeland map based on the indigenous classification was drawn. Previous experience with mapping these units showed that although supervised classification can be carried out with good results on portions of a satellite image, certain characteristics used for identifying the ILUs (like elevation) cannot be derived from such an image and the conventional classification results are therefore not reliable for all units. The GIS was then used to derive proportions of each land unit in the area and the proportion fenced to test if best ILUs for grazing were also more enclosed.

Grazing Condition

While collecting samples for mapping local land units, indicating mainly grazing potential rather than actual condition (Verlinden and Dayot, 2005), the 936 plots were also assessed for grazing condition using a local classification ranging from poor, medium, good to very good. The basis for the classification is shown in Table I and was based on local knowledge.

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Table I. Criteria for assessing grazing condition of local land unit plots

Class	Description
Poor	Very low cover, only annual grasses, heavily grazed, many herbs present. Often with *Aristida stipioides* in most land units
Medium	Only annual grasses dominant like: *Schmidtia kalihariensis* in **Omutunda**, **Ehenge** or **Omuthitu** *Digitaria debilis* in **Omuthitu** *Urochloa brachyura* in **Omutunda** and **Omutuntu**
Good	Good cover of annuals, low degree of bush encroachment and some perennials present like: *Stipagrostis uniplumis* in **Omutunda** and **Omutuntu** *Digitaria eriantha* in **Omuthitu** *Schmidtia pappophoroides*, *Brachiaria nigropedata* and *Antephora pubescens* in **Omutunda** and **Omutuntu**
Very good	Prominent presence of abovementioned perennial grasses and no bush encroachment

Vegetation Samples

Important is the distinction between actual condition of the veld and the grazing potential. The actual condition was evaluated using the criteria of Table I while the grazing potential was based on discussions with local people on plant indicators and the soil-water conditions of the ILUs (salinity, depth of hard pan, soil texture) during meetings. While certain ILUs have a high grazing potential, their actual condition may be poor. Table II summarises the main characteristics of the ILUs represented in the samples.

Table II. The main ILUs used for grazing, with their water holding characteristics and main potentials and limitations according to local perceptions

ILU	Land use	Potentials and limitations
Omutuntu/etuntu	Grazing	Considered very good grazing due to low tree cover and higher nutrient content on dune crests of the inverted Kalahari dunes
	Water	None
Omutunda	Grazing	Very good grazing but in competition with cropping for land
	Water	None
Omutunda-henge	Grazing	Less valued than **Omutunda**
	Water	None
Omutunda-ehenene	Grazing	Early growth after rains, better than **ehenene**
	Water	Temporary waterlogging after heavy rains
Ehenene	Grazing	Early growth after rains but quickly depleted, often saline
	Water	Waterlogged during rains
Omuthitu/Omufitu	Grazing	Important grazing and browsing in dry season due to presence of *Baphia massaiensis*, *Bauhinia petersiana* and *Philenoptera nelsii* shrubs
	Water	None in Kalahari woodland area, traditional wells in Central Cuvelai area
Ehenge	Grazing	Selected by cattle only in early wet season with early green flush after rains
	Water	Temporary shallow wells
Ongoya	Grazing	Good potential, but impenetrable, resulting from bush encroachment in **Ombuwa**
	Water	Only deep boreholes
Ehengethitu/omufituhenge	Grazing	Selected in wet/dry season after **Omutunda** is depleted
	Water	None
Ombuga	Grazing	Good, but saline in depressions and sensitive when grazed all year long
	Water	Only short-term in wet season

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To test the value of the local indicators in Table I and the value of the local understanding of links between indicator species for grazing and ILUs, 109 vegetation samples were collected throughout the study area. A homogenous area was selected within the ILUs identified by local people. The area was walked through with key informants and species noted until no more new species were found. Vernacular names were noted with their uses and potentials. Plot-less sampling was used and woody plants and grasses were identified to species level. Three structural classes were used: tree layer (woody plants taller than 3 m), shrub layer (woody plants lower than 3 m) and grass and herb layer. For each species at each layer the percentage cover was estimated. The data were entered making a distinction between structural classes: the same woody species can occur as a tree or as a shrub and are considered as separate species in the analysis. The samples were collected in March and April 2005 at the end of the wet season when the plants were still easily recognizable. Table III lists the environmental variables collected in the field together with the vegetation data, with differentiation in actual condition and grazing potential.

Canonical Correspondence Analysis (CCA) (Hill, 1979; ter Braak and Smilauer, 2002) was used for the ordination of species using CANOCO software (Jongman *et al*., 1995). CCA is probably the most widely used direct vegetation ordination method for species and samples (Kent and Coker, 1995). CCA is based on reciprocal averaging and assumes a unimodal model for the relationship between species and ordination axes. In CCA the ordination axes are constrained by the environmental variables that are used to explain the variation in the vegetation. Cover percentage was squareroot transformed and rare species were downweighted. The formula used for downweighting is as follows: first the frequency of the most common species, AMAX is calculated. The abundance of species with a frequency lower than AMAX/5 will be reduced in proportion to their frequency. Species more common than AMAX/5 will not be downweighted. Due to the appearance of an arch effect, detrending with 2nd order polynomials had to be applied, so that the ordination diagram in this study is a Detrended Canoncial Correspondence Analysis (DCCA). The first ordination axis and all four canonical axes together were tested for significance with a Monte Carlo Permutation test.

The location of the plant indicators in the ordination diagram should be consistent with the local perception, otherwise the local classification or the DCCA is not valid. Plants indicating good grazing should be associated with the environmental variables associated with good grazing and *vice versa*. Ordination is a standard practice in evaluating grazing condition in southern Africa (Stuart-Hill *et al*., 1986) although a degradation gradient was not used. Since the samples contained severely grazed and less grazed areas, the species ordination diagram has sufficient variability in grazing condition to allow testing the local condition classes with published data.

Table III. Environmental variables collected in the field in 109 samples and used in the canonical correspondence analysis

Abbreviation	Description
Grazlow	Grazing potential is low, depending on ILU potential
Grazmed	Grazing potential is medium, depending on ILU potential
Grazgood	Grazing potential is good, depending on ILU potential
Condlow	Actual grazing condition is low
Condmed	Actual grazing condition is medium
Condgood	Actual grazing condition is good
Bare	Percentage of estimated bare ground, not taking in account tree and shrub cover
Treecov	Percentage of estimated tree cover
Shrubcov	Percentage of estimated shrub cover
Grasscov	Percentage of estimated grass cover
Herbcv	Percentage of estimated herb cover
Termit	Termite activity, based on a scale between 0 and 3, based on termitaria seen
Hard pan	Depth of the hard pan (**oluma**)
Utilise	Degree of utilisation of the veld, between 0 and 4 (very high degree of utilisation)
Fire	Either 0 or 1 when recent fire scars were seen
Salinity	Based on opinions of key informants scored between 0 and 3 (high salinity)
Bush encroachment	1 is 20 per cent shrub cover, 2 is 30 per cent shrub cover, 3 is over 40 per cent shrub cover

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Termite activity was included as an environmental factor as Hillyer (2004) found a link between termite activity and higher soil nutrient status. The depth of the hard pan that is often present in the soils of Oshikoto, especially in the west, is a very important factor in plant growth in general. When shallow, it prevents the establishment of most woody plants, with notable exceptions of *Hyphaene petersiana*, *Acacia arenaria* and *Acacia nilotica* (Verlinden and Dayot, 2005).

For the nomenclature Coates-Palgrave (2002) was used for the woody species and Gibbs-Russell *et al*. (1990) for the grasses.

The value of the ILUs in assessing grazing potential was tested by selecting a set of indicators, followed by calculating their frequencies in the main ILUs.

Fencing

The following fences, related to types of tenure, were recognised and mapped based on aerial photographs and satellite imagery: fences erected by smallholders, often consisting originally of bush fences, gradually replaced by wire fences in densely populated areas; large wire fences of informally fenced areas; wire fences of demarcated farms (Mangetti) and a government quarantine camp (Figure 1).

Smallholder fences were mapped from geocorrected aerial photographs in a GIS. In areas were woody resources are depleted these fences are not very clear and increasingly taken over by wire fences. In forested areas the fences are very clear and often one can see a gradual increase of fencing to enlarge the grazing reserves, the **ekove**, around the homestead. Inside the fences there is a larger degree of ownership, in many cases outsiders are not allowed access to the grazing resources, unless with permission from the farmer.

The large informal fences, usually erected by more wealthy people, posed a mapping problem as the available information was incomplete and these fences could not be seen on aerial photographs. During the field trips, observed fences were located with a GPS and later combined with other existing information (Mendelsohn *et al*., 2000). Satellite imagery was helpful where areas were fully enclosed and grazing pressure low, therefore Landsat TM imagery available for April 2000 was used in conjunction with GPS data to map large fences. Existing data of formally demarcated fences were mostly accurate. A GIS was used to create overlays between the different types of fencing and the rangeland maps to investigate differences in proportions of ILUs occupied by the different fencing types.

Bush Encroachment (BE)

For the purposes of this study, the following classification was used to identify the degree of BE in 109 samples: No BE is an area with shrub cover <20 per cent, Low BE is an area with 20–30 per cent shrub cover, Medium BE is an area with 30–40 per cent shrub cover and High BE is an area with >40 per cent shrub cover.

Livestock Movements

After the meetings, movement patterns were drawn on background maps and later on summarised for the whole survey area. No quantitative data could be collected on livestock movements and livestock census data are not reliable.

RESULTS

Grazing Condition

The results of the grazing condition assessment are shown in Figure 2. The overall majority of the samples were classified as being in poor condition, less than 25 per cent were classified as medium or good. Less than 1 per cent of the samples were considered to be in a very good condition. This suggests that overall grazing pressure is very high and that the majority of the grazing resources consist of annuals.

Table IV lists the counts of different types of grasses and indicators in 109 detailed vegetation descriptions. The frequency of palatable perennial grasses is very low in comparison with annual grasses, except *Eragrostis*

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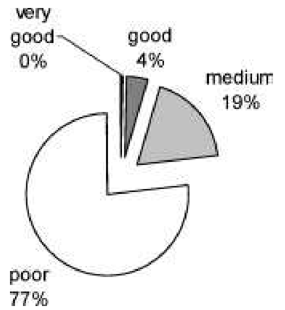

Figure 2. Vegetation condition ratings for grazing based on the local classification of Table I in the survey area ($n = 936$)

trichophora, a short-lived perennial thriving well in disturbed and heavily grazed places. The species occurring at the highest frequency in the samples is considered to be the worst grass for livestock keeping purposes: *Aristida stipiodes*. Plants indicating disturbance are also very common, although *Cynodon dactylon* is palatable, it is a weed in fields and often a reason for abandoning them. *Pechuel-Loeschea leubnitziae* is a very common disturbance indicator in the Cuvelai area.

Table IV. Counts of different indicator species in 109 vegetation samples

Species	Count
Perennial grasses	
Antephora pubescens	5
Brachiaria nigropedata	4
Digitaria eriantha	8
Eragrostis nindensis	1
Schmidtia pappophoroides	5
Pogonarthria squarrosa	7
Stipagrostis uniplumis	17
Annual grasses	
Antephora shinzii	17
Digitaria debilis	29
Urochloa brachyura	23
Eragrostis trichophora	59
Melinis repens	27
Pogonarthria fleckii	44
Schmidtia kalihariensis	38
Grasses indicating bad grazing	
Aristida congesta	15
Aristida stipioides	69
Aristida stipitata	25
Plants indicating disturbance	
Cynodon dactylon	14
Tephrosia purpurea	24
Hirpicium sp.	20
Pechuel-Loeschea leubnitziae	23
Sida cordifolia	4
Poisonous plants	
Geigeria ornativa	5
Dichapetalum cymosum	1

Counts are the number of occurrences of the species in all samples. Quality assessments are according to Van Oudtshoorn (1999).

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Poisonous plants are not very frequent. *Geigeria ornativa* is most common and could pose a threat in some places in the **ehenene** ILU. The data and observations suggest that certain plants like *Croton gratissimus*, *Mundulea sericea* and *Elephantorhiza suffruticosa* are largely avoided, and are only eaten when there are absolutely no other browse species left.

Validity of the Local Vegetation Condition Classes

Figure 3 shows the result of the CCA of all vegetation samples with environmental variables with exception of the following water-holding land units: **etapa**, **edhiya**, **ondombe** and **omulonga**. These appeared to be quite distinct from the other ILUs, largely selected by livestock for their temporary surface water rather than grazing potential and therefore considered as outliers. Table V lists the main statistics of the DCCA. A Monte Carlo Permutation test showed both the first axis and the four main axes to be significant at the $p < 0{\cdot}001$ level

The first ordination axis is associated with depth of the hard pan and grass cover. As a result, the woody species and associated grasses and herbs of deep sandy soils are found on the left hand side of the diagram, the typical

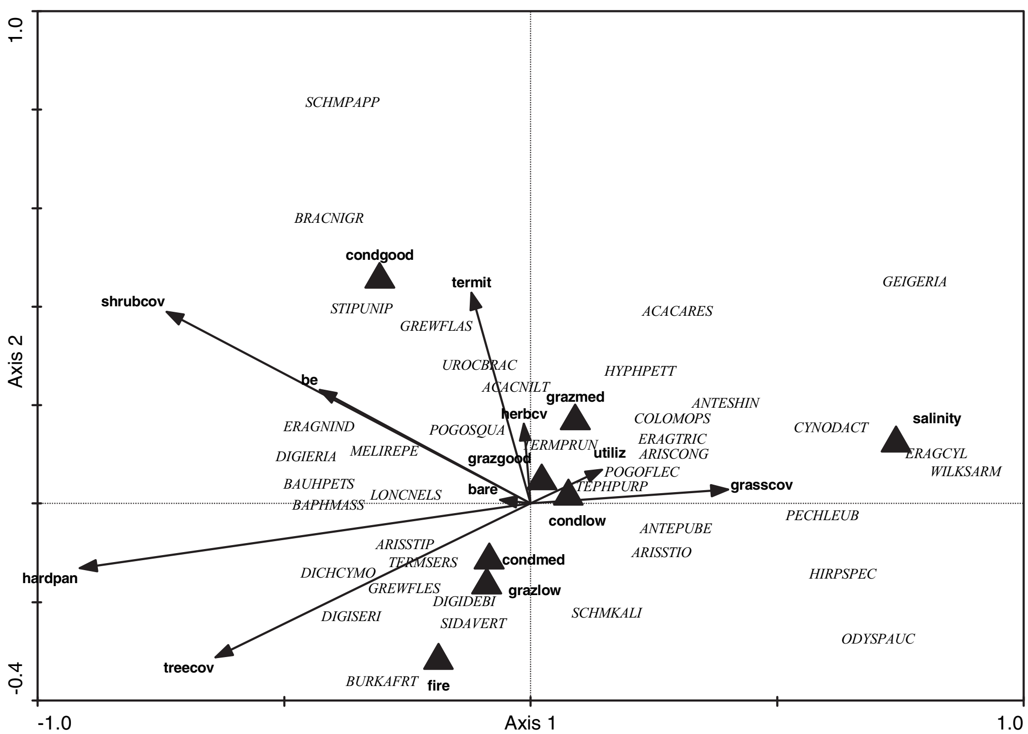

Figure 3. Detrended Canonical Correspondence Analysis (DCCA) of indicator species for grazing condition and some main woody plant species in 109 samples. Only selected species are shown in the diagram. Squareroot transformation of species cover and downweighting of rare species was applied. Grass names are abbreviated by the first four letters of the generic name and first four letters of the specific name, woody plant abbreviations have as last letter of the species name T, when taller than 3 m and S, when shorter than 3 m: ACACARE: *Acacia arenaria*, ACACNIL: *Acacia nilotica*, ANTEPUBE: *Antephora pubescens*, ANTESHIN: *Antephora shinzii*, ARISCONG: *Aristida congesta*, ARISSTIO: *Aristida stipioides*, ARISSTIP: *Aristida stipitata*, BAPHMAS: *Baphia massaiensis*, BAUHPET: *Bauhinia petersiana*, BRACNIGR: *Brachiaria nigropedata*, BURKAFR: *Burkea africana*, COLOMOP: *Colophospermum mopane*, CYNODACT: *Cynodon dactylon*, DICHCYMO: *Dichapetalum cymosum*, DIGIDEBI: *Digitaria debilis*, DIGIERIA: *Digitaria eriantha*, DIGISERI: *Digitaria seriata*, ERAGCYL: *Eragrostis cylindriflora*, ERAGNIND: *Eragrostis nindensis*, ERAGTRIC: *Eragrostis trichophora*, GEIGERIA: *Geigeria ornativa*, GREWFLA: *Grewia flava*, GREWFLE: *Grewia flavescens*, HIRPSPEC: *Hirpicium sp.*, HYPHPET: *Hyphaene petersiana*, LONCNEL: *Philenoptera nelsii*, MELIREPE: *Melinis repens*, ODYSPAUC: *Odyssea paucinervis*, PECHLEUB: *Pechuel-Loeschea leubnitziae*, POGOFLEC: *Pogonarthria fleckii*, POGOSQUA: *Pogonarthria squarrosa*, SCHMKALI: *Schmidtia kalihariensis*, SCHMPAPP: *Schmidtia pappophoroides*, SIDAVERT: *Sida cordifolia*, STIPUNIP: *Stipagrostis uniplumis*, TEPHPURP: *Tephrosia purpurea*, TERMPRUN: *Terminalia prunioides*, TERMSER: *Terminalia sericea*, UROCBRAC: *Urochloa brachyura*, WILKSARM: *Wilkommia sarmentosa*

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Table V. Eigenvalues, variance and sums of eigenvalues (inertia) of the DCCA

Statistic	Axes				Total inertia
	1	2	3	4	
Eigenvalues	0·514	0·162	0·10	0·062	
Cumulative percentage variance					
Of species data	10·5	13·8	15·8	17·1	
Of species-environment relation	36·4	47·9	55·0	59·4	
Sum of all eigenvalues					4·892
Sum of all canonical eigenvalues					1·411

grassland species on the right hand of the diagram. Those associated with saline soils and very shallow hard pans are found on the extreme right, those with a less shallow hard pan more to the centre of the diagram. Grass cover is substantially higher in the saline grassland areas than in the wooded areas, a reflection of the heavy grazing pressure in the non-saline grasslands and in the woodlands.

The second axis is associated with termite activity, grazing condition and potential grazing quality which are high on the positive part of axis 2 and low on the negative side of axis 2. Termites are more abundant on loamy-sand soils, the **Omutunda** and **Omutuntu** ILUs of the inverted Kalahari dunes. Most grasses known to be of good quality, except *Antephora pubescens* and *Digitaria seriata*, are located on the positive side of Axis 2. *Antephora pubescens* was also frequent outside the forested area in the **Ombuga** saline grasslands, while *Digitaria seriata* grew only on deep sandy-soils of the **Omuthitu**. Most annuals and indicators of poor grazing like *Tephrosia purpurea* and *Aristida* spp. are located near the centre of the diagram, showing that most samples contained mainly annuals and were in poor to medium condition. It has also to be noted that the difference between grazing potential and actual condition is very large in the class 'good'. Many samples had good potential but their actual condition was poor.

Good browse species like *Baphia massaiensis*, *Bauhinia petersiana* and *Philenoptera nelsii* are located on the left-hand side of the diagram in the forested area. BE is as expected associated with high shrub cover and these are also associated with the more palatable perennials which is in agreement with the finding that BE is more severe in the more fertile land units that have larger proportions of the better grasses if in good condition. *Grewia flava* is associated with good grazing on more loamy-sand soils and *Grewia flavescens* with low grazing potential on deep sandy soils, since both are quite common species these might be used as indicators for grazing potential.

The indicators for disturbance like *Pechuel-Loeschea leubnitziae*, *Cynodon dactylon* and *Hirpicium* sp. are associated with a high degree of utilisation in the densely settled areas, which are mostly located on the relatively shallow soils. *Odyssea paucinervis* is a perennial that remains abundant in heavily grazed areas, probably because of its low palatability. *Aristida stipioides*, *Digitaria debilis* and *Schmidtia kalihariensis* are also tolerant of high grazing pressures although the latter two are selected by livestock.

Validity of ILUs With Respect to Grazing Potential and Quality

Figure 4 shows for a selected set of species their association with different ILUs. The graph is the same DCCA diagram of Figure 3, the pie charts visualise the frequency of species in the different ILUs.

The most nutritious and palatable grasses (*Brachiaria nigropedata*, *Schmidtia pappophoroides*, *Stipagrostis uniplumis*, *Urochloa brachyura*) are largely restricted to the **Omutuntu** and **Omutunda** ILUs. Few palatable grasses occur more in the less fertile **Omuthitu** (*Digitaria eriantha*, *Digitaria seriata* and *Digitaria debilis*). Annual grasses have a much wider range over various ILUs (*Schmidtiakalihariensis*, *Antephora shinzii*).

The **ehenene**, **omutunda-ehenene** and **ombuga-ehenene** units are more associated with species affiliated with a high degree of salinity in the soil (e.g. *Wilkommia sarmentosa* and *Odyssea paucinervis*). The **Omuthitu** and **omutuntu** land units have more quality browse species (e.g. *Baphia massaiensis*) than the **omutunda** land units.

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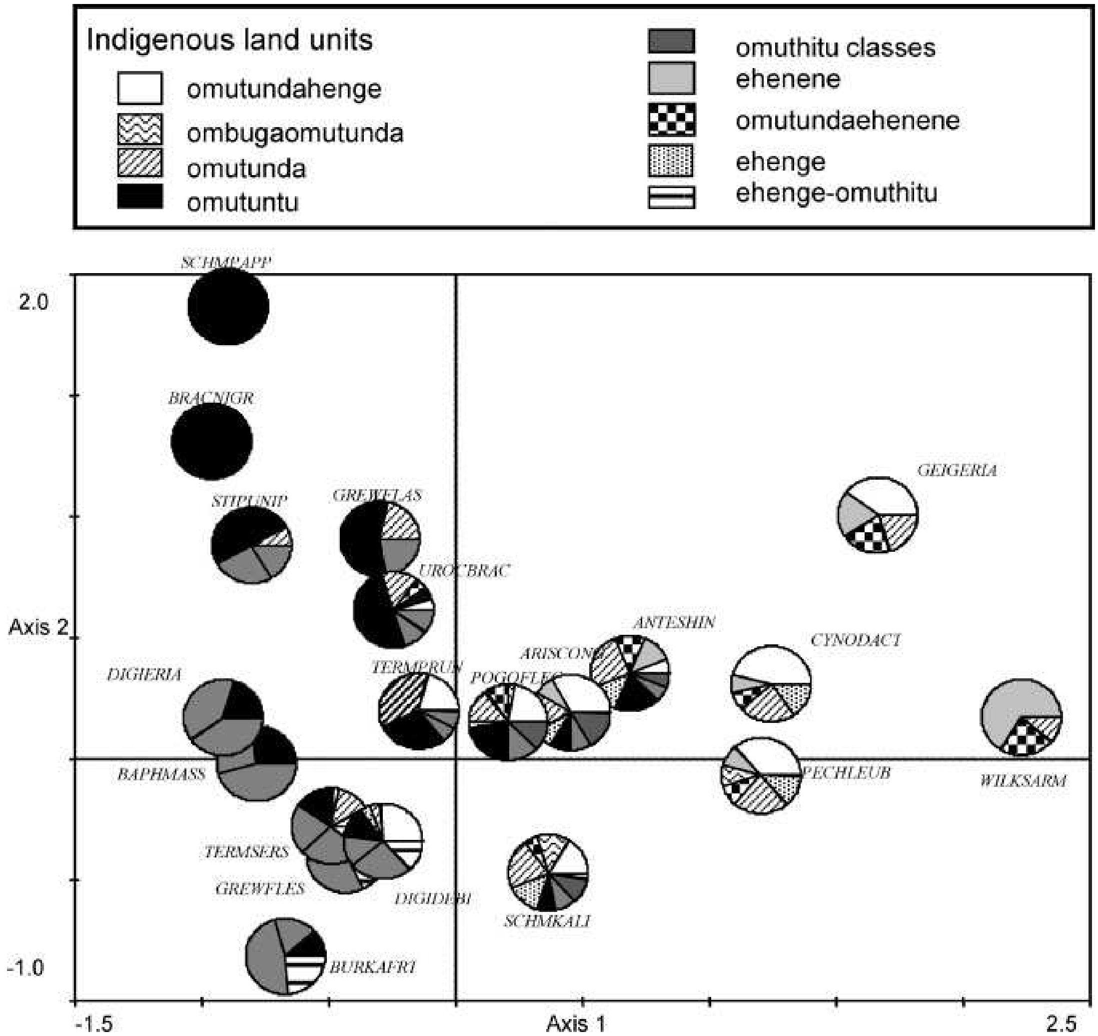

Figure 4. Frequency of selected species in different ILUs in the species DCCA diagram ($n = 109$). Abbreviations of species are the same as in Figure 3

Enclosures

The degree of fencing in the survey area is quite high for communal land: 40 per cent of the total area is fenced with the largest proportion of 17 per cent of the total area occupied by the large fences, while the smallholders together have fenced only 10 per cent of the land in 15 795 farms. The average size of each farm is 12·1 ha of which half may be occupied by **ekove** which are usually in much better condition than the unfenced areas.

The unfenced areas are generally considered to be open access, although in many cases traditional rules regarding use still exist in the form of designated grazing reserves (where people should not settle and permission for grazing needs to be sought from the traditional authorities) or where cattle numbers are controlled to a certain extent on the basis of who helps maintaining traditional wells. Enforcing of these traditional rules has become in general more difficult over time.

There are differences between the land units in the degree of fencing and these differences are associated with differences in grazing (and cropping) potential. Figure 5 shows the differences in degree of fencing in two groups of

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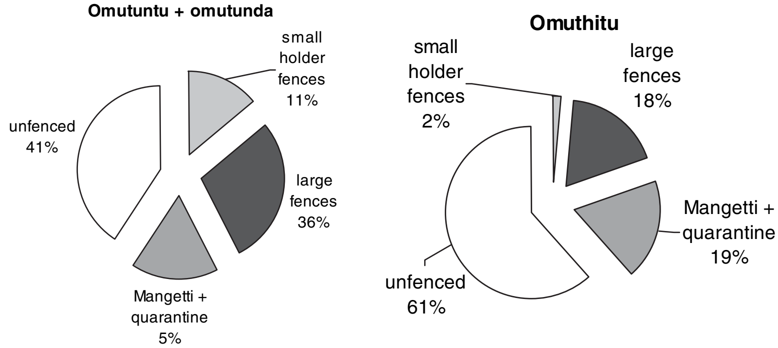

Figure 5. Degree of fencing in per cent of the more fertile **Omutuntu-Omutunda** land units and less fertile **Omuthitu** land units

land units: the more fertile **Omutuntu-Omutunda** units and all the less fertile **Omuthitu** units together. Almost 60 per cent of the more fertile **Omutuntu-Omutunda** are enclosed, a very large proportion of 36 per cent by large informal fences. These units are selected for cropping and are in severe shortage in the densely populated areas, yet only 11 per cent of the total area occupied by these land units is fenced by smallholders who are most dependent on them for cropping purposes. Only 40 per cent of the **Omuthitu** units are fenced and only 18 per cent is fenced by large informal fencing, half the value of the more fertile land units. The **Omutuntu-Omutunda** units cover about 500 000 ha and the **Omuthitu** units 800 000 ha in the survey area, indicating that the pressure on the more fertile land for both grazing and cropping is much higher than in the less suitable land. Less fertile land units are reportedly currently mainly selected for browse in the dry season.

Bush Encroachment

Thirty-six samples out of 75 woody vegetation samples had some degree of BE, almost 50 per cent, indicating that BE is a serious problem in cattle post areas and other areas not close to settlement. Furthermore it appeared that 60 per cent of the **Omutuntu-Omutunda** units were affected by BE, opposed to only 40 per cent of the **Omuthitu**, suggesting that the more fertile land units are more susceptible.

Livestock Movement Patterns

Current livestock movement patterns are summarised in Figure 6. Names that are referred to in the text are located on the map. Different types of arrows are used to indicate differences in types of movement. The map is derived from movement maps drawn at local level. The map shows the pipeline system in the west and the informal and formal fences in the east.

Four main long distance movement directions were noted into four distinct communal grazing areas. They have entirely different characteristics. They are marked with letters A–D in Figure 6.

The largest and most important is the eastern movement, mainly by people east of the main road that runs diagonally through the area (A). This is the area where migration of people was associated with shifting cattle posts further east, depending on availability of boreholes. In eastern Oshikoto there are only areas with permanent cattle posts around a borehole where the majority of cattle are kept year round. Cattle are not herded but watered by people looking after cattle, either family members or paid labourers. People in the Kalahari woodland area pointed out that cattle select different ILUs seasonally, depending on (1) proximity to surface water, (2) an early green flush after rains, (3) presence and abundance of locally high-ranked palatable grasses like *Brachiaria nigropedata*, *Schmidtia papphoroides*, several *Eragrostis* spp., *Urochloa brachyura* and *Digitaria debilis*, (4) locally considered important browse species like *Baphiamassaiensis, Philenoptera nelsii* and *Bauhinia petersiana* and (5) the degree of openness of the vegetation structure to avoid predators. Frequently mentioned was that the earliest settlers took these aspects into account when establishing **kraals** and cattle posts. Settlers arriving later had less choice and may lack certain ILUs in their grazing area to permit year-round grazing without any serious seasonal shortages, or lack

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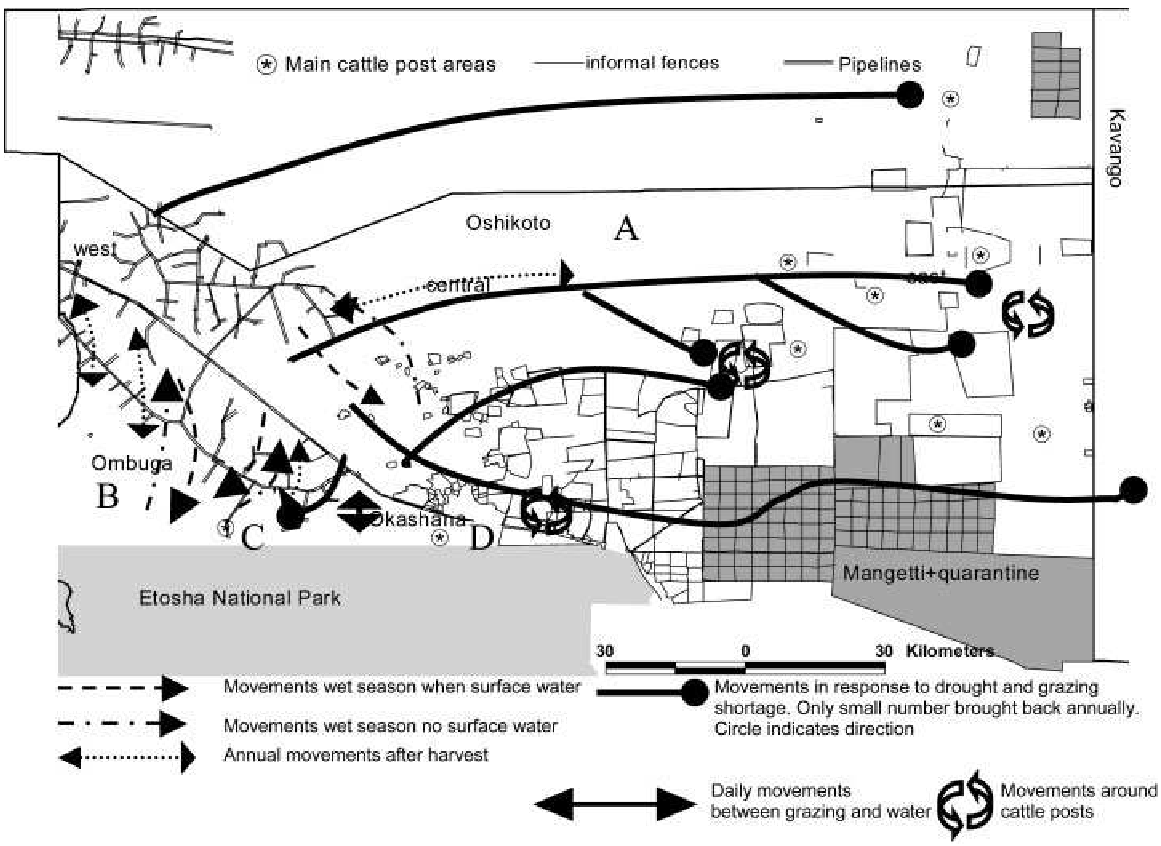

Figure 6. Overview of current livestock movements in the survey area. Arrows of different type indicates type of movement

sufficient amounts of them close to the water point. This forces animals to cover larger distances between **kraals**, water points and quality grazing areas.

The second is a southwestern movement (B) into the **Ombuga**, an open treeless saline plain where pipeline water is only partly developed. It is a traditional grazing reserve. When there is a lot of surface water in years of above median rainfall, cattle move further into the **Ombuga** because of better grazing. After the wet season they move back to areas with permanent water supply (the pipeline system). Grazing is generally poor and further decreasing because of settlement and informal fencing encroaching on the grazing reserve. Annual movements of cattle between cattle posts and the homesteads are still taking place in those areas where the **Ombuga** is the dry season grazing area, mainly for people living south of the main road.

The third is a southbound movement (C) close to Etosha National Park, an area with permanent wells in open mopane shrubland. This is a drought refuge area used when areas to the north have no forage. The grazing is considered better than in the **Ombuga** because of lower salinity.

The fourth is another southbound movement (D) into the open saline grasslands of Okashana, a traditional grazing reserve, mainly from surrounding farms and cattle posts depending on pipeline water, with daily to 3-day movements between water points and grazing areas. People who live more than 15 km away have little option but to acquire or share cattle posts close to the grazing reserve. As in the **Ombuga** the grazing reserve is being encroached by farms and fences, hampering daily movements.

Generally people move their livestock to the closest cattle post area, but it was stressed that livestock used to graze in the woodland areas do not thrive in the **Ombuga** and Okashana areas as the former cater mainly for

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browsing cattle in the dry season. Heavy browsing *of Baphia massaiensis* and *Bauhinia petersiana* was observed everywhere showing that browsing rather than grazing is indeed an important coping mechanism during the dry season and during droughts for cattle in that area.

The saline grasslands have no browse and contain predominantly the very prickly perennial *Odyssea paucinervis* that is reportedly avoided by cattle used to forested environments.

Movement patterns also depend on herd size. People with smaller herds (less than 12) do not engage in long-distance movements throughout the region. In the central Cuvelai where people cannot settle in the waterways people with small herds (±5, up to about maximum 10–12) keep their livestock around the farm and kraal them daily. Cattle graze around the homestead and get water from the pipeline or from pans in the wet season. Not all farms are fenced due to lack of fencing material and livestock are largely herded. East of the central Cuvelai, smallholder fencing is so dense that the only available grazing land consists of corridors. These are easily depleted and heavily trampled as those people with low numbers of livestock will herd their livestock daily between the **kraal**, water points and remaining grazing land outside the densely populated areas. It is estimated that **ekove** occupy about 80 000 ha in total, a considerable resource which is not sufficiently used for growing fodder like lucerne.

People from and around the forested area with larger herds (more than 12 cattle) moved their livestock further east even into Kavango region since the 1980s. Since this is a different tribal area, traditional authorities have stopped this migration of Owambo farmers. Almost all cattle posts visited in the east had permanent settlements with fields and are thus not strictly speaking cattle posts. During a meeting in the most eastern village visited, people pointed out that in 2005 the grazing was considered exhausted and they wanted to move their livestock but they had nowhere to go.

In central Oshikoto it appeared that people still decide on movements depending on the level of the local wells. When the level is low, those that have access to cattle posts to the east are encouraged to leave after cattle have finished the millet stalks on the fields. Others with large herds and no access to cattle posts are encouraged to water and move their animals to places with permanent water points (the new pipelines in the area). The remainder is allowed to stay, but there still are cattle coming in from further west.

DISCUSSION

This paper has described an approach, using farmer's knowledge of the environment, through classifications, range condition and their herd's itineraries, to map rangeland and movements at fine and coarse spatial scales across an agropastoral landscape. ITK on vegetation condition and land unit potential was compared with more conventional approaches for assessing vegetation condition. The ITK was consistent with the ordination diagram of a CCA and most species indicators were reliable and in agreement with published data based on a limited number of samples in the survey area (Strohbach, 2000a,b,c,d). This is not to state that there are no differences with conventional range management and range condition interpretation. It seems there is more appreciation of the quality of browse species and annuals as was also found in a similar environment in the Kalahari of Botswana (Thomas and Twyman, 2004). The recognition of different qualities and potentials of individual landscapes is similar to indigenous pastoralists in a variety of countries and ecosystems (Homewood and Rodgers, 1991; Fernandez-Gimenez, 2000; Oba and Kotile, 2001). As the majority of farmers in semi-arid areas traditionally express the need for water with little concern for grazing quality (Sweet, 1997), the socio-economic study of NASSP (2004) pointing to increasing concerns of farmers about grazing condition suggests a different local perception that could result in opportunities for improved range and livestock management.

Livestock in the area currently depend on vegetation in mostly poor condition with mainly annuals which are far less available in the dry season and their biomass more variable with rainfall. In the Kalahari woodland cattle survive mainly on browse. In a range survey carried out in 1997 just north of the present survey examples of open areas with a large cover of good perennials called **Ombuwa** could still be found without too much effort (Verlinden and Dayot, 2000). When part of that area was revisited in 2005, no **Ombuwa** was observed. This conventional image of good grazing land consisting of perennials like *Schmidtia pappophoroides*, *Brachiaria nigropedata* and

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Antephora pubescens with high cover was only seen in one fenced-off, ungrazed land during the present survey, suggesting it is a relic of the past. It is likely that grazing at high stocking rates this range allowed herds to grow and fatten significantly in the past, if only for a relatively brief period of a few years.

The degree of fencing (>40 per cent) is rather high for communal land. Smallholders have clearly fenced mainly the more fertile **Omutunda-Omutuntu** ILUs, but their contribution (10 per cent) is small in comparison with the 17 per cent occupied by larger informal fences. These occupy predominantly more fertile land units, showing a clear selection of good grazing land, not just land.

Based on satellite imagery from April 1997, just north of the present study area, Verlinden and Dayot (2000) found that more than 30 per cent was heavily bush encroached, comparable to the 40 per cent found in this study. For the lower classes of BE it can be argued that this has increased the amount of browse available for cattle. In the categories medium and high degree of encroachment low penetrability for cattle has seriously decreased grazing and browsing.

It appears that the frequently described transhumance (Marsh and Seely, 1992; Tapscott and Hangula, 1994; Kerven, 1997) was actually a migration pattern, best understood by decreased availability, both in size and quality, of **Omutunda-Omutuntu** ILUs on loamy-sand, as a result of increased cultivation and permanent settlement in the older cattle posts. This triggers the owners of larger herds to establish new cattle posts, which later on will also become a village. This pattern of increased settlement and migration is a result of the need for people to have access to food in cattle posts as most animals remain there when grazing is deteriorating in the older cattle posts. It is more convenient to establish a new field in the more recent cattle post, but this triggers the process of decreased availability of good grazing and subsequent migration. This is a push-effect as a result of competition between grazing and cropping, not a pull-effect looking for better grazing. People have reached the end of this migration to the east as they have reached the border of Kavango Region already in the 1980s. The increased fencing of rangeland in Kavango by Owambo graziers caused serious political turmoil in 2005.

The traditional livestock movement patterns where livestock were moved annually between villages and close by cattle posts have decreased to such an extent that the majority of people keep their large livestock herds permanently at far away cattle posts, due to the lack of grazing in settled areas. It seems to be that only in central Oshikoto, and on the periphery of the southern grazing reserves the movement patterns described previously (Marsh and Seely, 1992; Tapscott and Hangula, 1994; Kerven, 1997; Mendelsohn *et al*., 2000) seem to be still in place. Herds of cattle with herders on the move, both in eastern and western directions, were frequently encountered in these areas during the time the survey was carried out, before the harvest. A lot of these movements are depending on individual decisions taken by livestock owners depending on their particular circumstances, but the remaining grazing land consists almost entirely of **Omuthitu** units that are, due to their poor quality in species composition and low soil fertility (Hillyer, 2004), not likely to sustain cattle without access to **Omutunda** or **Omutuntu** units.

Historically the majority of the cattle were brought back to the homestead for a brief period after the harvest (Kerven, 1997), resulting in a transfer of nutrients to crop fields. None of the discussions carried out during the present survey mentioned annual movements of large herds, all stressed that the majority of the herds now remain year round at the cattle post due to overall lack of grazing and the predominant use of donkeys and tractors for ploughing. Loss of soil fertility of crop fields was cited as a major problem by the majority of farmers in the area and is confirmed by Hillyer (2004).

CONCLUSION

The present study has through a combination of ITK and more conventional analysis not only demonstrated that different types of livestock movements and different grazing strategies exist, but that farmers have a thorough knowledge of grazing indicators and land quality. Changes have occurred rapidly due to water development and population increases and have taken place in the living memory of many farmers. This facilitated the historical overview in comparison with other studies on rangeland in semi-arid environments.

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The study suggests that expansion of grazing into new land was the answer to the conflict between cropping and grazing in the agropastoral landscape for many decades. Expansion of herds was possible due to the opening up, by providing borehole water or pipelines, of a landscape with patches of high grazing quality, essential for grazing but also suitable for cropping. This landscape was previously created mainly by hunter-gatherers and was characterised by low grazing pressure and frequent fires. Virtually all this land has now been occupied and quality has deteriorated rapidly with low grass cover, low frequency of perennials and high degree of BE. The movements of livestock, thought to be strictly a transhumance, was actually mainly a migration of a segment of the population largely, but not exclusively, dependent on livestock. This migration was possible in an environment were both cropping and grazing were feasible. The process is similar to the 'pioneer syndrome' of the western United States, where a shifting frontier not only diluted population density (Otterstrom, 2001) but allowed to occupy new fertile land.

Informal fencing by commercial ranchers of mostly fertile areas with more nutritious grasses has exacerbated, not caused, an increasing problem of land shortage. Further expansion into new areas is now contested as the graziers have reached the end of their frontier, a serious challenge to the livelihoods of communal farmers who have to adapt to a new situation with more variable biomass and higher dependence on rainfall resulting in higher uncertainty (Ward *et al*., 2000). This adaptation seems to be difficult as many farmers express the wish to herd their livestock into the larger enclosed areas. The overall shortage of land has also reduced transhumance were it was practiced in traditional grazing reserves, as these have been reduced in size as a result of permanent water supply in previously saline areas and as a result of enclosures of remaining farming land as emergency grazing areas in the settled areas. Those herders without cattle posts have to move animals through corridors between **kraals**, water points and grazing. This increases labour costs and reduces time spent on grazing.

The reduced grazing in settled areas resulted in livestock remaining at cattle posts, preventing resting of the rangeland and reducing the quality of the rangeland and the fertility of the crop fields more rapidly than under transhumance. The data suggest that increased population, the trade-off between cropping and grazing, fencing, vegetation deterioration and other processes have reduced grazing options and strategies sharply. Increased investment in land through fencing of mainly more fertile areas has been carried out only by a relative minority of the population.

This study concludes that rangeland studies in semi-arid areas should not only take into consideration indigenous knowledge, but also put an emphasis on the historical context and changes over time in population and environment.

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