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Journal of Arid Environments ▮ (▮▮▮▮) ▮▮▮–▮▮▮

Journal of Arid Environments

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A comparison between indigenous environmental knowledge and a conventional vegetation analysis in north central Namibia

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Received 18 September 2003; received in revised form 29 October 2004; accepted 12 November 2004

Abstract

Local communities use an indigenous classification of environmental land units for natural resource management in central north Namibia. These indigenous land units (ILUs) were compared with a conventional vegetation analysis to improve understanding by scientists. The indigenous classification is based on many criteria. Detrended correspondence analysis was carried out on 388 vegetation samples, collected in a participatory way. The ordination diagrams of species and samples were a good reflection of ecological variation in the area. The data were used to draw sample standard deviation ellipses around the average ILU score. Classes with highly ranked vegetation criteria had little overlap with each other, while classes with no vegetation criteria often had large overlaps with other land classes. Advantages and disadvantages of working with indigenous environmental knowledge are discussed.

Keywords: Indigenous environmental knowledge; Vegetation; Ordination; Land classification; Resource use; Grazing

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doi:10.1016/j.jaridenv.2004.11.004

1. Introduction

Indigenous knowledge can be defined in its broadest sense as accumulated knowledge, skill and technology of local people derived from their direct interaction with the environment (Altieri, 1990, pp. 551–564). Information passed on through generations is refined into systems of understanding natural resources and relevant ecological processes (Pawluk et al., 1992). Such information systems are often considered to be primarily concerned with soils (Barrera-Bassols and Vinck, 2000, pp. 1–12). Ethnopedology is the indigenous knowledge of soils and encompasses many aspects including indigenous perceptions and explanations of soil properties and soil processes, soil classifications, soil management and knowledge of soil–plant inter-relationships (Williams and Ortiz-Solorio, 1981; Hecht, 1990, pp. 151–160). However, indigenous environmental knowledge (IEK) also includes perceptions and explanations on geomorphology, landscape classifications, settlement strategies, soil–water–plant relationships and range management (Verlinden and Dayot, 2000, pp. 63–78). Local classifications of land units are based on IEK and not on ethnopedology and soils alone.

Studies of IEK have been increasing during recent decades and in the late 1990s, studies on local land classifications were undertaken in northern Namibia (Dayot and Verlinden, 1999, pp. 254–283; Rigourd and Sappe, 1999, pp. 34–42; Rigourd et al., 1999; Shitundeni and Marsh, 1999; Verlinden and Dayot, 2000; Hillyer, 2004). These studies all aim to understand the ways that local people view and classify the land with the ultimate aim of understanding and improving indigenous resource management. The studies emphasize descriptions of the units, identification criteria and any potentials and limitations of the land. Most of the studies interpret classes as pedological units but Dayot and Verlinden (1999) found a separate soil classification system alongside a land classification, referred to as indigenous land units (ILUs). The land classification in northern Namibia is considered to be based on an appreciation of inherent patterns of geomorphology and ecological processes, some of which are very complicated and hard to measure like soil moisture movement (Rigourd and Sappe, 1999; Verlinden and Dayot, 2000). In a review of 800 ethnopedological studies, Barrera-Bassols and Vinck (2000) found the number of local classes range between 4 and 20. In Namibia, nearly 40 classes have been recorded in the study area indicating the existence of a relatively complicated system.

In classifying land, people make use of criteria (Ettema, 1994) that refer to 'physical' and 'perceptual' dimensions of land classifications (Weinstock, 1984). The 'physical' dimension concerns the most readily observable criteria that farmers use to differentiate their land units, namely soil characteristics that can be discerned by sight, feel, taste or smell (Osunade, 1992b). In Namibia, these are mainly soil color and texture or landscape characteristics that are identified by species composition, elevation, vegetation structure or abundance of termitaria.

Perceptual criteria are not as concrete as those in the physical dimension nor are they always readily recognized through the senses. Examples in Namibia are soil–water movement, soil workability, suitability classes for certain crops, suitability classes for grazing, biological indicators for soil fertility (e.g. fertility increase by termites) and grazing, sensitivity classes to certain agricultural problems (e.g. light soil indicating low fertility), and non-agricultural classes based upon the use of soil as building and pottery material.

While the local land classification system is widely used in Namibia, there is a lack of understanding by scientists or extensionists because it cannot be understood or verified with a simple soil analysis or soil classification. Many local classes fall into the FAO classification arenosol (sandy soil) (Rigourd, 1998) and this has been found elsewhere (Osbahr and Allen, 2003). Soil chemical analyses indicate some significant differences between ILUs but definitely not all of the identified ILUs (Rigourd and Sappe, 1999; McDonagh and Hillyer, 2001; Hillyer, 2004). An improved understanding could be gained by increasing the number of soil parameters but soil moisture processes are notoriously difficult to measure and in this semi-arid environment, some very important processes happen only rarely and unpredictably causing difficulties for replicable sampling.

Vegetation is the result of many ecological processes and is relatively well studied in southern Africa. In tropical savannas, the relationship between vegetation, soil, geomorphology and geology is close (Cole, 1982, pp. 145–174). Therefore, a conventional vegetation analysis, using ordination techniques like a detrended correspondence analysis (DCA) or classification techniques like clustering, could assist in understanding a local environmental classification. A vegetation ordination or classification would provide a simple tool, if local criteria for classes were only based on plant indicators, structure and plant species relationships. In such an hypothetical case, the local land classification could be understood as an ordination of vegetation samples falling within clear groups of samples of the same land unit and separate from other classes where vegetation characteristics differ. However, since a wide range of criteria are used including non-vegetation criteria, it is not that simple.

In the Namibian case, it appears that criteria are ranked according to their importance for each ILU. Some ILUs have vegetation criteria that rank high while some ILUs score higher with respect to geomorphology or other soil features. This suggests that the ordination diagram of ILUs with important vegetation criteria should show distinct groups in a sample ordination and other classes less distinctive. Also, the upper hierarchical groups in the local taxonomy should show more scattered samples, occupying more space in the ordination diagrams and overlapping with sub-classes. Nevertheless, there should be a consistent pattern; for example, ILUs with criteria for elevation should have types of vegetation indicating drier circumstances and ILUs with criteria for depressions should have a species composition indicating relatively more moist environments. The resulting ordination diagram should show whether or not the local criteria have ecological meaning. This study explores the use of vegetation analysis, including a conventional vegetation ordination, using DCA (Jongman et al., 1995) to improve the understanding of the ILU classification in north central Namibia.

2. Materials and methods

2.1. Study area

Fig. 1 locates the study area in Africa and Namibia.

Approximate rainfall isohyets indicate a range of annual precipitation of between 350 mm in the south-west and 550 mm in the northeast (Hutchinson, 1995, pp. 17–37). There are three seasons: cold dry, May–August; hot dry, September–December; hot wet, January–April. There is great variation in temperature between day and night: in winter, the night temperatures drop to 7 °C with day temperatures rising to 27 °C or higher. During the hot season, the soil temperature may rise above 36 °C, causing severe stress for plants. The southern end of the endorheic Cuvelai

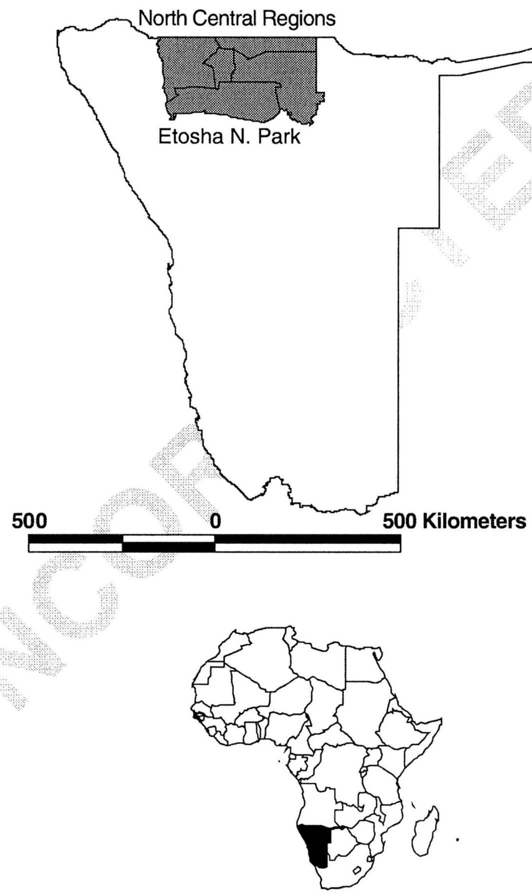

Fig. 1. Location of the study area. The lower map shows the location of Namibia in Africa. The upper map shows the location of the North Central Regions in Namibia. Etosha National Park is excluded from the survey.

drainage basin, which in itself measures about 37,000 km^2, consists of a 130 km wide delta that occasionally receives floodwater and migrating fish from the better watered catchment in southern Angola (van der Waal, 1991). The central area of north central Namibia is an inland drainage system with a surface area of 7000 km^2. Fresh surface water is of high quality but is temporary. Salinity increases toward the south where many salt pans occur. Most ground-water in the area is saline, but temporary fresh ground-water lenses are found in low dunes next to drainage channels.

2.2. Environment

The soils are mainly deep Kalahari sands. It is important to note that in the east the area belongs to the inverted Kalahari dune system, where former dune valleys are now dunes (Thomas and Shaw, 1991). The soils are deficient in most major nutrients. They are also deficient in micro-nutrients such as manganese, iron and zinc. While arenosols are present on the fringes of the central alluvial depression, there are also sands enriched with locally derived material in narrow lenses in the higher areas between the Oshanas. Solonetz soils cover a large portion of the central plain and are characterized by a white surface. The soils have a compacted horizon (hard pan) with lower permeability and high sodium activity (Rigourd and Sappe, 1999).

Giess (1971) classified the eastern part of the central north as Tree Savanna and Woodland. Stands of *Baikiaea plurijuga*, *Pterocarpus angolensis*, *Burkea africana*, *Schinziophyton rautanenii* and *Guibourtia coleosperma* occur. Dwarf Shrub Savanna fringe occurs in the south central area, close to Etosha. In places, *Acacia newbrownii* forms more or less thick stands and can be invasive. North of the Etosha Pan extends the Ombuga Grassland, a flat plain about 50 km wide with numerous pans. The western part of the central north belongs to the Mopane Savanna. The dominant tree species is *Colophospermum mopane*. The grass in well-developed Mopane stands is very sparse, possibly the result of the dense shallow lateral root system of *C. mopane*. In the most populated area, the Mopane Savanna has been extensively converted to agricultural fields and in the western part to grazing land.

More detailed classifications are found in Du Plessis (1991, pp. 11–19) and Marsh and Seely (1992), both recognized 11 habitat types. Subsequently, Mendelsohn et al. (2000) described 23 units for the same area. It is interesting that all these are a mixture of vegetation descriptions, geomorphology and structural units, very similar to the ILUs.

2.3. Settlement and population

Habitat and environmental conditions across north central Namibia are highly variable. Reliable data on fundamental ecological parameters, agro-meteorological data and the variation within regions are, however, scant (Matanyaire, 1995, pp. 105–123; EDG, 1996). Williams (1991) notes that the ecology of the region might be important in explaining why migrating hunting groups, arriving in what is now north central Namibia, adopted agriculture and animal husbandry and created permanent settlements. The north had a rich and varied wildlife fauna, which was a major attraction for immigrants. Wildlife was an important resource until around 35 years ago. Although the whole area is not to be regarded as fertile, access in the center of the area to permanent water and the relatively more fertile Cuvelai drainage system with associated floods and floodplains were probably important in forming the early Owambo society with the homestead as the production unit. The Owambo people are divided into seven cultural groups (EDG, 1996). This diversity is further evident in the heterogeneity of population density, language dialects and forms of land use.

The traditional farming and land-use system can be characterized as an agro-silvo-pastoral system (Kreike, 1995; Erkkilä, 2001) that combines crop cultivation, management of trees (for edible fruits and fodder) and livestock rearing. Diversification is thus a major strategy in coping with low fertility and high unpredictability, as elsewhere in sub-Saharan Africa (Githinji and Perrings, 1993).

Seventy percent of the Namibian population depends directly on natural resources including trees for much of their livelihood (Ashley, 1994; Tapscott, 1994, pp. 12–24). Trees are not only used for firewood and construction but also indigenous fruit trees contribute to the livelihoods of Namibians living in communal areas. *Sclerocarya birrea* is an important source of fruit and seed which is used for the production of beverages and oil as well as eaten in an unprocessed form.

Agriculturally, pearl millet (*Pennisetum glaucum*) is the staple crop, characterized by low average yields but fairly robust yields in the face of poor rain. Since there is a high degree of uncertainty about environmental and market conditions, there appears to be a conservative choice of products and techniques for cropping. Owambo people keep large millet stores, indicating that food shortages are a high probability in the four regions.

By 1921, the population of the central north was estimated to be 90,000, approximately 1.6 people/km^2 (Erkkilä and Siiskonen, 1992). In 1991, the population had increased to 615,057, giving a mean population density for the entire region of 11 people/km^2 (Marsh and Seely, 1992). The mixed savanna of the Oshana area in central north Namibia is one of the most populated areas in Namibia, supporting 28% of the country's population on 1% of the land area and the population density reaching 100 people/km^2 (Tapscott, 1990; Marsh and Seely, 1992) compared to the national average of less than 0.5/km^2. The present growth rate for the population in central north Namibia is around 3%, although this is decreasing (Mendelsohn et al., 2000). There are currently an estimated 100,000 homesteads in the area. Eighty percent of the people in north central Namibia live on individual farms of 2–15 ha in the central Oshana area (Tapscott, 1990). Traditionally, homesteads are situated around the edges of the low sandy dunes in the Oshana area, mainly because of the larger variety in soil moisture conditions and soil fertility found there (Hillyer, 2004). Outside this area people are more dependent on livestock.

The overall image of the study area is of a relatively dense population, largely dependent on the natural resources of a low fertility sandy environment, with input and labor shortages. There are indications of the use of high precision agriculture, e.g. where different local varieties of melons are grown in different ILUs found in one field, or where different mixtures of millet and sorghum are sown depending on the presence and combinations of ILUs in the field. These factors are found to be indicators where traditional knowledge systems are a useful basis for further development (Osbahr and Allen, 2003). It is, therefore, prudent to understand local systems better.

2.4. *Local knowledge information collection*

The collection of local knowledge for this study relied on individuals with a comprehensive knowledge of the environment. These key informants held specific knowledge on the indigenous classification of the local environment and on the various uses of resources (rangeland, forest, cropping, soil and water). They were solicited to join the team either during field observations of land units or for interviews on use and management of areas/resources. Identification of the key informants was based upon discussions with community leaders and local extension technicians and they were appointed by the headman and sub-headmen of the villages and sub-villages. Fig. 2 shows the diagram used to contact local people. It is based on the traditional hierarchical authority structure and includes representation of the locally elected government officials. Several hundred people were involved in the discussions, men and women, mostly either born or residing for a long time in the studied areas. Semi-structured interviews with small groups of people during transect drives and walks were used to identify and describe the land according to their local knowledge. If the land unit was outside a plowed field, the discussion was followed by a description of the vegetation, an evaluation of the resources and a description of resource use and management. Views on environmental changes were also captured. Findings were analysed and later discussed in larger community meetings to verify and amend results. Twenty-two areas with different groups of people were visited. Each area was visited at least twice with between 2 and 5 different key informants for

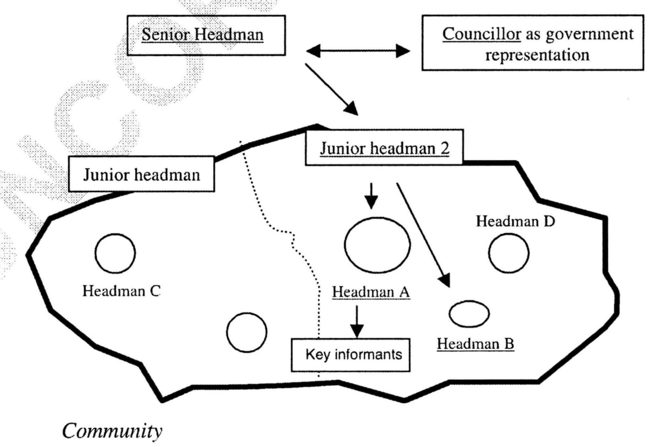

Fig. 2. Diagram of the consultation of the local, traditional authorities and key informants of the community in order to carry out the surveys on local environmental knowledge.

each trip. The total number of key informants involved in the study was around 170. The vast majority were farmers and most were elderly people, often accompanied by younger people. There were men and women but in the grazing areas, the majority were men. Feedback meetings were held in 20 areas; some of these were workshops held over several days and numbering up to 60 people each. In total, more than 300 people attended such meetings.

To facilitate the identification of land units with important vegetation structure or species composition criteria, the main criteria for each land unit were ranked and any available indicators listed in the tables. The rankings were generated during the interviews and discussions in the communities. The criteria mentioned most frequently were allocated the rank of 1, indicating the highest importance.

2.5. Vegetation analysis

The units were described in the field using a rapid and practical method. The analysis considers vegetation descriptions only and does not consider environmental descriptions. A total of 388 samples, collected between 1998 and 2002, were available for this analysis. Fig. 3 shows how they were distributed throughout the area with the vegetation classification of Giess (1971) as the background.

Sampling was done by selecting a homogeneous area within the land units identified by local people. Key informants walked through the area with researchers noting the presence of species until no more new species were found. Vernacular

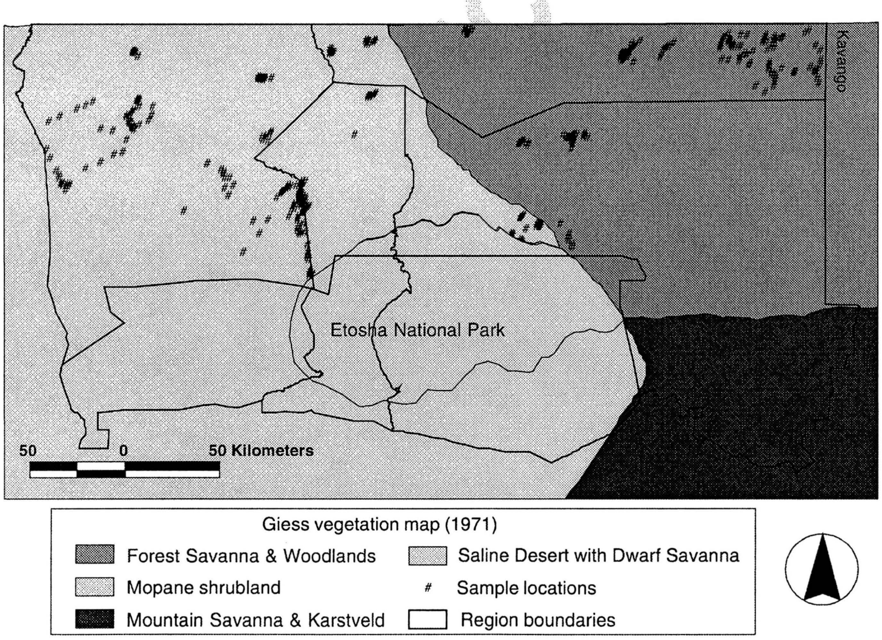

Fig. 3. Location of the sample plots for comparing local land units with the vegetation in north central Namibia. The vegetation map of Giess (1971) is put in as background.

names were recorded 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. The percentage cover of each species at each layer was estimated. 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 frequency of locally important plant species was calculated as the percentage occurrence of each species in the samples of each ILU. These were species mentioned by people to be more or less frequent in different ILUs. The significance of different frequencies between ILUs was tested using Mann–Whitney tests.

DCA (Hill, 1979) was used for the ordination of samples using CANOCO software (Jongman et al., 1995). DCA is probably the most widely used indirect vegetation ordination method for species and samples (Kent and Coker, 1995). DCA is based on reciprocal averaging and assumes a unimodal model for the relationship between species and ordination axes. The ordination axes are to be interpreted indirectly using knowledge of the ecology of the plant species. Cover percentage was square root transformed and rare species were downweighted. This transformation was used to avoid seasonal and inter-annual influences in grass cover on the ordination. Downweighting of rare species was used to avoid a large influence of rare species on the ordination result. 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 at all. For ecological interpretation of species and samples, Clarke (1999), Van Oudtshoorn (1999) and Coates-Palgrave (2002) were used. For the nomenclature, Coates-Palgrave (2002) was used for woody species and Gibbs-Russell et al. (1990) for the grasses.

To compare the indigenous land classification with the DCA, samples were grouped according to local land unit class. The average scores on the first two axes of the ordination of each land unit were calculated together with their standard deviation. Average values and standard deviations were used to draw standard deviation ellipses on the scatter diagram of each land unit with more than six samples. The resulting degree of overlap is an indication of how important species composition and structure is for identification of the ILU by local people. In the analysis of overlap, a distinction is made between: (1) land units where species criteria are very important, (2) where vegetation structure criteria are important and (3) where vegetation criteria are not important.

Table 1
List of identified units in the study area with their criteria and ranking of the importance of the criteria for identifying the unit

Criteria: ILU	Soil					Vegetation		Landform		
	Hardness	Color	Texture	Salinity	Hardpan	Structure	Species	Elevation	Depression	Pan
ILUs holding temporary surface water										
Ekango				3	4				2	1
Elonzi							3		2	1
Elamba									1	
Etapa		2	3						1	
Ondombe/Endambo			3				2			1
Otha							2			1
Edhiya/Ediva			2				3			1
Omungenye			3				2		1	
Etaka									1	
Oshana									1	2
Ehenene		3		2	1	4	5			
Omulonga									1	
Etapayela		1	2						3	
ILUs without surface water but important vegetation criteria										
Oshalala				3	2	1				
Oshitenenge					2	1				
Ombonde	3				4	1	2			
Omufitu/Oshiku	2				1	3	4			
Omufitu-Omupapa		2			1	4	3			
Omufitu-Omutundungu		2			1	4	3			
Omufitu-Epumbu					1	2				

Omufitu-Ombuwa				1	2				
Elondo	2	3			4		1		
Elondo-Omupapa	2	5			4	3	1		
Elondo-Omuva	2	5			4	3	1		
Iitunu	2	3			4		1		
Ehenga		3			2	4		1	
Ehenge		2				3		1	
Ongoya	2				1	3			
Ehengethitu/oshikuhenge					1	2			
ILUs with mainly landform and soil criteria									
Oshikurundundu	3		2				1		
Etathapya	2	1	3	4					
Oluma	2	4	3	1					
Ombuwa-Ekango				3	4	5	1		2
Omutunda							1		
Omutunda-Ekango	5	4		3			1		2
Omutunda-Omusati	4	5		2		3	1		
Omutunda-henge	4	2		3			1		

Note: 1 = highest importance. If a '/' is used, this means the same unit in different dialects. If a '-' is used, this means a subunit (in the case of a local tree name) or a transition unit between two different ILUs, but recognized as a separate ILU.

3. Results

3.1. Indigenous land units and their criteria

Table 1 lists 39 ILUs described so far with the main criteria classes and their ranking. Different dialects for the same unit are separated with the symbol '/' while '-' is used to identify a sub-unit (in the case of a local tree name) or a transition unit between two different ILUs, but recognized as a separate ILU. Results show that criteria for soil aspects, vegetation characteristics and landform are jointly used in most classes. Elevation, soil and soil–water characteristics are the only ones used to identify land units found uniquely on agricultural fields (e.g. Etathapya and Oluma). Landform is the only identifier for main drainage areas like Omulonga, Elamba and Oshana while landform is the main identifier for local drainage areas like Ondombe/Endambo, Ekango, Etaka, Etapa, Elonzi, Otha, Edhiya/Ediva, Omungenye and Etapayela. Only for Ondombe/Endambo and Elonzi are there local vegetation indicators. Ondombe/Endambo are ponds receiving water from neighboring areas. Ekango are pans with little vegetation while Etapa, Omungenye and Etapayela are small drainage areas on clay, often with calcrete. Etaka, Elonzi and Otha are small depressions, while Edhiya/Ediva are often compared with small lakes or areas with 'sweet water' standing for a long time.

Omutunda are elevated areas with a hardpan at a depth between 0.5 and 1 m and they are often target areas for cultivation. The vegetation is diverse and variable and a sub-unit with *C. mopane* is recognized (Omutunda-Omusati). Areas with shallow hard pans are Oshalala and Ehenene. The latter ILU has a surfacing hard pan with the result that woody plants are generally lacking. Oshitenenge are short shrubbed areas, mainly with *C. mopane* shrubs less than 1 m high. A hard pan is not necessarily present and if absent, the vegetation structure is maintained by frequent fires.

The Kalahari woodland types Omufitu, Ehenga, Elondo and sub-divisions are characterized by the absence of a hardpan in the soil, while vegetation structure and species composition become more important than landform. The sub-divisions are based on some plant species being more abundant, e.g. Omufitu-Omutundungu has more *B. africana*, Omufitu-Omupapa more *B. plurijuga*, Elondo-Omuva is woodland on somewhat higher elevations with more *P. angolensis*. Ehenga is a woodland type on light colored sand in interdunal valleys and has taller trees and more *Guibourtia coleosperma* than other units. Ehenge is a depression in a sandy area where water can collect temporarily during heavy rains. This is the most important indicator as it is one of the few sources of water in an environment devoid of shallow ground-water. It is associated with deep loose sand and has therefore a high abundance of the woody plant *Terminalia sericea*, but this species is by no means confined to Ehenge.

Ongoya is largely characterized by being impenetrable to cattle and humans and it is recognized as being largely the result of heavy grazing and lack of fire. In English, it is identified as 'bush encroachment'. Ongoya are more common on harder and reddish soils (ferralic arenosols). Iitunu are small elevated areas and these range from old termitaria to narrow dunes of up to 10 m wide. Omutunda-Ekango are transitions between pans and the surrounding forest. They are widespread and a pronounced slope is their main characteristic. Ombuwa-Ekango are very open woodlands close to a pan, while Ombuwa-Omufitu are very open woodlands not associated with pans. There was confusion in the field over this unit as it appeared that the criteria used for identification did not match the actual observations. Later, during discussions it became clear that the vegetation had changed significantly over time, due to an increase in the shrub layer but many people remembered the landscape to be classified as Ombuwa-Omufitu in the past. Samples from this unit had to be excluded from the analysis.

3.2. Indicator species

Table 2 presents a list of plant species indicators used in the identification of land units. Sometimes, it is the relative abundance of a species and not the unique occurrence in a unit that is used as an indicator. For example, some plant species like the grass *Wilkommia sarmentosa* or the tree *Terminalia sericea* are known to be associated with a set of land units but occur more commonly in some than in others. Other indicators are only locally valid, due to a high diversity of landscapes in the area. It is also worth noting that these are not the only plant indicators used. Several grass species are used as indicators for vegetation condition. In general, it was found that all key informants ($n = 170$) identified most woody species without hesitation,

Table 2
List of indicator species for the local land units

Land unit	Indicator plant species
Ombuwa-Ekango	*Peltophorum africanum*
Omutunda-Omusati	*C. Mopane*
Ehenene	*W. sarmentosa*, *Eragrostis porosa*, *Sporobolus ioclados*
Oshitenenge	*W. sarmentosa*
Oshalala	*W. sarmentosa*
Elonzi	*Eragrostis rotifer*
Ondombe/Endambo	*Combretum imberbe*, *Diospyros mespiliformis*
Edhiya/Ediva	*Diplachne* spp., *Nymphaea nouchallii*
Ombonde	*Terminalia prunioides* dominant
Omufitu/Oshiku	*Terminalia sericea*
Omufitu-Omupapa	*B. plurijuga*
Omufitu-Omutundungu	*B. africana*
Elondo-Omupapa	*B. plurijuga*
Elondo-Omuva	*P. angolensis*
Etunu	*Dicrostachys cinerea*
Ehenga	*Guibourtia coleosperma* more abundant
Ehenge	*Terminalia sericea*

Note: Species are listed that people indicated to be more abundant in these units than elsewhere. The indicator species are not unique criteria, their classification is a combination of the indicator species and the criteria listed in Table 1. If a '/' is used, this means the same unit in different dialects. If a '-' is used, this means a subunit (in the case of a local tree name) or a transition unit between two different ILUs, but recognized as a separate ILU.

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while the majority identified the main common grass and herb species. A minority of informants identified almost all grass and herb species.

3.3. Resource uses

Appendix A lists the major land uses and some of the potentials and limitations of each ILU. This table arises from the interviews and discussions with key informants in all the areas. Most suitable for cropping are: Omutunda, Omutunda-Ekango, Ombuwa-Ekango, Etathapya, Oluma and Omutunda-henge. This does not mean that crops cannot be planted in other ILUs but that cropping depends on the proximity to and combinations with more suitable units.

The table shows that a large number of ILUs hold temporary water and that these will be selected by people and/or cattle during these times. People in the Kalahari woodland area pointed out that cattle also select different ILUs seasonally, depending on (1) proximity to surface water, (2) an early green flush after rains, (3) presence and abundance of locally ranked high palatable grasses *Brachiaria nigropedata*, *Schmidtia papphoroides*, several *Eragrostis* spp., *Urochloa brachyura* and *Digitaria debilis*, (4) locally considered important browse species *Baphia massaiensis* and *Bauhinia petersiana* and (5) the degree of openness of the vegetation structure to avoid hyenas. 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 seasonal shortages.

Some of the grazing issues appear in Appendix A; Ehenge and Ehenga have a rapid green flush that arrives with the early rains and attracts cattle to these ILUs. After the early rains, cattle move to the Omutunda-Ekango, Ombuwa-Ekango, Iitunu and related ILUs because palatable grasses (and water in the first two ILUs) are more abundant. Cattle spend most of the wet and early dry season there, depending on the area of the specific ILUs and the cattle density. For example, a smaller area would hasten the degree of depletion. Later in the dry season when browse becomes more important, cattle move to the Omufitu related ILUs.

Table 3 lists the frequency of the more common plant species per ILU in 128 Kalahari woodland samples. The species considered important by local people for grazing and browsing are in bold. The table suggests that less palatable grasses (like *Aristida stipioides* that when flowering has large awns that can get into the eyes of livestock) are more abundant in Ehenge, possibly a reason why these areas are reported to be avoided by cattle after these grasses are flowering there. Omutunda-Ekango, Ombuwa-Ekango, Elondo, Ongoya and to a lesser degree Iitunu have a higher frequency of the more palatable *B. nigropedata*, *S. papphoroides*, *U. brachyura* and *Digitaria debilis* than many other ILUs. Considered locally to be the most important grazing species, the results for *B. nigropedata*, *S. papphoroides* and *U. brachyura* are significant (respectively, Mann–Whitney Z-adjusted $= 2.35$, $p = 0.02$, Z-adjusted $= 2.65$, $p = 0.01$; Z-adjusted $= 2.55$, $p = 0.01$). The first two ILUs are also situated close to pans that hold water during the wet season, providing another reason for livestock to be around those areas during the wet season. Table 3 also

Table 3
Common species of Kalahari woodland in north central Namibia with frequencies of occurrence per ILU (total $n = 128$)

ILU	1	2	3	4	5	6	7	8	9	10	11	12
Acacia acataxantha	0	25	27	0	30	0	25	0	22	13	11	0
Acacia erioloba	20	75	33	17	50	100	50	25	11	88	56	43
Acacia fleckii	40	17	20	0	50	17	25	38	44	63	39	29
Acacia hebeclada	0	25	0	0	0	33	0	0	0	50	0	0
Acacia mellifera	0	25	0	0	20	0	0	0	0	25	6	0
Albizia anthelmintica	0	42	0	0	10	17	0	0	0	0	6	0
B. plurijuga	50	0	73	0	50	17	25	100	44	25	44	14
Baphia massaiensis	**60**	**17**	**53**	**33**	**70**	**17**	**83**	**100**	**89**	**38**	**78**	**86**
B. petersiana	**20**	**17**	**47**	**67**	**70**	**0**	**50**	**75**	**100**	**25**	**67**	**14**
Berchemia discolor	20	0	0	0	0	0	0	0	0	0	11	14
Boscia albitrunca	20	17	20	17	40	0	8	25	11	63	22	14
B. africana	90	50	53	33	20	17	92	50	89	13	33	86
Combretum apiculatum	10	8	47	33	70	0	33	75	33	25	61	0
Combretum collinum	100	50	80	50	90	50	100	88	100	25	89	57
Combretum engleri	30	8	53	33	60	0	58	63	56	13	44	14
Combetum hereroense	10	8	0	0	10	33	0	0	11	50	11	0
Combretum zeyheri	10	8	47	0	30	17	42	13	33	25	11	0
Commiphora africana	0	0	0	0	30	17	0	25	0	25	6	0
Commiphora angolensis	10	17	7	17	50	0	17	13	33	0	6	0
Commiphora pyracanthoides	30	33	20	33	40	0	17	25	11	25	50	29
Croton gratissimus	50	42	67	33	100	17	42	88	67	38	94	57
Croton meyarthii	60	0	53	33	70	0	17	63	67	25	78	43
Dialium engleranum	20	0	7	0	0	0	17	0	0	0	0	0
Dicrostachys cinerea	20	50	27	33	90	33	42	63	56	50	72	14
Diplorhynchus condylocarpon	40	8	7	0	0	0	8	0	0	0	0	0
Erythrophleum africanum	30	17	33	0	10	0	42	50	11	0	6	29
Euclea divinorum	10	8	7	33	20	17	0	13	11	13	11	0
Grewia bicolor	10	0	0	0	20	50	17	0	0	0	11	0
Grewia flava	30	33	47	33	60	100	17	50	78	50	28	0
Grewia flavescens	0	33	27	33	0	33	67	0	0	0	6	14
Grewia retinervis	10	0	0	33	10	0	0	0	0	13	0	0
Guibourtia coleosperma	50	0	13	0	0	0	0	0	0	0	0	43
Lonchocarpus nelsii	**40**	**17**	**27**	**33**	**80**	**50**	**25**	**75**	**44**	**63**	**61**	**43**
Mundulea sericea	20	17	13	17	40	17	25	50	33	13	44	0
Ochna pulchra	60	8	47	33	30	17	67	63	78	25	39	0
Ozoroa insignis	0	33	47	0	20	67	25	25	11	63	22	0
Peltophorum africanum	0	25	20	0	10	83	0	0	0	13	6	0
P. angolensis	70	8	67	33	0	33	42	50	11	0	0	29
Rhigozum brevispinosum	0	0	0	0	10	0	8	0	0	0	0	0
Rhus tenuinervis	20	25	27	17	40	83	67	38	11	88	39	0
Schinziophyton rautanenii	10	0	20	0	0	0	0	0	11	13	0	43
Sclerocarya birrea	0	17	7	0	0	0	0	0	0	13	0	0
Spirostachys africana	0	0	7	0	0	0	8	0	0	0	0	14
Strychnos pungens	50	0	0	0	0	0	0	0	0	0	0	29
Terminalia sericea	90	83	100	33	80	67	92	75	89	63	78	71
Vangueria infausta	0	8	13	0	0	17	8	0	0	13	0	14
Ximenia americana	0	25	13	17	10	17	0	0	11	13	0	0
Ximenia caffra	0	17	27	0	10	17	17	0	11	13	6	14

Table 3 (*continued*)

ILU	1	2	3	4	5	6	7	8	9	10	11	12
Ziziphus mucronata	0	17	7	0	0	67	0	0	0	38	11	0
Acrotome inflate	20	33	27	0	20	17	33	38	11	25	6	0
Antephora shinzii	0	8	0	17	10	0	0	0	0	0	6	0
Aristida adscensionis	0	33	27	17	30	83	17	50	11	50	22	14
Aristida congesta	20	42	60	17	10	50	58	75	33	0	28	0
Aristida meridionalis	10	0	0	0	0	0	0	0	11	0	0	0
Aristida stipioides	40	92	73	17	20	67	83	88	33	13	22	71
Aristida stipitata	30	17	47	33	10	17	67	13	44	13	33	0
Asparagus sp.	0	17	0	0	10	0	17	25	11	25	17	0
B. nigropedata	**0**	**0**	**13**	**0**	**0**	**17**	**0**	**13**	**0**	**25**	**11**	**14**
Cynodon dactylon	**0**	**17**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**25**	**0**	**0**
Dactyloctenium giganteum	0	0	0	0	20	0	0	0	0	13	6	0
Digitaria debilis	**20**	**67**	**53**	**33**	**20**	**0**	**75**	**25**	**56**	**0**	**56**	**0**
Digitaria milanjiana	0	0	13	17	20	0	8	13	22	0	11	14
Enneapogon cenchroides	0	0	0	17	10	0	8	0	0	13	0	14
Eragrostis dinteri	0	8	20	17	30	0	8	0	11	13	6	14
Eragrostis lehmanniana	**0**	**8**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**13**	**11**	**14**
Eragrostis pallens	30	8	33	33	20	0	33	38	33	0	28	14
Eragrostos porosa	0	17	0	0	0	17	0	0	0	0	0	0
Eragrostis nindensis	20	0	13	0	0	0	0	0	0	0	0	0
Eragrostis rigidior	**0**	**8**	**0**	**0**	**20**	**0**	**0**	**0**	**0**	**50**	**11**	**0**
Eragrostis tricophora	30	83	67	17	60	83	83	50	33	63	39	14
Eragrostis viscose	0	33	0	0	10	33	0	13	0	0	11	0
Hyparrhenia rufa	20	8	0	0	0	17	0	0	11	25	0	57
Melinis repens	10	17	47	50	30	0	8	63	44	13	44	0
Tricholaene monachme	10	17	27	17	20	17	8	25	0	13	6	0
Panicum maximum	0	0	7	17	20	0	17	25	0	0	6	0
Perotis patens	10	8	20	17	20	0	17	38	33	13	11	0
Pogonarthria fleckii	10	42	53	0	60	83	33	50	33	50	28	14
Pogonarthria squarrosa	0	0	0	0	0	17	0	0	0	13	6	0
Schmidtia kalihariensis	0	33	27	33	0	17	17	0	0	13	0	0
S. papphoroides	**10**	**0**	**7**	**0**	**0**	**17**	**0**	**0**	**0**	**25**	**6**	**0**
Stipagrostis uniplumis	50	0	33	33	10	17	0	13	11	0	6	0
Triraphis purpurea	10	0	7	0	10	0	8	13	0	0	22	43
U. brachyura	**10**	**8**	**60**	**17**	**40**	**50**	**25**	**25**	**11**	**63**	**39**	**0**

ILUs: (1) Ehenga; (2) Ehenge; (3) Elondo; (4) Epumbu; (5) Iitunu; (6) Ombuwa-ekango; (7) Omufitu; (8) Omufitu-omupapa; (9) Omufitu-omutundungu; (10) Omutunda-ekango; (11) Ongoya; (12) Ombuwa-omufitu.

suggests that the important browse species *Baphia massaiensis*, *B. petersiana* and to a lesser extent *Lonchocarpus nelsii* have a much higher frequency in most Omufitu related ILUs in comparison to all others. *Baphia massaiensis*, considered to be the most important and the most abundant browse species, is significant (Mann–Whitney Z-adjusted $= 2.31$, $p = 0.02$). *B. petersiana* is only marginally more frequent in Omufitu related ILUs (Z-adjusted $= 1.95$, $p = 0.05$). These species are virtually the only ones with leaves at browse height during the dry season. The species frequency list in Table 3 does not contradict the opinions expressed by local people on the different grazing potentials of each ILU in the Kalahari woodlands.

3.4. Vegetation analysis

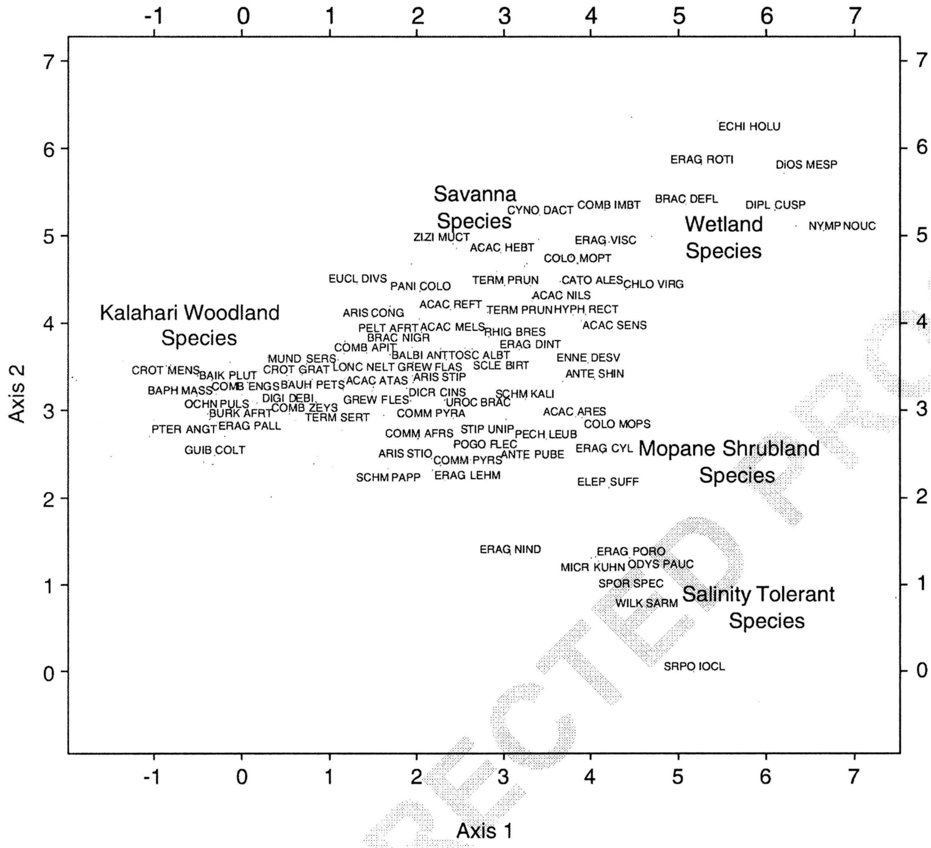
An eigenvalue measures the importance of an ordination axis with values ranging between 0 and 1. Including the downweighting of rare species and using the square root transformation of estimated species cover, the eigenvalue of the first two axes of ordination was, respectively, 0.63 and 0.28. The very high value of the first axis indicates a very high level of explanation of the variance of the species data along that ordination axis. The ordination diagram of species according to the two main axes is presented in Fig. 4 and this shows clearly several groups of species, which could be classified as Kalahari dry deciduous woodland species, savanna species, mopane shrubland species, wetland species and salinity tolerant species. The first axis is clearly related to a gradient between species occurring on dry sandy areas on the left and wetland species on the right. Axis 2 differentiates between salinity indicators on the bottom and less saline tolerant species on the top.

The savanna species are located in the middle of the diagram, indicating less extreme ecological circumstances. They include several indigenous fruit trees like *Sclerocarya birrea*, *Schinziophyton rautanenii* and *Berchemia discolor*. Other important savanna species are *Terminalia prunioides*, *Albizia anthelmintica* and *Acacia reficiens*. The mopane shrubland species include besides the woody shrubs *C. mopane*, *Acacia arenaria* and *Elephantorhiza suffruticosa*, several grasses like *Antephora schinzii*, *Eragrostis cylindriflora* and *Enneapogon desvauxii*. Saline tolerant grasses include *W. sarmentosa*, *Sporobolus ioclados* and other *Sporobolus* spp., besides *Odyssea paucinervis* and *Microchloa kuhntii*. There are many species confined to the Kalahari woodland vegetation types and the list includes *P. angolensis*, *B. plurijuga*, *B. africana*, *Croton menyarthii*, *Croton gratissimum*, *Dicrostachys cinerea*, *Ochna pulchra*, *Grewia* spp. *Terminalia sericea* and *Mundulea sericea*. The species less tolerant or intolerant of salinity include the indigenous fruit tree *Diospyros mespiliformis* and the typical wetland grasses like *Diplachne cuspidata*, *D. amboensis*, *Echinochloa holubii* and *Eragrostis rotifer*. *Nymphaea nouchallii* is also located in this group.

The sample ordination is presented in Fig. 5 and a similar configuration with the species ordination in Fig. 4 is apparent. There are clearly discernible clusters of Kalahari woodland samples, savanna samples and Mopane shrubland samples. The samples belonging to the wetlands and saline grasslands do not form tight clusters, due to the dominance of different species in different samples and as a result of the samples being species poor.

3.5. Comparison with indigenous land units

Fig. 6 shows the standard deviation ellipses around the average location of the main ILUs for the Kalahari woodland samples. Fig. 7 shows the same for the other samples. The ordination diagram of the Kalahari woodland samples was split into



two because of the tight cluster formed in Fig. 5. In Kalahari woodlands, there is considerable overlap between some of the ILUs that are mainly characterized by species criteria and especially between the sub-classes Omufitu-Omutundungu, Omufitu-Omupapa and Elondo-Omuva. The Ehenga land unit is largely different from the other classes identified by species, as is the Omufitu ILU.

There is also an overlap with the largely structurally identified class Ongoya with Omufitu-Omutundungu, Omufitu-Omupapa and Elondo-Omuva, suggesting that they are closely related. Iitunu and Ongoya are overlapping each other to a large extent, suggesting that dense shrubbed types could be classified as Ongoya or Iitunu depending on whether they occur on small dune ridges or not. There is an overlap between Omufitu and Ombuwa-Ekango as the latter is a more open woodland closely related to Omufitu. ILUs that have a landform as their main characteristic or that is related to the temporary availability of water, to a large extent overlap with at least one other unit, e.g. Omutunda-Ekango with Ombuwa-Ekango and Omufitu with Ehenge. Although important to farmers, the short-term availability of water in

Fig. 4. Species ordination of the first two axes using segmented DCA with square root transformation of percentage cover and downweighting of rare species. Only a selection of the species is displayed. The descriptions refer to the general ecology of the species. 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: ECHI HOLU, *Echinochloa holubii*; ERAG ROTI, *Eragrostis rotifer*; BRAC DEFL, *Brachiaria deflexa*; DIPL CUSP, *Diplachne cuspidata*; NYMP NOUC, *Nymphaea nouchalii*; COMB IMB, *Combretum imberbe*; CYNO DACT, *Cynodon dactylon*; ERAG VISC, *Eragrostis viscosa*; ZIZI MUC, *Ziziphus mucronata*; ACAC HEB, *Acacia hebeclada*; COLO MOP, *Colophospermum mopane*; TERM PRU, *Terminalia prunioides*; CATO ALE, *Catophractes alexandrii*; CHLO VIRG, *Chloris virgata*; ACAC NIL, *Acacia nilotica*; HYPH REC, *Hyphaene petersiana*; ACAC SEN, *Acacia senegalensis*; RHIG BRE, *Rhigozum brevispinosum*; ERAG DINT, *Eragrostis dinteri*; ENNE DESV, *Enneapogon desvauxii*; ANTE SHIN, *Antephora shinzii*; ACAC ARE, *Acacia arenaria*; ERAG CYL, *Eragrostis cylindriflora*; ELEP SUFR, *Elephantorhiza suffruticosa*; ERAG NIND, *Eragrostis nindensis*; ERAG PORO; *Eragrostis porosa*; ODYS PAUC, *Odyssea paucinervis*; SPOR SPEC; *Sporobolus* sp.; SPOR IOCL, *Sporobolus ioclados*; WILK SARM, *Wilkommia sarmentosa*; PECH LEUB, *Pechuel-Loeschea leubnitziae*; ANTE PUBE, *Antephora pubescens*; POGO FLEC, *Pogonarthria fleckii*; COMM PYR, *Commiphora pyracanthoides*; ERAG LEHM, *Eragrostis lehmanniana*; SCHM PAPP, *Schmidtia papphoroides*; ARIS STIO, *Aristida stipioides*; COMM AFRI, *Commiphora africana*; STIP UNIP, *Stipagrostis uniplumis*; UROC BRAC, *Urochloa brachyura*; SCHM KALI, *Schmidtia kalihariensis*; SCLE BIR, *Sclerocarya birrea*; ALBI ANT, *Albizia anthelmintica*; GREW FLA, *Grewia flava*; BOSC ALB, *Boscia albitrunca*; COMB API, *Combretum apiculatum*; BRAC NIGR, *Brachiaria nigropedata*; PELT AFR, *Peltophorum africanum*; ACAC MEL, *Acacia mellifera*; ACAC REF, *Acacia reficiens*; PANI COLO, *Panicum coloratum*; EUCL DIV, *Euclea divinorum*; ARIS CONG, *Aristida congesta*; LONC NEL, *Lonchocarpus nelsii*; MUND SER, *Mundulea sericea*; CROT GRA, *Croton gratissimus*; ACAC ATA, *Acacia ataxacantha*; BAUH PET, *Bauhinia petersiana*; DIGI DEB, *Digitaria debilis*; COMB ZEY, *Combretum zeyheri*; TERM SER, *Terminalia sericea*; BAIK PLU, *Baikiaea plurijuga*; COMB ENG; *Combretum engleri*; OCHN PUL, *Ochna pulchra*; BURK AFR, *Burkea africana*; ERAG PALL, *Eragrostis pallens*; CROT MEN, *Croton menyarthii*; PTER ANG, *Pterocarpus angolensis*; GUIB COL, *Guibourtia coleosperma*

Ehenge (to a depth of a few meters after heavy rains) does not influence species composition to a large extent.

In contrast with the Kalahari woodland ILUs, there is no overlap between the ILUs identified to some degree by species in Fig. 7. There is only overlap between ILUs that are identified by structure and by landform. Both Oshana and Ekango occupy a large area of the diagram, indicating that there is a relatively large variation in species composition and abundance within them. For the Ekango this appears to be caused by their occurrence in a large variety of habitats (e.g. saline and non-saline) and low species diversity in each habitat. In the case of Oshana, this is related to their position in a taxonomic hierarchy. The diagram demonstrates that various ILUs like Ehenene, Etapa, Oshalala, Ekango can occur within the larger complex of Oshana but they can also exist outside an Oshana. Interesting is that field observations show that an Ediwa/Edhiya wetland can also be part of an Oshana, but then mainly in depressions outside the main channels of the Oshana system. The geomorphology suggests that these wetlands receive water locally and hence there is less salinity in the system. Vegetation found there is entirely different from the Oshana related land units.

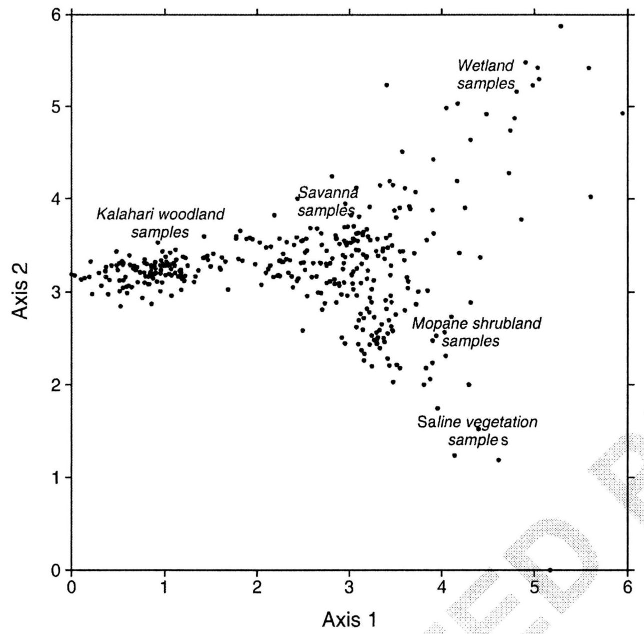


Fig. 5. Sample ordination ($n = 388$) with segmented DCA using square root transformation of percentage cover of species and downweighting of rare species. The descriptions of the sample groups are based upon the ecology of the species composition in the samples.

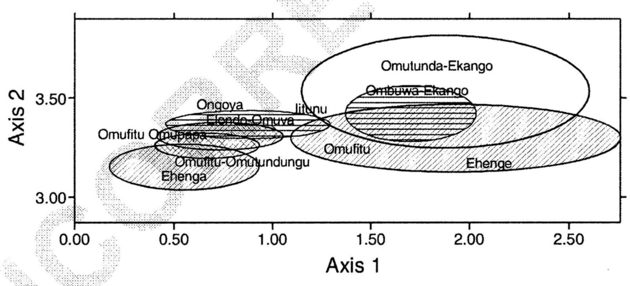


Fig. 6. The sample ordination diagram of the left hand part of Fig. 5, with the ellipses locating the local land units with their standard deviation in Axis 1 and Axis 2 of the Kalahari woodland samples. The hatched ellipses identify those land units identified with important vegetation criteria (species and structure), the horizontal striped ellipses are identified by vegetation structure, not species, and the white ellipses identify those land units not characterized by important vegetation criteria.

4. Discussion

Results of this study confirm the relevance of comparing the ordination result with the indigenous environmental classifications. The ordination of species and samples showed very high eigenvalues on the first two axes (Jongman et al., 1995), indicating

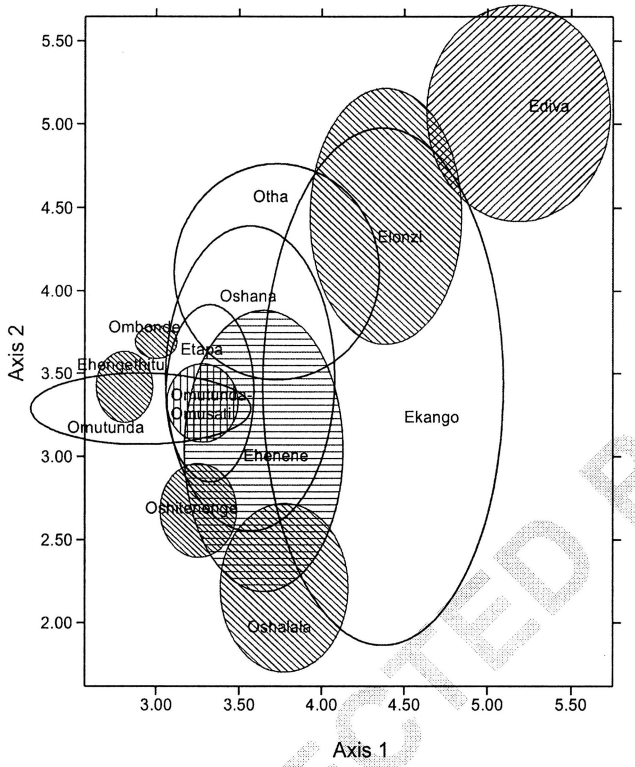


Fig. 7. Sample ordination with the ellipses locating the local land units with their standard deviation in the x- and y-axis of the savanna, wetland and saline grassland plots of Fig. 5. The hatched ellipses identify those land units identified with important vegetation criteria (species and structure), the horizontally striped ellipses are identified by vegetation structure but not species, and the white ellipses identify those land units not characterized by important vegetation criteria.

that most of the variation in the vegetation ordination is explained by the first two axes. Furthermore, the diagrams of the species and samples could be clearly interpreted with the main ecological aspects of the environment in the study area. However, a general lack of literature prevents a comparison of the results of this study due to a focus on pedological aspects in IEK studies, rather than the wider ecological and social framework (Osbahr and Allen, 2003). Other studies in northern Namibia have focused on the comparison between ILUs and soil chemical analysis (Rigourd and Sappe, 1999; McDonagh and Hillyer, 2001).

Ranking was used to indicate the importance of criteria but the aggregation of all interviews possibly masked regional differences. It is worth noting that although ranked species criteria might sometimes be low, they are still important. Only when vegetation does not receive any ranking, can it be assumed unimportant in the classification. The expectation that ILUs with important vegetation characteristics would show low overlap in their standard deviation ellipses was not always confirmed. In the Kalahari woodland, there is an overlap between many sub-classes of Omufitu, suggesting variation in interpretation between local people. However, key indicator species for differentiating the sub-units are located very closely together in the species ordination diagram. ILUs with quite different species composition, e.g. Ehenga and Omufitu, show no or little overlap. While the use of the square root transformation might have contributed to the relatively large overlap between the sub-classes of Omufitu, the differences between them in the field were shown to be small. It may be the case, as with an orthodox soil analysis (Osbahr and Allen, 2003), that subtle differences in the local knowledge framework are not captured in a conventional vegetation analysis.

The ILUs identified to some extent by species in the savanna, mopane shrubland, wetland and saline vegetation types show little or no overlap and confirm the expected pattern. ILUs with structural criteria and no species indicators were expected to show a higher overlap with other ILUs. This is indeed the case with Ongoya, Ombuwa-Ekango and Ehenene. The ILUs with mainly landform characteristics all conform to the expectation that they would overlap with other ILUs and have large sample standard deviation ellipses in the ordination diagram. The results suggest that correspondence analysis, in conjunction with ranked criteria, can be used to improve understanding of local environmental classifications.

There was similarity between local perceptions on grazing potential and seasonality of ILUs in Kalahari woodland and palatable species composition and frequency. The most important indicator species for grazing and browsing, that people related to grazing potentials of ILUs, were significantly more frequent in the ILUs selected by cattle. This suggests a more profound knowledge of grazing requirements by the local people than previously thought (Ashley, 1994; EDG, 1996; Erkkilä, 2001). Such agreements between local perceptions on grazing potential, species composition and cattle movements have been found before (Scoones, 1995).

Two ILUs with vegetation structure characteristics of the Kalahari woodlands that had to be discarded from the analysis were Epumbu and Ombuwa-Omufitu. Epumbu was omitted because the vegetation analysis did not differentiate shrubs with a height of less than 1 m from other shrubs, although it was an important aspect of classification by local people. Ombuwa-Omufitu was not used because the interpretation by local people was based upon how it used to be (i.e. an historical perspective) rather than the characteristics current when the sampling was done. Only when the survey team knew enough about criteria used to identify ILUs was this issue resolved. The fact that a local facilitator of the survey team had spent considerable time abroad in exile and remembered how the landscape looked 15 years ago possibly contributed to the initial misunderstanding. This shows that care must be taken with translation and it points to the need for descriptions, frequent cross-checks and repeat visits, a case of mutual learning (Pawluk et al., 1992; Dialla, 1993).

The issue regarding the historical perspective with Ombuwa-Omufitu was raised during community meetings and an interesting vegetation state and transition model based on ILUs was developed by the people. This model indicates which ILUs have increased and decreased over a period of several decades and what stages they went through. It seems that the unit Ongoya (meaning: one cannot pass) has vastly increased, at the expense of many others, over the past 30–40 years. Ongoya is a largely inaccessible shrubbed woodland or thicket but was found to have high grazing potential, using *B. nigropedata* and *S. papphoroides* as indicator species for good grazing, since these grasses are highly palatable perennial species (Van Oudtshoorn, 1999).

Ehenga and Omufitu-Omutundungu apparently took much longer than other land units to be transformed to Ongoya. From the descriptions and observations it appears that Ehenga and Omufitu-Omutundungu are confined to the current dune valleys, formerly the more infertile dune ridges in the now inverted Kalahari sand dune system. Both units are well differentiated from the land units on heavier sandy soils. Elondo-Omuva, Omufitu-Omupapa and Iitunu appear to be more susceptible to the transition to Ongoya. These occur on elevations in the inverse Kalahari sand dune system of the area. The former dune valleys are now dune ridges and the soils are heavier in texture and more fertile. Finally, Epumbu was noted to change to Omufitu as a result of changed fire management. Overall, the main processes identified behind the state and transition model based on the ILUs were drought, grazing and fire.

While the problem of bush encroachment was apparent to researchers, the people of the Kalahari woodlands were initially very reluctant to confirm any changes in the land units. Livestock rearing is their main livelihood and at first, they did not attribute changes to heavy grazing. Nevertheless, in discussing IEK the changes were eventually discussed. In 2002, a village group started a debushing experiment to evaluate methods for improving grazing in the area.

The study shows that within the IEK in northern Namibia there is a very good temporal understanding of landscape change as a result of human intervention and different types of management (or lack of it). Similar knowledge has been found elsewhere in the study area on changes between Ehenge, Etathapya and Omufitu (Hillyer, 2004). It is also striking that the local understanding of changes could be easily translated into modern ecological models of vegetation change. These are cases of good local understanding of the impact of actions and practice on the landscape and this is important for advocating IEK as essential for sustainable land management.

That there should be closer understanding between indigenous knowledge and conventional science can be illustrated by the location of the agricultural experimental station in the study area. It is almost entirely situated on Omufitu and all experiments carried out there until recently involved high inputs of fertilizer. Local knowledge indicated that putting manure on Omufitu is a waste, as its effects disappear at the most after 3 years (McDonagh and Hillyer, 2001; Hillyer, 2004) and no farmers are prepared or can afford to bear the cost of frequent application of a scarce resource. Another example is the perception by some outsiders that the whole Oshana system could be turned into rice cultivation fields. The present study and field experiments suggest, however, that only the Ediwa/Edhiya ILU is very suitable for rice. These occupy only a fraction of the Oshana system and are highly scattered.

In north central Namibia, there are several years of practical experience on working with IEK. The whole area north of Etosha National Park, a key tourism income generator for Namibia, has been surveyed and the ILUs mapped (Nott et al., 2003) for the purpose of detecting likely future settlement trends on the park border and for addressing grazing-cropping conflicts. Lechevallier and Weill (2001) have analysed the farming systems of a portion of north central Namibia and addressed different cropping strategies of farmers with different ILUs on their farm. Rigourd and Sappe (1999) and McDonagh and Hillyer (2001) have studied chemical properties of ILUs and related these to yields of various crops. Both studies also made extension recommendations using ILUs on pearl millet intercropping with legumes and on minimum tillage. Shitundeni and Marsh (1999) studied ILUs and their possible relevance for forestry extension.

It can be argued that working with IEK is time consuming initially and therefore costly. It appeared, however, that after some time, once a mutual understanding was reached between the scientists and the farmers, the participatory research in various fields went faster than conventional approaches. Gobin et al. (2000) also discuss costs of conventional methods versus participatory and GIS, concluding that in the end it is cheaper because the results are already useful and adapted to local circumstances as opposed to having to go through a process of local adaptation. This suggests that an initial investment in IEK research is worthwhile. The biggest stumbling block for working with IEK is the scepticism by many scientists and extensionists toward indigenous knowledge, making it difficult to institutionalize the approach. Insufficient understanding of the local context by outsiders and (often prudent) distrust of outsiders' 'science' account for much of the low adoption rates of many 'improved' practices and technologies among African smallholders (Barrett et al., 2001). This emphasizes the need for closer understanding of the local context by outsiders. The recently adopted farming systems research and extension policy by the Government of Namibia is a move in the desired direction.

Besides these problems, the lack of clear methods and models to address the differences between concepts of conventional science and those of the more holistic IEK, remain an issue. There is a danger that modern approaches such as multi-agent systems will remain out of reach for local rural development institutions, especially because these computer models are unfortunately considered to be the intellectual property of the developers, not the local people. In southern Africa, GIS is largely mainstreamed by practitioners over the past decade and it is likely that GIS will remain a main platform for integrating IEK with conventional methods for some time to come (Verlinden et al., 2003).

Acknowledgements

The participation by so many individuals in the field work and their willingness to share their knowledge is highly appreciated. M.K. Seely and A.E.M. Hillyer are gratefully thanked for commenting thoroughly on drafts of the paper. The Department for International Development (DfID), UK through the Northern

Namibia Environmental Project, the French Mission for Co-operation and Cultural Affairs through the Northern Livestock Development Project in Windhoek and the Department for International Development Cooperation of Finland through the Namibia–Finland Forestry Program are thanked for funding part of this research. The Namibia Nature Foundation is thanked for funding other parts of the research.

Appendix A. Potentials and limitations of ILUs with respect to some important land uses

ILU	Land use	Potentials and limitations
Ekango	Crops	None
	Wood resources	None
	Grazing	Generally low due to low cover
	Water	Very often important seasonal water supply for livestock
Ombuwa-Ekango	Crops	In Kalahari woodland area targeted for cropping Millet
	Wood resources	Most woody plants cleared when fields are established
	Grazing	Considered good grazing due to low tree cover and higher nutrient content in the transition to pans
	Water	Sometimes the area is used for digging traditional wells
Omutunda	Crops	Suitable for many crops, less so for most legumes
	Wood resources	Most woody plants cleared when fields are established, small size construction/fencing poles
	Grazing	Good grazing but in competition with cropping for land
	Water	None
Omutunda-Ekango	Crops	Similar to Omutunda
	Wood resources	Similar to Omutunda
	Grazing	Similar to Omutunda
	Water	Close to pans with seasonal water
Omutunda-Omusati	Crops	Similar to Omutunda

	Wood resources	Similar to Omutunda, *C. mopane* important multi-purpose tree
	Grazing	Similar to Omutunda
	Water	None
Omutunda-henge	Crops	Mainly millet and sorghum, some legumes
	Wood resources	Similar to Omutunda
	Grazing	Less valued than Omutunda
	Water	None
Ehenene	Crops	Mostly not suitable due to proximity of a hardpan and sometimes salinity
	Wood resources	Limited to a few species like *Acacia arenaria*, *A. nilotica* and *Hyphaene petersiana*
	Grazing	Waterlogged during rains
	Water	
Oshitenenge	Crops	Variable, usually not suitable for cropping, except in the West, where vegetation is similar to Omutunda due to soil conditions
	Wood resources	Limited due to the low height of shrubs
	Grazing	Usually good due to open structure
	Water	None
Oshalala	Crops	Mostly not suitable due to proximity of a hardpan and salinity
	Wood resources	Very limited to low height and cover of shrubs
	Grazing	Usually good due to open structure
	Water	None
Elonzi	Crops	None
	Wood resources	None, mainly used for collecting thatching grass *Eragrostis rotifer*
	Grazing	Good in dry season
	Water	Standing water during and after rains
Elamba	Crops	None
	Wood resources	Variable
	Grazing	Variable but not used for kraals due to night frost during winter
	Water	

		Temporary standing water in very high rainfall years
Etapa	Crops	Generally not suitable due to waterlogging
	Wood resources	Generally low, sometimes *C. mopane*
	Grazing	Only in wet season suitable for grazing
	Water	Temporary standing water in high rainfall years
Ondombe/Endambo	Crops	None
	Wood resources	*Diospyros mespiliformis* fruit tree surrounding this unit in Central Oshana area
	Grazing	Not suitable
	Water	Important water source during most of the year
Otha	Crops	None
	Wood resources	Various tree species surrounding the unit, important for larger construction material
	Grazing	Not important
	Water	Only during rains standing water
Edhiya/Ediva	Crops	Rice possible in some locations
	Wood resources	Various fruit trees can surround the unit, especially *Hyphaene petersiana*
	Grazing	Not important
	Water	Almost permanent supply of water
Omungenye	Crops	None
	Wood resources	Sparse *C. mopane* trees
	Grazing	Good grazing due to high moisture content and clay soil
	Water	Only during rains and flooding
Etaka	Crops	None
	Wood resources	Sparse *C. mopane* trees
	Grazing	Variable
	Water	Only during rains
Oshana	Crops	None
	Wood resources	None
	Grazing	

		Good throughout the year, except when heavy grazing depletes grass during dry season
	Water	Only during rains and during flooding
Ombonde	Crops	Similar to Omutunda
	Wood resources	*Terminalia prunioides* very important for construction material
	Grazing	Lower ranked than Omutunda
	Water	None
Omufitu/Oshiku	Crops	Limited potential for millet, better for most legumes. Known to lose fertility after 3 years of applying manure
	Wood resources	Various important species for various purposes
	Grazing	Important grazing and browsing in dry season due to presence of *Baphia massaiensis*, *B. petersiana* and *Lonchocarpus nelsii*
	Water	None in Kalahari woodland area, traditional wells in Central Oshana area
Omufitu-Omupapa	Crops	As for Omufitu/Oshiku
	Wood resources	*B. plurijuga* for construction and other species for various purposes present
	Grazing	As for Omufitu/Oshiku
	Water	As for Omufitu/Oshiku
Omufitu-Omutundungu	Crops	As for Omufitu/Oshiku
	Wood resources	*B. africana* for construction and other species for various purposes present
	Grazing	As for Omufitu/Oshiku
	Water	As for Omufitu/Oshiku
Omufitu-Epumbu	Crops	As for Omufitu/Oshiku
	Wood resources	As for Omufitu/Oshiku
	Grazing	Selected by cattle due to open structure. Rated higher than Omufitu due to low shrub cover
	Water	Only deep boreholes
Omufitu-Ombuwa	Crops	As for Omufitu/Oshiku
	Wood resources	Limited due to low tree cover
	Grazing	

		Selected during wet season by cattle, as there is less browse available in dry season than in Omufitu/Oshiku
	Water	Only deep boreholes
Elondo	Crops	Good for Millet and other crops
	Wood resources	As for Omufitu/Oshiku
	Grazing	Selected by cattle in wet and dry season until depleted
	Water	Only deep boreholes
Elondo-Omupapa	Crops	Good for millet and other crops
	Wood resources	*B. plurijuga* is important for construction and other species for various purposes present
	Grazing	Selected by cattle in wet and dry season until depleted
	Water	Only deep boreholes
Elondo-Omuva	Crops	Good for millet and other crops
	Wood resources	*P. angolensis* is important for construction and other species for various purposes present
	Grazing	Selected by cattle in wet and dry season until depleted
	Water	Only deep boreholes
Iitunu	Crops	Good for millet, less for legumes
	Wood resources	Thorn scrub for brush fences
	Grazing	Selected in wet season by cattle when shrubs not too dense
	Water	Only deep boreholes
Ehenga	Crops	None
	Wood resources	Various species for construction
	Grazing	Selected by cattle only in early wet season due to early green flush after rains
	Water	None
Ehenge	Crops	None in Kalahari woodlands, sorghum in Oshana area
	Wood resources	*Terminalia sericea* important for construction
	Grazing	

		Selected by cattle only in early wet season due to early green flush after rains
	Water	Temporary shallow wells
Ongoya	Crops	Good for millet, less for legumes
	Wood resources	Thorn scrub for brush fences
	Grazing	Good potential, but impenetrable
	Water	Only deep boreholes
Omulonga	Crops	None
	Wood resources	Mostly limited
	Grazing	Selected in wet season for grazing and surface water
	Water	Temporary riverbed
Ehengethitu/oshikuhenge	Crops	Moderate for millet, good for legumes
	Wood resources	Medium size construction/fencing poles
	Grazing	Selected in wet/dry season after Omutunda is depleted
	Water	None
Etapayela	Crops	None
	Wood resources	Medium size construction poles of *C. mopane*
	Grazing	Limited, but selected in wet season for surface water
	Water	Surface water in wet season
Oshikurundundu	Crops	None
	Wood resources	Medium size construction poles
	Grazing	Medium, rocks present
	Water	None
Etathapya	Crops	Good for most crops, less suitable for legumes
	Wood resources	None
	Grazing	None
	Water	None
Oluma	Crops	Good for most crops except legumes
	Wood resources	None
	Grazing	None
	Water	None
Ombuga	Crops	Low, only millet on elevations

Wood resources	None
Grazing	Good, but saline in depressions
Water	None

Note: If a '/' is used, this means the same unit in different dialects. If a '-' is used, this means a sub-unit (in the case of a local tree name) or a transition unit between two different ILUs, but recognized as a separate.

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