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Present vegetation in the Kavango Region

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Abstract
Vegetation in the Kavango Region is largely determined by topography (mainly depth of sand cover), substrate, climate and the compounding impacts of fire, clearing and grazing. With the exception of clearing, all these are natural determinants of savanna vegetation, but today it is almost impossible to distinguish between natural and human-altered environmental conditions. Due to these multiple impacts Kavango vegetation is very dynamic, undergoing continuous changes in response to large-scale disturbances caused by burning, herbivory and clearing. Many successional phases are thus encountered. Based on a land regions classification, nine major mapping units encompassing recurring patterns of vegetation types, though in different combinations, were identified. These were: (a) western stabilised dunes, (b) karst pediplain, (c) northern sandplain, (d) Okavango River valley, (e) Omatako river, (f) Omatako slopes, (g) catchment divide, (h) eastern drainage and (i) southern panveld. Vegetation types associated with each of these broader units are described.

Zusammenfassung
Savannenwälder herrschen im nordöstlichen Namibia vor - so auch in der Kavango Region. Die Savannenwälder des Kavangos zeichnen sich durch eine offene, vielschichtige Struktur und Dominanz mehrerer prominenter Baumarten, wie zum Beispiel *Burkea africana, Pterocarpus angolensis* und *Baikiaea plurijuga* aus.
Sowohl Landform, Boden und Klima, als auch die Eingriffe von Feuer, Beweidung und Ackerbau bestimmen die derzeitige Artenzusammensetzung. Die Vegetation kann daher als ein Mosaik unterschiedlicher Sukzessionsfolgen beschrieben werden. In einer Kartierung in 1999 wurden auf regionaler Ebene neun Landregionen mit zugehörigen Vegetationstypen identifiziert. Diese werden in dieser Publikation beschrieben.

Keywords: fire, Kavango, land regions, Namibia, plants, soils

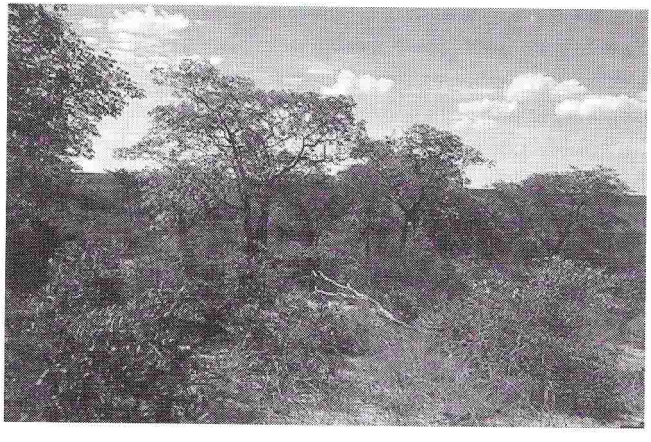
Introduction

The north-east of Namibia is the only area supporting extensive woodlands in the country. In a national context the vegetation of the Kavango has thus been broadly defined as forest savanna and woodland (Giess 1998). These woodlands comprise broad-leaved savanna characterised by deciduous trees such as *Pterocarpus angolensis,* in the northern parts, with fine-leaved savanna, dominated by *Acacia* species becoming increasingly more prevalent in the south. The presence of timber species, grazing and browse for livestock, abundant firewood and a variety of veld products highlight the importance of these woodlands to the livelihood of people in the Kavango Region (Geldenhuys 1996). Like savanna regions elsewhere, fire, shifting cultivation and grazing impacts have largely transformed these woodlands. Savánnas are inherently dynamic systems (Huntley & Walker 1982) and vegetation is to some extent adapted to these often dramatic impacts. As a result of these on-going dynamics, vegetation changes continuously, with various successional phases evident in areas that have been cleared, burnt or heavily grazed during previous years. Vegetation mapping on a community level, particularly using a phytosociological approach thus faces nearly insurmountable challenges. Various attempts in the past few decades had been made to classify the vegetation of the Kavango Region. As part of a comprehensive land use planning document, AOC Technical Services compiled a map of veld types, characterising 10 major veld types with associated smaller units (Page 1980). Using a broad descriptive approach based on land use units, de Sousa Correira & Bredenkamp (1986) delineated 12 land use units and linked these with dominant vegetation. The authors recognised the importance of sand cover and thus rooting depth in the determination of vegetation types. There have also been mapping exercises by the Directorate of Forestry, most recently during the forest cover reconnaissance mapping (Chakanga 1995). Only the latter exercise used modern techniques such as satellite images, but the forest cover mapping focussed on cover rather than delineation based on plant species. Taking these previous classifications into account, where applicable, this study provides a broad classification of the recent vegetation of the Kavango Region.

Study area

Geology and landforms

The Kavango Region is located approximately between 17°20' - 19°12' S and 18° - 21° E in north-eastern Namibia. With nearly 84 000 km^2 the region covers a substantial part of the country. The perennial Kavango River forms its northern border while all other boundaries are based on administrative delineation. Topographically, the Kavango Region is flat to gently undulating with maximum altitude differences of 200 m across



Dune crests throughout the western stabilised dunes support *Schinziophyton rautanenii* woodland.

this vast region. The steepest relief gradients are encountered towards the Okavango River and where dry rivers *(omiramba)* have incised the Kalahari sands (Simmonds 2000).

The entire Kavango Region is positioned in the Kalahari Basin, a vast depression in existence since the Cretaceous which covers most of the central parts of the southern African continent. Since its development it has been the main catchment of erosion products, today bearing the most extensive sheet of aeolian sand in the world (Partridge 1997).

Presently the land surface of the Kavango Region is characterised by an increasing differentiation of aeolian sands. Older, Tertiary Kalahari sands deposited on the margins of the Kalahari Basin underlie younger red sands deposited from the Late Holocene period to today. Fluctuating wet and drier conditions during the Late Holocene resulted in the formation of calcrete deposits. Increasing aridity has been documented during the most recent geological past, still lasting today. As a result, the current land surfaces of the Kavango Region are characterised by extensive areas of aeolian sand-drift and dune formations deposited on calcrete erosion surfaces (Simmonds 2000). These sandy soils are fairly poor in nutrients.

Climate

The study area is semi-arid with an average annual rainfall of 400 - 600 mm, most of which falls during the summer (December-April). Rainfall decreases more or less in a north to south and south-west direction (van der Merwe 1983). The mean annual temperature of the weather station at Rundu is 22.2°C. Mean summer temperature (December to February) is 24.8°C and mean winter temperature (June to August) 17.1°C. Daily temperature ranges are highest in winter when frosts can occur. The frequency of strong winds starts increasing in winter and usually peaks during November, prior to the onset of the rainy season (Simmonds 2000). During the survey period (February and April/May 1999) a total of 485.6 mm precipitation was recorded at Rundu for this rainy season.

Methods

Within the framework of natural resource mapping for the Environmental Profile of the Kavango Region Project (el Obeid & Mendelsohn 2001), a broad description of vegetation types had been commissioned in 1998. This vegetation mapping exercise was based on satellite image interpretation, synthesis of available geographic backgrounds and a land systems classification that was undertaken parallel as part of a soil survey of the region (Simmonds 2000).

Digital data for 6 LANDSAT TM satellite images captured on 17 April, 24 April and 1 May 1997 were initially used to delineate broad mapping units. The satellite images were geo-corrected and an optimal band combination of three bands was selected for the production of false colour composite images. Cluster analysis was used to select the appropriate bands for digital classification. An unsupervised classification of approximately 24 classes was run and the results were filtered to remove isolated pixels (Interconsult 2001). This unsupervised classification was then used to ground truth the classes, but no correlation with either soil type or vegetation could be found. Subsequent further processing did not result in satisfactory correlation between processed satellite images and the current land cover. The effects of fires appeared to largely mask the soil and vegetation types.

Because of these problems the final mapping units were based on a manually derived land systems classification. In very broad terms, an integrated land systems classification is a hierarchical method based on land regions, land systems and land units as the smallest mapping entity. Land units are defined based on altitude, slope angle, profile curvature, plan curvature and aspect. These were often determined by active geomorphological processes and surface geology. The land units were consolidated to land systems using recurring pattern of topography, landform, depth of sand mantle, surface drainage, groundwater levels, soil and vegetation within relatively uniform growing period zones. Land regions were largely delineated by drainage area and substrate. The mapping was undertaken at a scale of 1: 250000. At the level of mapping required for the Environmental Profiles Project, land regions proved best suited for an assignment of broad vegetation types at a regional level.

Results

Vegetation of the Kavango

Vegetation mapping at a regional level cannot capture the fine nuances of habitats and associated vegetation. At the regional scale each vegetation mapping unit thus presents a mosaic of small-scale habitats with their associated characteristic vegetation. For example the intricacies of catenas in relation to sand depth (e.g. dune valley to dune crest and their distinct woodland types) are not mapable at a regional scale. This study focuses on the regional scale for mapping purposes (Fig. 1), but describes individual vegetation types in more detail within each broader mapping unit.

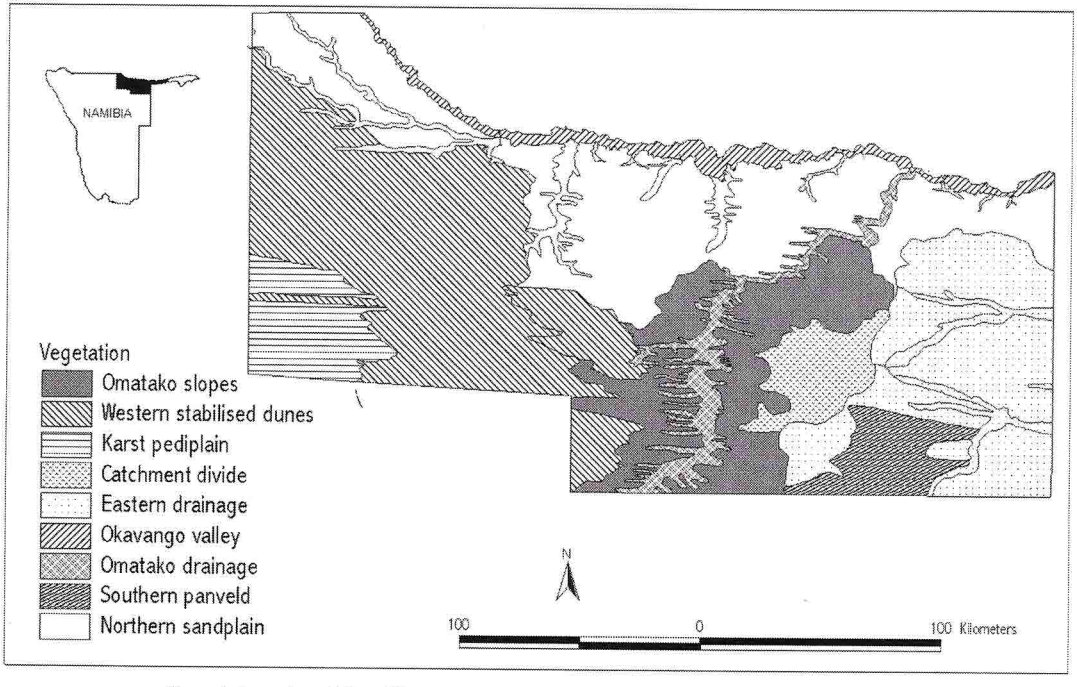


Figure 1. General vegetation of Kavango.

Nine major land regions were used to delineate broad vegetation units. These were:
* Western stabilised dunes
* Karst pediplain
* Northern sandplain
* Okavango River valley
* Omatako drainage
* Omatako slopes
* Catchment divide
* Eastern drainage and
* Southern panveld.

The following section describes the landforms and vegetation of these main units.

Western stabilised dunes

East-west orientated dunes characterise most of western Kavango. Dune amplitude, depth of sand mantle and outcropping of calcrete are the determinants of habitats (Simmonds 2000) supporting distinctly different vegetation. A pronounced catena in relation to depth of sand cover is evident.

Several woodland and shrubland types are associated with these stabilised dunes of western Kavango. The typical sequence of vegetation types is closely associated with topography, likely determined by rooting depth (de Sousa Correira & Bredenkamp 1986). *Baikiaea plurijuga* and *Schinziophyton rautanenii* woodlands with deep-rooted trees dominate on dune crests, followed by *Pterocarpus angolensis* (Kiaat) on dune slopes and shrubland with *Acacia erioloba* (Camelthorn), *Terminalia sericea* (Silver terminalia), *Acacia fleckii* and *Bauhinia petersiana* prevalent in dune valleys (Fig. 1). Within these woodlands trees are widely spaced, averaging at about 20% crown cover. *Croton gratissimus, Terminalia sericea, Combretum collinum* and *Baphia massaiensis* often form dense stands of shrub undergrowth, while *Digitaria seriata* is the most important grass component (Table 1).

The dune valleys in the northern parts are covered by a mosaic of grassland and shrubland with occasional *Acacia erioloba, Lonchocarpus nelsii* and *Combretum collinum* trees. The shrubs *Combretum hereroense, Acacia fleckii* and *Bauhinia petersiana* may form single species thickets. Occasional depressions support grassland with species such as *Anthephora pubescens*. Shallower rooting depth possibly caused by impeding layers of cemented fine material (hard pan) may explain the prevalence of shrubs and grasses in these habitats.

Terminalia sericea - Bauhinia petersiana shrubland is prevalent in interdune valleys of the western stabilised dunes, northern sandplain and the Omatako drainage.

The dune fringes present a transitional zone between dunes and sandplain, still showing the west-east alignment of dunes where dunes are present, but the dunes are lower, widely spaced and often not continuous. The vegetation of sandplains and dune valleys is thus more prominent. *Burkea africana* woodlands are prevalent on dune crests and areas with reasonable sand cover, while *Baikiaea plurijuga* (Zambesi teak) woodlands form occasional outliers on higher dunes.

The dune valleys in the south support mainly *Bauhinia petersiana* shrubland, with patches of *Terminalia sericea* shrubland and *Catophractes alexandri* and *Dichrostachys cinerea* indicating possible hardpan formation and calcrete crusts in the subsoil. *Schmidtia pappophoroides* is one of the dominant grasses in these shrublands.

The woodlands and shrublands of the western stabilised dunes extend west and south into the Oshikoto Region (Mendelsohn et al. 2000).

Today the majority of dune valleys have been cleared for agriculture and multiple sequences of re-growth of shrubs and trees mask the natural distribution of vegetation types.

Karst pediplain

The southwest corner of Kavango intersects the northern tip of a broad flat pediplain where calcretes are exposed near the surface in a matrix of shallow and predominantly red sands. The pediplain peters out to the north and east where the calcretes gradually disappear under sand drift and dunes. Thought to be the fringe of a calcrete apron skirting the Karst Otavi mountain complex, the pediplain is characterised by numerous pans and dune remnants (Simmonds 2000).

The woodlands and shrublands of the Karst pediplain extend south beyond the Kavango border to the Omuramba Owambo (Fig. 1). Only the remnants of dunes and the fringes of pans support larger trees, e.g. *Baikiaea* and *Burkea* woodland patches on dunes and *Acacia erioloba* trees near pans. Occasional *Ziziphus mucronata* and *Peltophorum africanum* trees also occur although shrubs such as *Terminalia sericea, Bauhinia petersiana, Combretum hereroense, Acacia fleckii, Baphia massaiensis* and *Combretum collinum* dominate the vegetation cover. Dense patches of *Catophractes alexandri* indicate calcrete crusts near the surface. In depressions grasses can form locally dense patches with *Hyparrhenia hirta* and *Anthephora pubescens* being the most prominent (Table 1).

Northern sandplain

The northern Kalahari sandplain comprises a deep sand sheet which gradually increases to the north and east, until dipping down to the Okavango valley where the sand is eroded by the permanent stream. Due to the depth of sand very few pans are present. The sandplain is dissected by several north and east-flowing omiramba (dry rivers) (Fig. 1).

The terrace slopes support open stands of *Schinziophyton rautanenii*, possibly still prevalent despite human impact because of their value as fruit trees. Although *Pterocarpus angolensis* and *Schinziophyton rautanenii* woodlands are prominent, localised patches of *Baikiaea plurijuga*

Table 1. Land region and associated vegetation types in Kavango Region.

Land region	Main associated vegetation types
Western stabilised dunes	• *Baikiaea plurijuga* woodland • *Schinziophyton rautanenii* woodland • *Pterocarpus angolensis* woodland • *Burkea africana* woodland • *Acacia erioloba* shrubland - woodland • *Acacia erioloba - Acacia fleckii* shrubland • *Terminalia sericea* shrubland • *Bauhinia petersiana* shrubland • *Burkea africana - Terminalia sericea* shrubland • *Dichrostachys cinerea* shrubland • *Terminalia sericea* shrubland • *Catophractes alexandri* shrubland
Karst pediplain	• *Baikiaea plurijuga* woodland • *Burkea africana* woodland • *Acacia erioloba* shrubland • *Combretum collinum* shrubland • *Bauhinia petersiana - Terminalia sericea* shrubland • *Catophractes alexandri* shrubland
Northern sandplain	• *Pterocarpus angolensis* woodland • *Schinziophyton rautanenii* woodland • *Baikiaea plurijuga* woodland • *Burkea africana* woodlands • *Acacia erioloba* shrubland • *Terminalia sericea* shrubland • *Terminalia sericea - Bauhinia petersiana* shrubland
Okavango River valley	• *Acacia nigrescens - Peltophorum africanum* riverine forest • *Combretum imberbe - Acacia erioloba* shrubland • *Terminalia sericea - Bauhinia petersiana* shrubland • *Catophractes alexandri* shrubland
Omatako drainage	• *Cynodon dactylon - Enneapogon desvauxii* grassland • *Cynodon dactylon* grassland • *Acacia erioloba* shrubland • *Terminalia sericea* shrubland • *Terminalia sericea - Bauhinia petersiana* shrubland • *Acacia erioloba - Acacia fleckii* shrubland • *Dichrostachys cinerea* shrubland
Omatako slopes	• *Burkea africana* woodland • *Burkea africana* shrubland • *Dichrostachys cinerea* shrubland • *Terminalia sericea* shrubland • *Catophractes alexandri* shrubland
Catchment divide	• *Burkea africana* woodland • *Baphia massaiensis* shrubland • *Terminalia sericea* shrubland • *Acacia erioloba - Peltophorum africanum* shrubland • *Acacia erioloba - Hyphaene petersiana* shrubland • *Bauhinia petersiana - Terminalia sericea* shrubland • *Eragrostis lehmanniana* grassland • *Combretum hereroense - Acacia fleckii* shrubland • *Dichrostachys cinerea* shrubland
Eastern drainage	• *Burkea africana* woodland • *Burkea africana - Guibourtia coleosperma* woodland • *Baphia massaiensis* shrubland • *Combretum imberbe - Acacia erioloba* shrubland • *Burkea africana* shrubland • *Terminalia sericea* shrubland • *Acacia erioloba- Acacia fleckii* shrubland • *Combretum imberbe - Acacia erioloba* shrubland • *Baikiaea plurijuga* woodland • *Terminalia prunioides* woodland • *Acacia fleckii* shrubland • *Catophractes alexandri* shrubland • *Acacia mellifera* shrubland • *Cynodon dactylon* grassland • *Combretum imberbe - Acacia erioloba* shrubland
Southern panveld	• *Terminalia sericea* shrubland • *Acacia fleckii* shrubland • *Catophractes alexandri* shrubland • *Burkea africana - Terminalia sericea* shrubland • *Burkea africana* shrubland

and *Burkea africana* woodlands occur throughout this map unit. *Combretum collinum* forms another important tree component, while *Combretum zeyheri, Combretum psidioides, Bauhinia petersiana* and *Baphia massaiensis* are prominent in the shrub layer. Common grasses associated with these woodlands are *Digitaria seriata, Schmidtia pappophoroides* and *Urochloa brachyura.*

Several shallow dry rivers *(omiramba)* dissect the northern sandplain draining towards the Okavango River. These are also heavily transformed by human activities and support a mosaic of cultivated fields, old fields with largely shrubby re-growth and occasional patches of *Acacia erioloba* trees and shrubland. In addition to *Acacia erioloba,* common shrubs are *Terminalia sericea* and *Bauhinia petersiana* (Table 1). The woodlands of the northern sandplain extend west into Oshikoto and Ohangwena Regions (Mendelsohn *et al.* 2000) and east into the Caprivi Region (Mendelsohn & Roberts 1997).

Okavango River valley

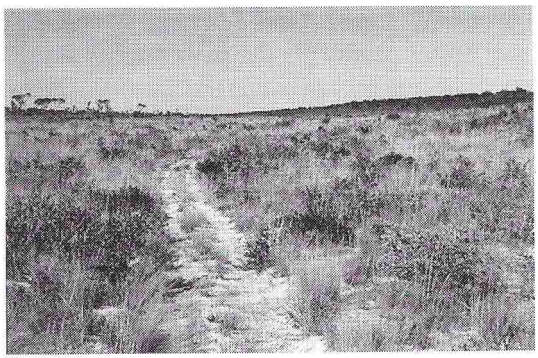
The perennial Okavango River shows the features typical of a subtropical river, such as meanders, oxbow lakes and other erosion and deposition features. There are wide floodplains which are seasonally inundated, and multiple terraces, signs of previous levels of river activity. This area is the most populated part of the Kavango Region, and today presents a cultivated landscape which is intensively transformed by farming activities, deforestation and intense livestock grazing.

Floodplain, river bank, old flood plain (terrace) and terrace slope comprise the main sequences of landforms bordering the Okavango River. Taking the definition broadly, i.e. including some of the low lying terraces, this map unit has been described as Okavango valley (Fig. 1). Grasslands with species such as *Vossia cuspidata, Cynodon dactylon* and *Setaria sphacelata* dominate the floodplain, while riverbanks originally supported riverine forests with *Acacia nigrescens, Peltophorum africanum* and *Diospyros mespiliformis* as dominant trees and a dense shrub undergrowth of variety of species. However, due to intense clearing and cultivation along the river, riverine forest has disappeared almost entirely and only few, localised patches remain. Today's river banks and terrace present an open parkland with few trees, cultivated land interspersed with many villages. Remnants of shrubland with *Combretum imberbe, Acacia erioloba, Terminalia* sericea and *Bauhinia petersiana* indicate the potential vegetation types of former terraces. However, human impact has also resulted in increasing shrub cover, often on old farmland.

Omatako drainage

The main channel floor of the Omatako valley is covered by a mosaic of recent and old fields, grassland and localised patches of shrubland mapped as Omatako drainage. Occasional *Acacia erioloba* trees, and shrubby forms of *Acacia erioloba* and *Acacia fleckii* are the most prominent woody components of the vegetation, often forming dense stands at the margin of the channel floor. *Cynodon dactylon, Enneapogon desvauxii, Aristida stipitata* and *Stipagrostis hirtigluma* are some important grasses. The majority of the Omatako main channel and associated slopes has been greatly altered by agricultural activities.

The tributaries to the Omatako and lower slopes form a transition from the main channel floor to the stabilised dunes to the west and sandplain to the east. Largely altered by agricultural activities and fires shrubland is most prominent on these slopes, with *Acacia erioloba, Acacia fleckii, Terminalia sericea* and *Bauhinia petersiana* most dominant (Table 1).



Grassland and shrubland is prevalent in the wide open valley of the Omatako Omuramba.

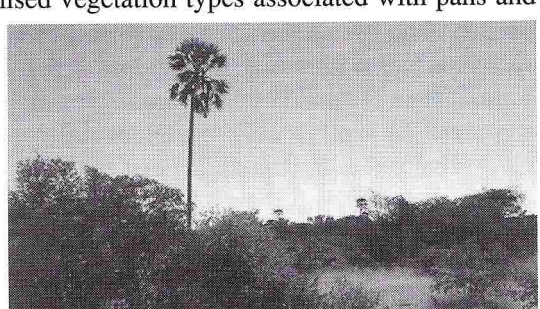
Omatako slopes

The Omatako slopes show a sequence of shrubland and woodland similar to the dune and dune valley arrangement (Fig. 1). The shrubland of lower slopes are followed by *Burkea africana* woodlands towards the upper slopes. As agricultural activities are still evident in the tributaries to the Omatako and upper slopes, *Burkea* shrubland could also indicate the impact of disturbance by clearing and thus present regrowth of former *Burkea* woodlands. Where calcrete appears at the surface and possible other impeding layers limit root penetration, *Catophractes alexandri* and *Dichrostachys cinerea* shrubland prevail (Table 1).

Catchment divide

An indistinct sandy plateau in central Kavango marks the water divide between eastern-draining *omiramba* (Khaudom system) from the large north-draining *Omatako omuramba*. Extensive areas of consolidated parent material lie shallow below the surface impeding drainage throughout this unit (Simmonds 2000).

This is one of the most complex map units (Fig. 1) and provides a mosaic of localised differential substrate conditions ranging from deep sand to calcrete outcropping and possible calcrete and silcrete based impeding layers in the subsoil. As such, the vegetation is dominated by open *Burkea africana* woodlands, intercepted by many localised vegetation types associated with pans and other hard substrates not visible at the surface.



Shallow soils and pan fringes support stands of *Hyphaene petersiana* in the catchment divide area in eastern Kavango.

Apart from the ubiquitous *Burkea africana*, other prominent trees are occasional stands of *Pterocarpus angolensis* and *Combretum collinum*. The tall palm *Hyphaene petersiana* is usually associated with pan margins. Shrublands are diverse and include almost all shrub vegetation types encountered in previous map units. *Acacia erioloba, Peltophorum africanum, Acacia fleckii, Combretum hereroense, Baphia massaiensis, Terminalia sericea, Di-*

chrostachys cinerea and *Bauhinia petersiana* occur in different combinations throughout this map unit. Accordingly the same grasses associated with these woodland and shrubland vegetation types are prevalent and include *Digitaria seriata* and *Schmidtia pappophoroides*. The centre of pans support grassland, often formed by a single species, such as *Eragrostis lehmanniana*.

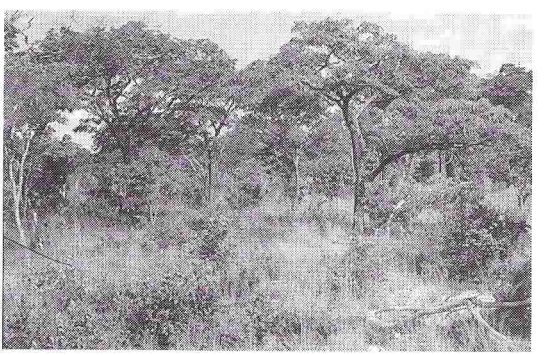
Eastern drainage

Drained to the east by two prominent omiramba, the Khaudom and Nhoma River, this land region, comprises variable topography with thick sand cover in its northern parts, and a gradual decrease and break up of the sand sheets towards the south and east. Calcrete deposits underlie the extensive sand plains of this region, and where they surface or lie at shallow depths in depressions, they are associated with numerous small and large pans (Simmonds 2000).

A variety of shrublands and woodlands are contained in this unit (Fig. 1). Where moderate sand cover and numerous small pans are prevalent *Burkea africana* woodlands are associated with deeper sand, while shrubland prevails on shallower soils near pans. *Baphia massaiensis* is the most prevalent shrub, followed by *Combretum imberbe - Acacia erioloba, Acacia erioloba - Acacia fleckii* and *Terminalia sericea* shrubland. In areas with larger and more widely spaced pans the most conspicuous feature is the presence of *Guibourtia coleosperma* trees, resulting in *Burkea africana - Guibourtia coleosperma* woodland as the dominant vegetation type. Shrubland is less prominent here than on moderate sand cover and includes *Acacia erioloba, Combretum imberbe* and *Burkea africana* shrubland (Table 1).

The eastern omiramba (with the Khaudom River and Nhoma River as the two main channels) are part of an ancient drainage system and, been exposed to erosion processes for long periods, present today wide open valleys, mainly supporting grassland in the centre and shrubland along their fringes. Although *Cynodon dactylon* is the dominant grass in most parts, other grasses such as *Setaria sphacelata* and *Eragrostis echinochloidea* are locally common. In the vicinity of surface water *Phragmites australis* forms dense conspicuous stands. Dense stands of *Acacia mellifera* shrubs likely indicate the presence of subsurface calcrete.

Underlying Nosib quartzite of the Damara sequence, although not surfacing, is probably responsible for the formation of a hardpan in the subsoil. Here in a matrix of *Terminalia sericea* shrubland on shallow soils numerous, interspersed patches of *Baikiaea plurijuga* and *Terminalia prunioides* woodlands occur. Although almost no relief is evident, the *Baikiaea* woodlands are thought to be growing on remnants of dunes, while a hardpan near the surface supports the growth of *Terminalia prunioides* woodland. *Terminalia prunioides woodland* shows shrub undergrowth with *Dichrostachys*



The northern sandplain and western stabilised dunes contain large areas with *Pterocarpus angolensis* woodlands.

cinerea, Mundulea sericea and *Croton gratissimus,* while prevalent grasses are *Aristida stipitata* and *Enneapogon cenchroides.*

Remnants of west-east aligned dunes and wide open valleys are prevalent in the western part of this map unit. Here *Terminalia sericea* and *Acacia fleckii* shrubland are the most prominent vegetation. Calcrete crusting occurs locally supporting *Catophractes alexandri* shrubland. *Burkea africana* shrubland may present re-growth in fire impacted areas or indicate subsurface hardpans preventing the growth of taller trees. These shrubland and woodland types of the eastern drainage extend east into Botswana and south into Odjozondjupa region.

Southern panveld

The southern panveld has been proposed to be a relic ephemeral watershed which is now physically separated from the main catchment divide by sand drift (Simmonds 2000). It presents the northern fringe of the Tsumkwe panveld which includes the Klein Dobe and Cin Qo wetlands and the "Pannetjies veld". These areas are renown for their temporary wetlands which are associated with drainage lines and hardpan layers supporting small and large water bodies of temporary existence (Hines 1990).

In Kavango this map unit consists largely of shrublands composed of *Terminalia sericea, Acacia fleckii* and shrubby forms of *Burkea africana,* with larger trees only framing the margin of pans and areas with deeper sand cover (Table 1). These vegetation types extend south into northern Bushmanland (Hines 1992).

Discussion

Factors affecting vegetation in the Kavango

Landform, together with disturbance regimes (fire and clearing), emerged as the two most significant environmental factors controlling the distribution of vegetation types in the Kavango Region. Overall, climate (a gradient of decreasing rains from north-east to south-west) plays a significant role in defining the distribution of vegetation, and resulted in the division of the Kavango Region into two distinct growing period zones (De Pauw 1996). This climatic gradient is broadly matched by a change in species composition from species with more tropical affinities, such as broad-leaved, deciduous trees (e.g. *Baikiaea plurijuga*) to fine-leaved savanna trees such as *Acacia* species. Local topographic conditions reflect different microclimatic influences and underlying substrate also plays a significant role. As a result, similar (smaller scale) vegetation types recur throughout the broad land regions, although in different combinations depending on the underlying landforms synthesised in a particular land region.

The influence of fire and clearing

The contemporary vegetation in the Kavango presents a mosaic of climax vegetation and multiple successional stages caused by disturbance (fire and clearing). The predominance of shrubland, for example, has been suggested to be attributed to impeding layers limiting root penetration (De Sousa Correira & Bredenkamp 1986), but the successive impact of fires could have a similar effect. This pattern is further complicated by the fact that fires are not only changing vegetation composition, but also soil structure and soil development, possibly resulting in impermeable layers in the soil.

Slash-and-burn agriculture is practised throughout the region, although activities are concentrated along the perennial Okavango River and other areas where water is available. All major dry rivers *(omiramba)* serve as access routes and water points for settlements from where agricultural activities have extended far into the woodlands.

In addition to clearing for agriculture, fires appear to be raging through the Kavango woodlands more frequently than in the past (Trigg 1997). This can largely be attributed to burning for traditional hunting and resource management (Powell 1998), burning of fields and possibly war-time activities in the past. As a result the vegetation in the Kavango Region has been extensively altered by clearing and burning and presents an intricate mosaic of different phases of recovery from disturbance.

One of the most problematic aspects which could not be addressed adequately in this study was the separation of human-induced factors (e.g. clearing and fire) from natural causes (e.g. substrate and landform) controlling the distribution of vegetation types. This is particularly difficult as fire is part of the natural system, although the fire regimes have been greatly altered due to human activities.

Conclusion

The following main points have arisen from this study:

- Landform and disturbance regime (fire and clearing) appear to be the two most significant environmental factors controlling the distribution of vegetation types in the Kavango Region.
- It is difficult to separate human-induced from natural causes which are responsible for the distribution of vegetation types in the Kavango.
- Local topography (landform), reflecting different microclimatic influences and variations in substrate, may play a more significant role in the distribution of vegetation types than differences in growing periods as suggested by agro-ecological zone boundaries.

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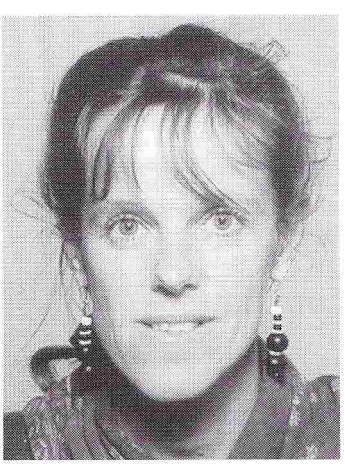

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