

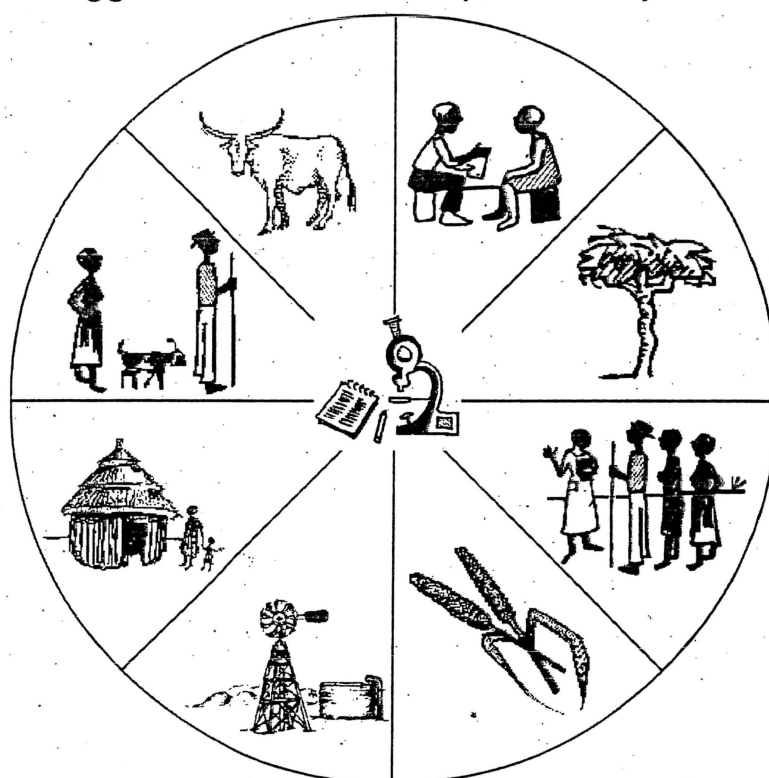


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# HOANIB RIVER CATCHMENT STUDY, NORTHWESTERN NAMIBIA Vegetation

June 2001

Authors: Keith Leggett, Julian Fennessy, and Stephanie Schneider



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Desert Research Foundation of Namibia  
P O Box 20232, Windhoek  
Tel: + 264 61 229855  
Fax: + 264 61 230172  
email: drfn@drfn.org.na

The Gobabeb Training and Research Centre  
P O Box 395, Walvis Bay  
Tel: + 264 64 694198  
Fax: + 264 64 205197  
email: gobabeb@iafrica.com.na

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## **GENERAL INTRODUCTION**

This paper is a result of the research work carried out during the Hoanib River Catchment Study (HRCS) which began in 1998. The HRCS focused on appropriate basic socio-economic, biophysical and policy research on environmental issues important for sustainable use and development of natural resources in the Hoanib River catchment. The investigation examined present methods of lands and associated living conditions and highlighted potential alternatives to existing demands and expectations. Potential conflicts in the area revolve around the dynamics of different discourses and include: escalating, uncontrolled tourism; increasing aspirations and expectations of local residents often based upon popular misinformation; interactions between and among Non Government Organisations (NGOs), Government Ministries, and local people of different language groups; limited water availability and a relatively fragile environment.

This study has been a collaborative effort between relevant Government Ministries and Departments as well as local NGOs. The communities of the Hoanib River catchment are an integral part of the project, as a collaborative process has been used to identify problems, collect data and disseminate results.

As a result of HRCS, four occasional papers have been published by the Desert Research Foundation (DRFN). These papers cover the general topics of soil, water, fauna, and vegetation in the Hoanib catchment, and are available for purchase through the DRFN library.

## **SECTION I**

# ***FAIDHERBIA ALBIDA:* DISTRIBUTION, DENSITY & WILDLIFE INFLUENCES HOANIB RIVER CATCHMENT, NORTHWESTERN NAMIBIA**

By: Julian Fennessy\*  
Keith Leggett  
Stephanie Schneider

Contact Address:  
Hoanib River Catchment Study  
Desert Research Foundation of Namibia  
P.O. Box 20232  
Windhoek  
Namibia  
E-mail: [drfn@drfn.org.na](mailto:drfn@drfn.org.na)

\*Person to whom all correspondence should be addressed

June 2001

## ABSTRACT

*Faidherbia albida* is valuable dry season fodder for both wildlife and domestic stock in Namibia's northwest. The Hoanib River forms the basis for life in the catchment yet the communities rely less on the collection of pods compared to those in the south.

Experimental methods of the study are described and their limitations are discussed in this paper. *Faidherbia albida* was found along the entire Hoanib River and were greatest in densities nearest the Hoanib Floodplain. The size of the trees was directly proportional to the stem diameter, while the predominant number of trees were single-stemmed.

The browse heights of *Faidherbia albida* varied markedly along the course of the Hoanib River with observed browse heights lower than 3m in areas where domestic stock were predominant. Away from these areas, concentrations of wildlife existed and increased browse heights were observed.

The impact of wildlife, predominantly elephant, on *Faidherbia albida* was greatest in the eastern and extreme west sections of the river, particularly close to available water sources i.e. Dubis wetland and Hoanib Floodplain. However, floods were observed to cause the greatest change in *Faidherbia albida* populations.

A slight shift in the population, age and size structure of *Faidherbia albida* in the lower Hoanib River was observed when compared to previous research.

## KEY RESEARCH QUESTIONS

The *Faidherbia albida* studies were conducted along the Hoanib River to examine the following research questions:

- (a) What are the population densities and distribution of *Faidherbia albida* in the Hoanib River?
- (b) What impacts do domestic stock and wildlife have on the browse heights of *Faidherbia albida* in the Hoanib River?
- (c) Have population shifts of *Faidherbia albida* occurred along the lower Hoanib River?
- (d) Do elephants have the greatest impact on *Faidherbia albida* in the Hoanib River?

## BACKGROUND

### *FAIDHERBIA ALBIDA*

*Faidherbia albida* (Del.) A.Chev., (formerly *Acacia albida* Del.), is often referred to as one of the most potentially important species for conservation in arid and semi-arid regions (CTFT, 1989). Its natural distribution throughout Africa is vast with its range stretching from southern Algeria to Gauteng Province in South Africa, and from the Atlantic to the Indian Ocean (CTFT, 1989; BOSTID, 1990; Jacobson *et al.*, 1995). Occurring throughout two major climatic zones (the Dry Mediterranean and Tropical), *Faidherbia albida* extends across an altitude range from below sea level to 2 500m, and across highly variable rainfall conditions (0-1 800mm per annum). This is an extensive natural distribution and one which is an obvious indication of its ecological adaptability (CTFT, 1989; BOSTID, 1990; Jacobson *et al.*, 1995).

Throughout the continent, people have used *Faidherbia albida* for numerous purposes. Not only is it used as a fodder source, but it is also important in agroforestry, medicinal use and in the sustenance of soils (CTFT, 1989; BOSTID, 1990; SDP 2, 1996). Its potential for agricultural productions, other than as a source of timber (commonly used in the Sudan-Sahel area where resources are limited), is not highly regarded.

Throughout Africa, in particular Namibia, *Faidherbia albida* is important as a supplementary fodder source for domestic stock and wildlife in arid environments (CTFT, 1989; BOSTID, 1990; Jacobson *et al.*, 1995; SDP 2, 1996; Jacobson and Jacobson, 1998). Its importance as a fodder source is best understood by equating it to grasses available in the same environment during the dry season. The dry season provides little grazing and most livestock seek forage on woody species. Prior research (CTFT, 1989) has reported that in the drier periods the leaves and pods of the *Faidherbia albida* can provide up to double the amount of net energy and a larger amount of digestible protein compared to that of dry grass. Providing a necessary and adequate supplement to the herbaceous fodder during the dry season, *Faidherbia albida* can contribute by providing essential protein and nutritional requirements, which can be most important in a marginal environment (CTFT, 1989; BOSTID, 1990).

However, *Faidherbia albida* as a fodder source is not accessible for extensive periods of the dry northwest season, and is unavailable for up to 9 months or more in severe years. Domestic stock cannot feed solely on woody vegetation, thus the pods of *Faidherbia* trees act only as a supplementary, rather than a substitute, fodder source (CTFT, 1989). For wildlife, *Faidherbia albida* also provide essential fodder during the dry months and extended periods of high aridity, although competition between people, domestic stock and wildlife limits availability of such a resource to them.

## INTRODUCTION

### Hoanib River Catchment Study (HRCS) Area

The Hoanib River catchment is one of twelve major ephemeral river catchments that occupy the semi-arid areas of north-western Namibia. All twelve rivers flow into the Atlantic Ocean or end in the Namib Sand Sea. The Hoanib originates in the western edge of the Etosha National Park, flows through commercial and communal farming areas and, near its mouth, traverses the protected Skeleton Coast Park. The Hoanib River catchment occupies an area of 17 200 km<sup>2</sup>, 3% of which lies in private farm lands, 91% in communal farm lands, and 6% is protected in the Etosha National Park and Skeleton Coast Park (Jacobson *et al.*, 1995; Leggett, 1998).

The Hoanib River constitutes the boundary between the former Damaraland and Kaokoland. Since Namibia's independence in 1990, these two areas have been incorporated into the Kunene and Erongo Regions (see Fig. 1). The Hoanib River catchment can be divided into three broad geographic (and vegetation) sections. The eastern section (east of the Khowarib Schlucht) is relatively densely vegetated with mopane woodland being dominant. The middle section of the Hoanib River (from the Khowarib Schlucht to the Skeleton Coast Park's eastern boundary) is sparsely vegetated. In the western section of the river (from the Skeleton Coast Park boundary to the coast), virtually no vegetation exists outside the river course. A broad flood plain (some 70km<sup>2</sup>), which is in front of the coastal dunes, offers substantial grazing for wildlife after flood events during the wet season (Jacobson *et al.*, 1995; Leggett, 1998).

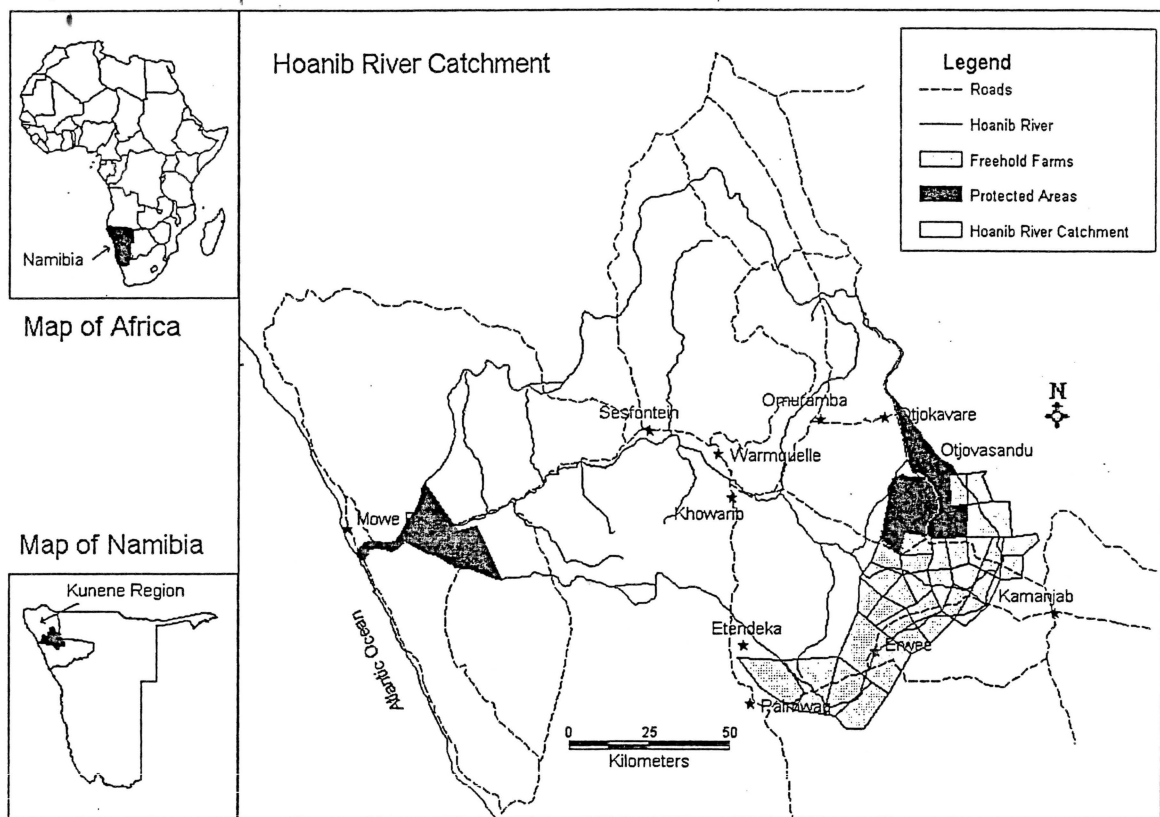


Fig. 1: Map of the Hoanib River Catchment

The rainfall in the Hoanib River catchment varies from a mean of 13.2mm at the coast, to a mean of 325mm in the eastern section of the catchment. This rainfall has a high degree of variability, up to 50% annually in the east and 90% in the west (Jacobson *et al.*, 1995; MWTC, 1999). Drought or periods of aridity are the normal occurrence in arid and semi-arid areas. Drought is defined as a period of more than two years with rainfall lower than the long-term mean (Jacobson *et al.*, 1995; Warren and Khogali, 1992).

Throughout Namibia, *Faidherbia albida* exists predominantly along the riparian environments of the country's major westerly flowing ephemeral rivers (Jacobson *et al.*, 1995). However, due to the collection of pods by farmers as supplementary fodder for domestic stock and movement patterns of elephant, *Faidherbia* trees have been established in unexpected environments i.e. Erwee to Palmwag road culvert (Jacobson *et al.*, 1995; SDP 2, 1996).

## SECTION I

In other ephemeral river catchments south of the Hoanib, the reliance of farmers on the *Faidherbia albida* is far greater than that observed elsewhere within the Hoanib. Studies in both the Kuiseb and Ugab catchments reported collection of pods by local farmers as an essential hard-times fodder source throughout the drier periods of the year (SDP 2, 1996).

Increased productivity of livestock in Namibia's northwest has created greater pressure on the land during the harsh arid periods. The wildlife does not have such a great impact on the environment due to their mobility and lack of water requirements.

Finally, *Faidherbia albida* is also recognised as a good indicator of environmental change (CTFT, 1989). Being a relatively large tree with shallow roots, any change in the river water level can eventually be reflected in the survival or mortality of the trees. A large tree in stature, *Faidherbia albida* reaches a height in excess of 30m and a diameter greater than 2m in the Hoanib River. An individual tree produces, on average, between 10 and 50kg of dry indehiscent pods yearly, with as much as 150kg possible (CTFT, 1989; BOSTID, 1990; Jacobson and Jacobson, 1998). The increased soil moisture content of the river beds due to seasonal flooding, enables these stately trees to prosper in the otherwise hostile environment of the Hoanib River catchment (CTFT, 1989; Jobst, 1996).

This study surveyed all *Faidherbia albida*'s in the Hoanib and Ombonde Rivers (referred to as the Hoanib River) (see Appendix B for case study of the lower Hoanib River). Previously only isolated stretches of the lower Hoanib River had been surveyed, therefore this study hoped to provide a greater understanding and comparative study of the density, size class distribution, and elephant *Loxodonta africana* influences with previous research reported (Nott 1987; Viljoen and Bothma 1990; Schoeman, 1982 in Jacobson and Jacobson, 1998).



## METHODS

Nott (1987), Viljoen and Bothma (1990) and Jacobson and Jacobson (1998) previously reported on the impact of elephant on *Faidherbia albida* and other vegetation in the lower Hoanib River. A variety of different survey methods was undertaken during these studies e.g. selective surveying of stands for age structure and mortality, bark analysis and use of aerial photos as a tool for assessing changes in *Faidherbia* populations. This study set out to survey the entire length of the Hoanib River for the below parameters.

### FIELD SAMPLING TECHNIQUES

#### SURVEY TECHNIQUE

With the assistance of Raleigh International venturers, international scientists, friends and the HRCS community researchers, the survey was completed over a 12-month period: October 1998 to September 1999.

The vegetation transects were undertaken by groups of individuals walking along the Hoanib River, covering more than 220km and collecting bio-data on over 3 800 trees (see Appendix A for data sheets). The eastern section of the Hoanib River (Khowarib to Kamdescha) was surveyed in an easterly direction, starting above the sand weir in the Khowarib Schlucht and surveyed towards the Kamdescha veterinary gate. Along this eastern section of the river, Global Positioning System (GPS) co-ordinates were recorded at the start of each survey day and subsequent 10km intervals.

The western (Dubis to Khowarib) and extreme western (Hoanib Floodplain to Dubis) sections of the Hoanib River were measured in a westerly direction, starting from below the sand weir in the Khowarib Schlucht and surveyed towards the Hoanib Floodplain. GPS co-ordinates were recorded for every tree along these stretches of the river.

All trees in the river were measured and data collected for the parameters listed below. A database was compiled of *Faidherbia albida* densities, dynamics, use and impact along the entire Hoanib River.

## SECTION I

### CIRCUMFERENCE

Wherever possible the circumference of the tree was measured. When circumference measurement was not possible due to build up around the base from flood events, diameter was taken. Measurements were taken at 1m above the ground or above any buttress swelling occurring on the tree trunk.

### HEIGHT

Numerous methods were trialed in an attempt to obtain a quick and accurate technique of obtaining tree heights. Methods included: (a) standing a person of a known height at the base of a tree and estimating how many times they fit into the tree height; and (b) using an Inclinometre to obtain an accurate measure. This was not accurate enough and too laborious when measuring such vast numbers of individuals. However, a more accurate and non-laborious method was developed (see Fig. 2).

A ruler was held at arms length and both the person and tree heights taken from the one position. The height of the person (physical height already known i.e. 1.5m) standing at the base of the tree was then measured e.g. 10cm. The ruler height of the tree, e.g. 20cm, was also measured. The actual height of the tree and formula for the measurement was obtained by:

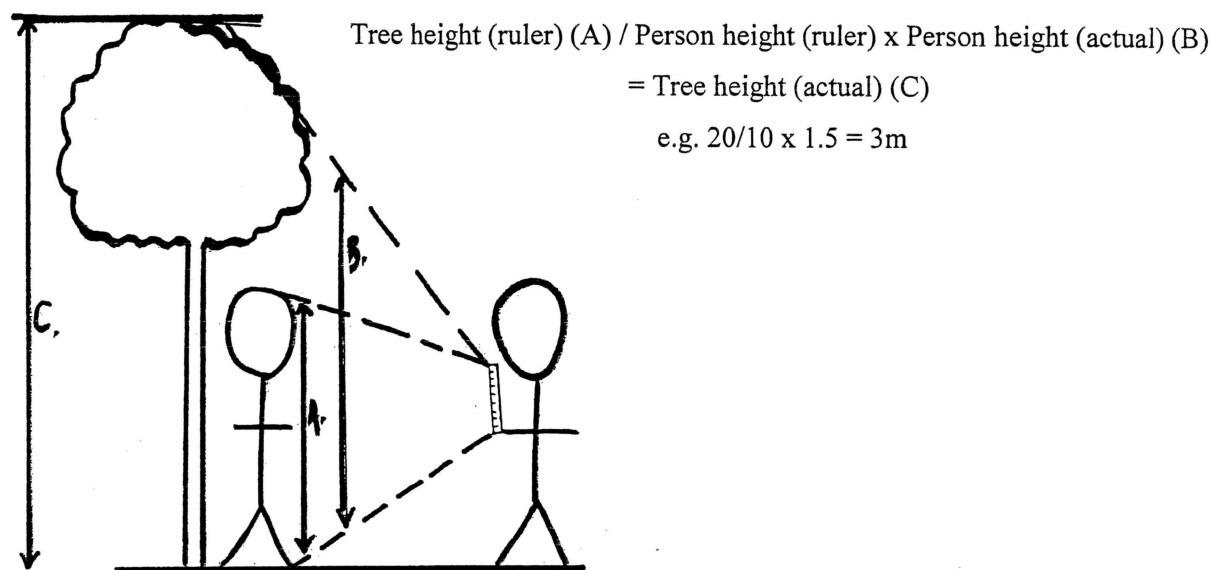


Fig. 2: Stick figure diagram of Height measurement method.

#### CANOPY DEPTH AND HEIGHT TO THICKEST PART OF CANOPY

The depth and height of the thickest part of the canopy were measured in an attempt to establish the average biomass of a tree. An estimation of the total cover of the tree's canopy could be ascertained by using the same technique as mentioned above.

#### STEMS

In the Hoanib River, *Faidherbia albida* is the predominant single-stemmed tree species. However, it can also be multi-stemmed, and if a tree was divided at ground level or into a number of separate stems below a metre, then the number of stems was recorded. The largest stem of the tree was then measured for circumference and height (as mentioned above). Damage assessments for all stems were averaged (see below).

As a result of flood events or animal behaviour, *Faidherbia albida* are occasionally knocked over. In response to this, *Faidherbia albida* have the tendency to coppice. This coppicing growth

## SECTION I

pattern has the ability to produce a number of stems (sucker shoots) that eventually develop into trees with their own root systems. Throughout the survey, these coppicing growth patterns and multiple stemmed-trees were observed and recorded.

### DAMAGE

In the past, external influences such as flood events or animals have changed the growth characteristics of individual *Faidherbia albida*. Whether the damage had a minor effect on the canopy or the total destruction of the tree, it is important to note that any impact may indirectly affect the life span of a tree (CTFT, 1989).

Assessment of animal damage was measured using a number of means and was classified as follows:

- (i) Leaf stripping (LS); this was generally low level damage, resulting in the branches of the tree being stripped of their leaves.
- (ii) Branch Breaking (BB); this was generally moderate level damage, resulting in the branches of the tree broken, either at the main stem or at the ends of larger branches.
- (iii) Main Stem Breakage (MSB); this was generally high level damage, resulting in the main stem of the tree broken, either at the base or along its stem.
- (iv) Bark Stripping (BS); this could vary between low and high level damage. It was recorded when bark had been stripped off the trunk of a tree. If bark stripping had occurred, then the damage was further broken down into the percentage of damage done and whether the damage was recent or had occurred within one year or more. The following categories and their percentages of damage were used:

- (1) = 0-12%
- (2) = 13-25%
- (3) = 26-50%
- (4) = 51-75%
- (5) = 76-86%
- (6) = 87-95%
- (7) = 96-100%

NOTE: It was possible for there to be any combination of damage on the same tree. Previous researchers have used different categories to assess damage but the above categories were used to compare data collected during this study to other previous studies.

- (v) Uprooting (UR); this referred to any tree that had been uprooted and was still alive. Damages, diameter, as well as vertical height, were measured.
- (vi) Standing Dead (SD); this referred to any tree that had died but was still standing upright. Both circumference and height were measured. (For confirmation that the tree was dead, the tips of a branch were broken and examined for 'greenness'. If the tip had any moisture in the stem or it was green, the tree was deemed to be still alive.)
- (vii) Lying Down Dead (LDD); this referred to any tree that had died and fallen down (uprooted). Circumference was measured.

## BROWSE

Browse heights within an area can provide a good indication of use and which animals had been feeding in that environment. For example elephant and giraffe are able to feed much higher than domestic stock and thus produce distinctively high browse lines (>3m). For individual trees, the height to which the *Faidherbia albida* had been browsed was recorded and an assessment was made of which species had been using or feeding off the tree. Initially the browse line was categorised into one of the following:

- (i) Definite      referred to a lack of foliage below a certain height where the canopy had been removed or altered significantly.
- (ii) Some        referred to any amount of browsing which resulted in a change to the canopy but not a removal of the canopy below a certain height.
- (iii) Nil         no change had occurred to the canopy.

The age of the browsing was then considered, specifically if it was either new or old. Most definite browse lines were old, but areas where browsing had occurred recently were classified as new browsing. The height of the browse line was measured from ground level to the height where the canopy began. Three height categories were used:

## SECTION I

- (i) 0-1.5m
- (ii) 1.5-3m
- (iii) >3m

## RESULTS

### HOANIB RIVER

#### FAIDHERBIA ALBIDA DISTRIBUTION

The number of *Faidherbia albida* varied significantly along the length of the Hoanib River (per 5km section) with notable trends observed (see Fig. 3). The highest number of trees occurred in the extreme west nearer the Hoanib Floodplain (approximately 60-70 trees/km) with a marked reduction towards Dubis ( $r^2 = 0.63$ ,  $P < 0.001$ ). Two other areas with high *Faidherbia albida* numbers were observed: western section (approximately 5-10km west of Khowarib) and eastern section (10km east of the Khowarib Schlucht). Lower number areas were associated with either a narrowing of the riverbed, a wetland or human settlement. The exception to this was in close proximity to Khowarib, a semi-floodplain environment. No data were available with respect to the correlation between *Faidherbia albida* numbers and the narrowing or broadening of the riverbed. However, an increase in tree numbers in floodplains and reduced numbers in a narrowing riverbed was observed and supported by research undertaken in the Kuiseb River (Seely *et al.*, 1980).

## SECTION I

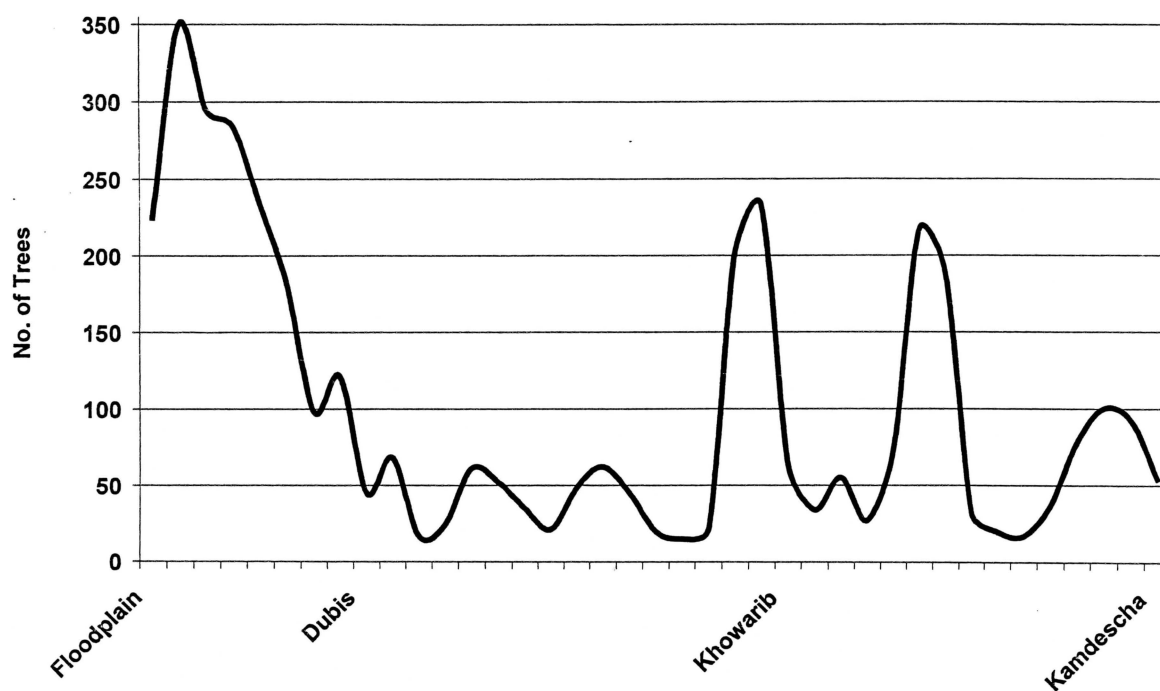


Fig. 3: Numbers of *Faidherbia albida* per 5km, Hoanib River 1998-1999 ( $n = 3845$ )

## SIZE CLASS DISTRIBUTION

The size distribution of *Faidherbia albida* observed throughout the Hoanib River indicates a healthy recruitment of trees in the extreme west, while in the western and eastern stretches, older stands were more dominant ( $n = 3539$ ) (see Fig. 4).



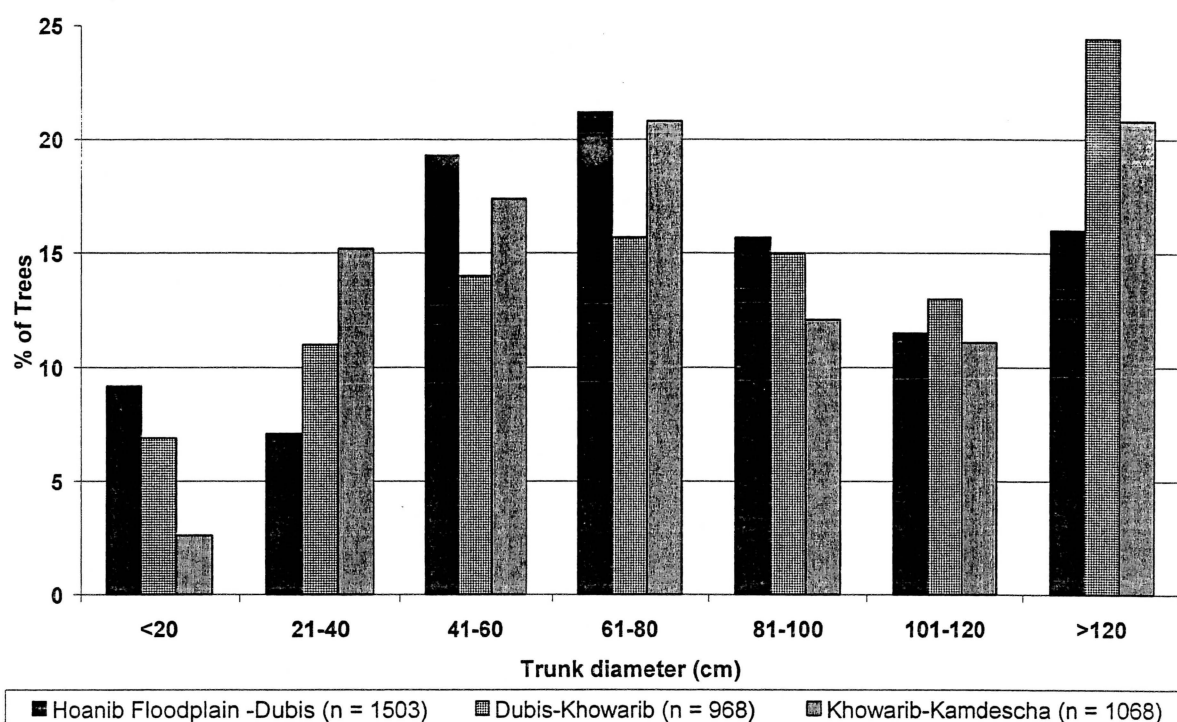


Fig. 4: Size class distribution of *Faidherbia albida*, Hoanib River 1998-1999 ( $n = 3539$ )

The size distribution of <20cm *Faidherbia* trees throughout the three distinct areas of the river decreased in percentage and density from east to west (9.2% ( $n = 139$ ), 7.1% ( $n = 67$ ) and 2.6% ( $n = 28$ ), respectively). However, the size distribution of 21-40cm *Faidherbia* trees increased in percentage and density from east to west (7.1% ( $n = 106$ ), 11% ( $n = 106$ ) and 15.2% ( $n = 162$ ), respectively).

In the 41-60cm and 61-80cm size distribution classes, both the eastern and extreme western sections, had slightly higher percentages of *Faidherbia albida* when compared to the western section [19.3% and 21.2% ( $n = 186$  and 222), 17.4% and 20.8% ( $n = 290$  and 318), and 14% and 15.7% ( $n = 136$  and 152), respectively].

In the largest size class, >120cm, the eastern ( $n = 236$ ) and western section ( $n = 222$ ) percentages were markedly higher than observed for the extreme west ( $n = 241$ ) (24.4%, 20.8% and 16%, respectively).

## SECTION I

Along the river, only three sections showed a significant deviation from a relatively even height distribution (see Fig. 5). The greatest mean heights were observed toward Kamdescha (eastern section) ranging from 14.85 to 19.44m. However, an observed drop in mean heights occurred following the Kamdescha stretch and continued 30km downstream into the Khowarib Schlucht – ranging from 12.6 to 14.7m ( $r^2 = 0.53$ ,  $P < 0.001$ ). In the extreme west, the lowest mean heights were observed in the Hoanib Floodplain, ranging from 11.29 to 14.29m over a 20km stretch ( $r^2 = 0.599$ ,  $P < 0.001$ ).

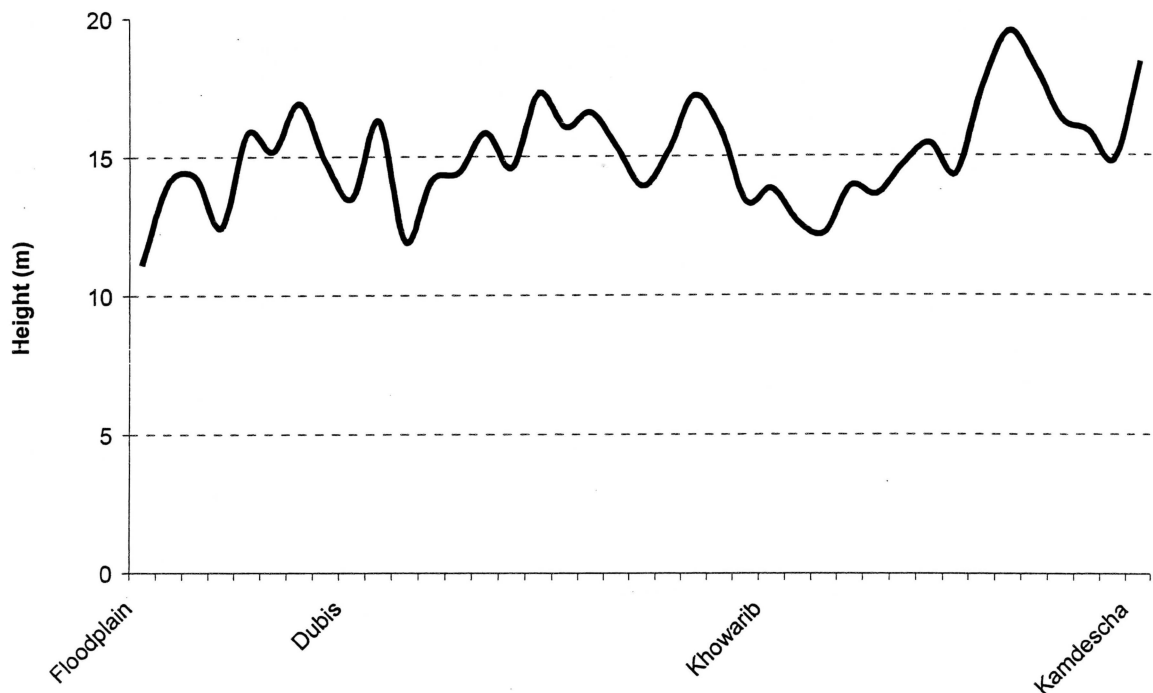


Fig. 5: Mean Heights of *Faidherbia albida* per 5km, Hoanib River, 1998-1999 ( $n = 3740$ )

A significant exponential or 'J curve' growth pattern was observed when comparing mean tree heights with diameters ( $r^2 = 0.99$ ,  $P < 0.001$ ) (see Fig. 6). Insufficient data were available for trees  $< 1.5$ m in the eastern section, though it was clearly evident that the taller the tree, the larger the diameter.

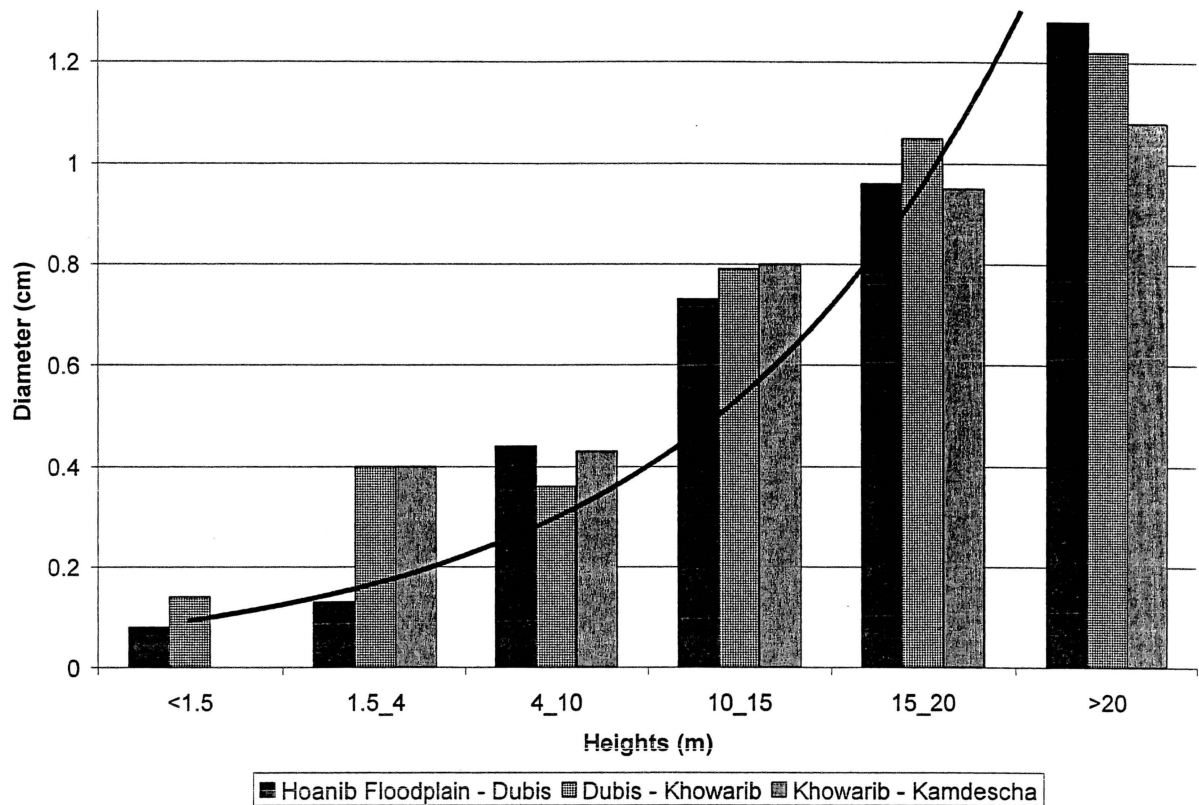


Fig. 6: Mean Heights (m) vs Diameter (cm) of *Faidherbia albida*, Hoanib River 1998-1999 ( $n = 3484$ ) (with exponential curve)

The number of stems per *Faidherbia albida* were analysed with 1 stem being the greatest in number, while >4 stems, and up to 40 stems, were observed for a single tree (in excess of 0.5m) (see Fig. 7). The results of the study showed single-stemmed *Faidherbia albida* to be predominant, although numerous multi-stemmed trees are prevalent (Nott, 1987; Viljoen and Bothma, 1990).

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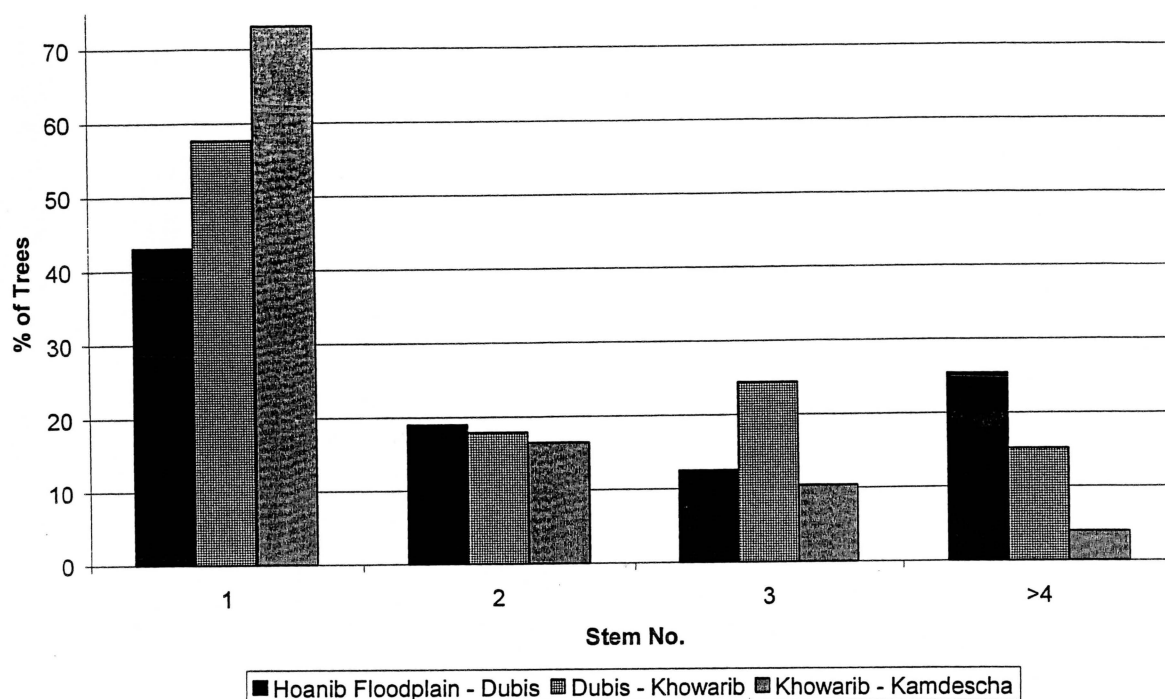


Fig. 7: Mean number of *Faidherbia albida* stems per 5km, Hoanib River, 1998-1999 ( $n = 3623$ )

A comparison of stem numbers with mean diameters shows a significant trend (and strong linear correlation) for the east and extreme west (see Table 1). A gradual decline in mean diameter size was observed for trees with 1 stem to those with >4 e.g. extreme west, diameter of 1.03m for a single stemmed tree to 0.6m for multi-stemmed trees with >4 stems ( $r^2 = 0.81$ ,  $P < 0.001$ ) and eastern section 0.9m diameter for 1 stem to 0.59m for >4 stems ( $r^2 = 0.96$ ,  $P < 0.001$ ). The western section consisted of a relatively even mean diameter, whether a tree had 1 stem or more (0.88-0.91m range).

Table 1: Stem number vs Mean Diameter (m) of *Faidherbia albida*, Hoanib River 1998-1999 ( $n = 3684$ )

Section of River	Stem number vs Mean Diameter			
	1	2	3	>4
East ( $n = 1073$ )	0.9m	0.75m	0.66m	0.59m
West ( $n = 933$ )	0.88m	0.91m	0.89m	0.89m
Extreme west ( $n = 1678$ )	1.03m	0.84m	0.88m	0.6m

## BROWSE HEIGHTS

The browse heights observed throughout the Hoanib River indicated a relationship between those areas populated by wildlife only and those populated by both domestic stock and wildlife seasonally (see Figs. 8 and 9).

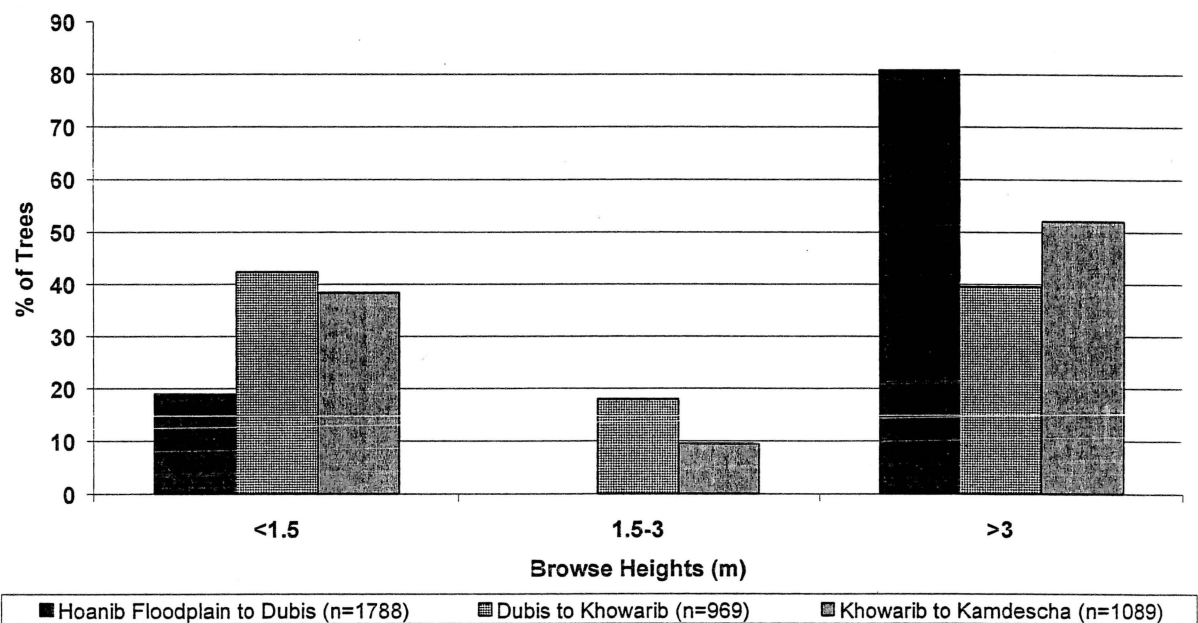


Fig. 8: Browse heights of *Faidherbia albida* in the Hoanib River, 1998-1999.

A marked variance was observed in browse heights from the extreme west ( $n = 1788$ ), as compared to the western ( $n = 968$ ) ( $r^2 = 0.53$ ,  $P < 0.001$  (neg. correlation)), and eastern sections ( $n = 1089$ ) ( $r^2 = 0.59$ ,  $P < 0.001$ ). 80.9% ( $n = 1446$ ) of all *Faidherbia albida* in the lower Hoanib River had a browse height greater than 3m, indicating a large influence by elephant and giraffe. The percentage of browse heights greater than 3m observed for the western ( $n = 384$ ) and eastern sections ( $n = 568$ ) was relatively high (39.6% and 52.1%, respectively), and most likely influenced by areas frequented by large herbivores in these stretches of the river.

At least double the percentage of trees with browse heights at or below 1.5m were observed in Dubis to Khowarib ( $n = 410$ ) ( $r^2 = 0.48$ ,  $P < 0.001$ ) and Khowarib to Kamdescha ( $n = 418$ ) ( $r^2 =$

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0.41,  $P < 0.001$ ), compared with the Hoanib Floodplain to Dubis ( $n = 340$ ): 42.4%, 38.4% and 19%, respectively.

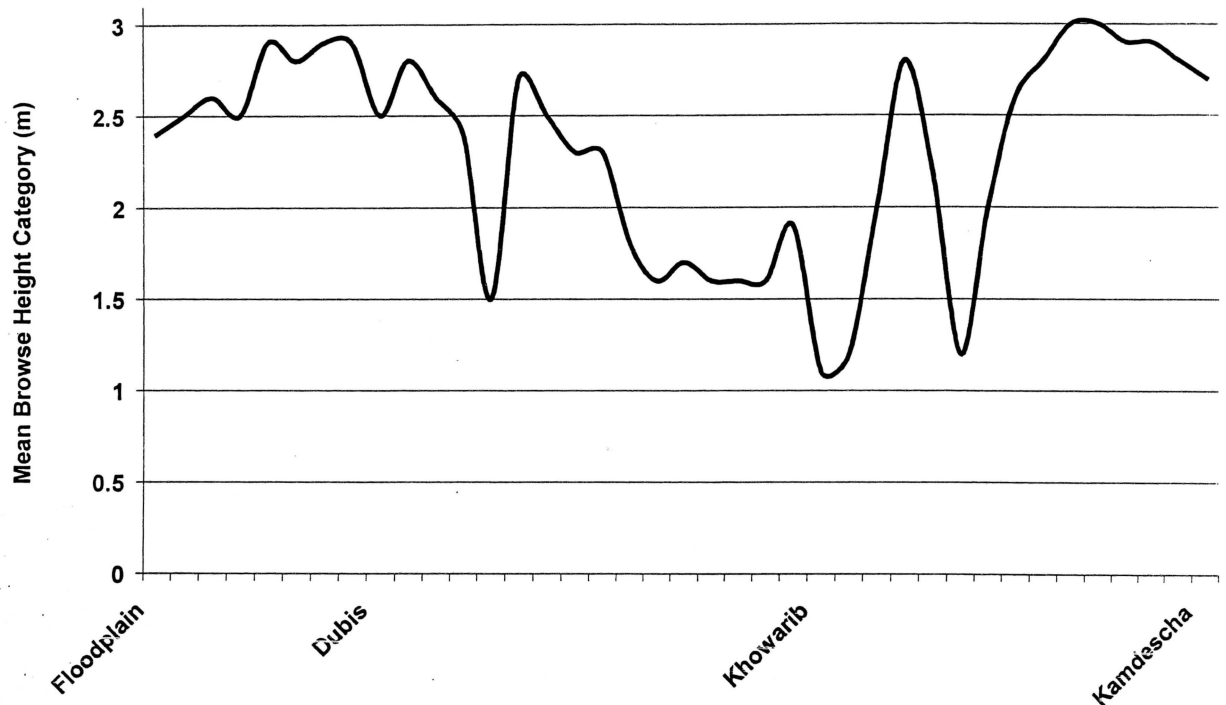


Fig. 9: Mean browse heights of *Faidherbia albida* per 5km, Hoanib River, 1998-1999 ( $n = 3845$ )

There is possibly a relationship between villages and domestic stock ranges, and lower mean browse heights (Leggett *et al.*, 2001). The lower mean browse heights of *Faidherbia albida* were observed at or within close proximity to permanent or semi-permanent settlements; Khowarib, Sesfontein, and Ombaadjie (eastern entrance of the Khowarib Schlucht) (1.1 – 1.9m mean browse range).

The greatest influences on mean browse heights were observed at opposite ends of the river course; between Dubis and Hoanib Floodplain (2.4-2.9m mean browse range), in the 30km stretch downstream from Kamdescha (2.6-3m mean browse range) and in the Khowarib Schlucht (2.7m mean browse height). The increased mean browse heights correspond positively with the density and impact of large herbivores residing in or seasonally using the river.

## FODDER USE AND IMPACT

Leaf stripping (LS) and branch breaking (BB) were observed in high percentages along the entire length of the river (see Table 2); a good indication of *Faidherbia albida* use as an important food source. Bark stripping (BS), indicated a high percentage of tree use, particularly in the extreme west and eastern reaches of the Hoanib River. Significant percentages (14.8%) of trees with main stem breakage (MSB) were observed in the extreme west, with a gradual decline heading east. The percentage of uprooted (UR) trees observed along the river was not significant, although slightly higher percentages were observed in the western and eastern reaches (3.9% and 3.1%, respectively). Lying down dead (LDD) and standing dead (SD) trees were observed in small percentages along the river.

**Table 2: All forms of damage of *Faidherbia albida* (as percentage), Hoanib River, 1998-1999**

Section of River	Damage Categories (%)						
	LS	BB	BS	MSB	UR	LDD	SD
East ( <i>n</i> = 1073)	75.8	71.3	56.9	4.9	3.1	2.2	0.9
West ( <i>n</i> = 933)	95.2	88.6	34	11.9	3.9	1.9	0.6
Extreme west ( <i>n</i> = 1678)	84.7	84.4	48.9	14.8	0.4	3.3	1.7

LS – Leaf Stripping

BB – Branch Breaking

BS – Bark Stripping

MSB – Main Stem Breakage

UR – Uprooting

LDD – Lying Down Dead

SD – Standing Dead

After the exceptional 1999/2000 wet season, in which the river flowed through the dunes into the coast, a count of the lower Hoanib River recorded 100 uprooted *Faidherbia albida*. This was approximately 15 times greater than the percentage of trees observed before the flood events (see Table 2) and accounted for 6% of the *Faidherbia albida* population in the lower Hoanib River. Jacobson and Jacobson (1998) reported that the flood event following their survey eroded 2.8% of the *Faidherbia albidas*, and attributed the impact to lateral channel erosion and mass wasting of the banks.

The eastern reaches of the river were also surveyed but no uprooted *Faidherbia albida* were observed. However, a significant percentage of Mopane *Colophospermum mopane* were found uprooted.

## BARK USE

Bark damage was observed on almost all *Faidherbia albidas* along the Hoanib River ( $n = 3845$ ) (see Fig. 10). However, no bark damage was observed along a 5km stretch of the eastern stretch (Khowarib Schlucht), an indication of a lack of large herbivore use, accessibility and human pressures.

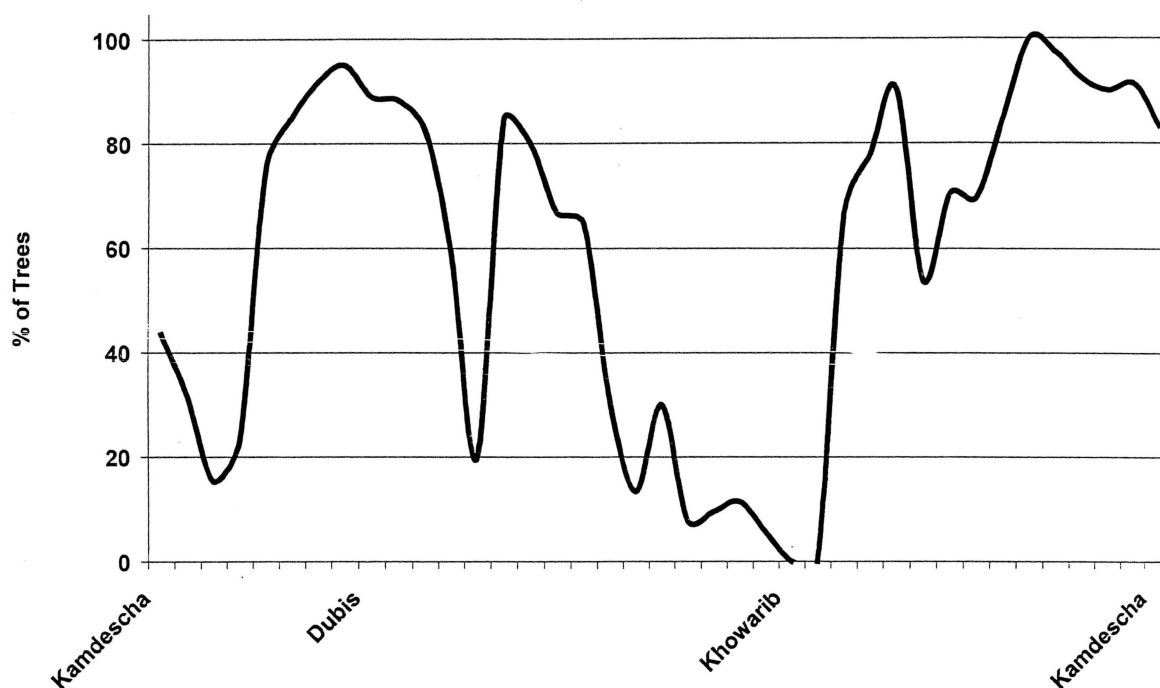


Fig. 10: Percentage of bark damage of *Faidherbia albida* per 5km, Hoanib River, 1998-1999 ( $n = 3845$ )

The percentage of bark damage was highest in areas where wildlife predominate (permanently or seasonally):

- Extreme west: Dubis wetland , from 10km east to 20km west ( $n = 748$ ; 75.2–95% range)
- West: 30km east of Dubis wetland for 10km ( $n = 72$ ; 80–84.6% range)
- East: 20km east of Khowarib Schlucht for 10 km ( $n = 87$ ; 77.8–90.4% range) and Kamdescha to 30km west ( $n = 361$ ; 83.3–100 % range)



The lowest percentage of damage was observed in the western and eastern stretches (Khowarib and the Schlucht ( $n = 39$ ; 5.6–11.4% range) and also 10-15km east of the Hoanib Floodplain) while in the extreme west a steep decline in bark use at 20-25km west of Dubis wetland was observed. Along the extent of the river a weak correlation between distance and damage can be inferred: extreme west ( $r^2 = 0.67$ ,  $P < 0.001$ ), west ( $r^2 = 0.68$ ,  $P < 0.001$ ) and east ( $r^2 = 0.41$ ,  $P < 0.001$ ).

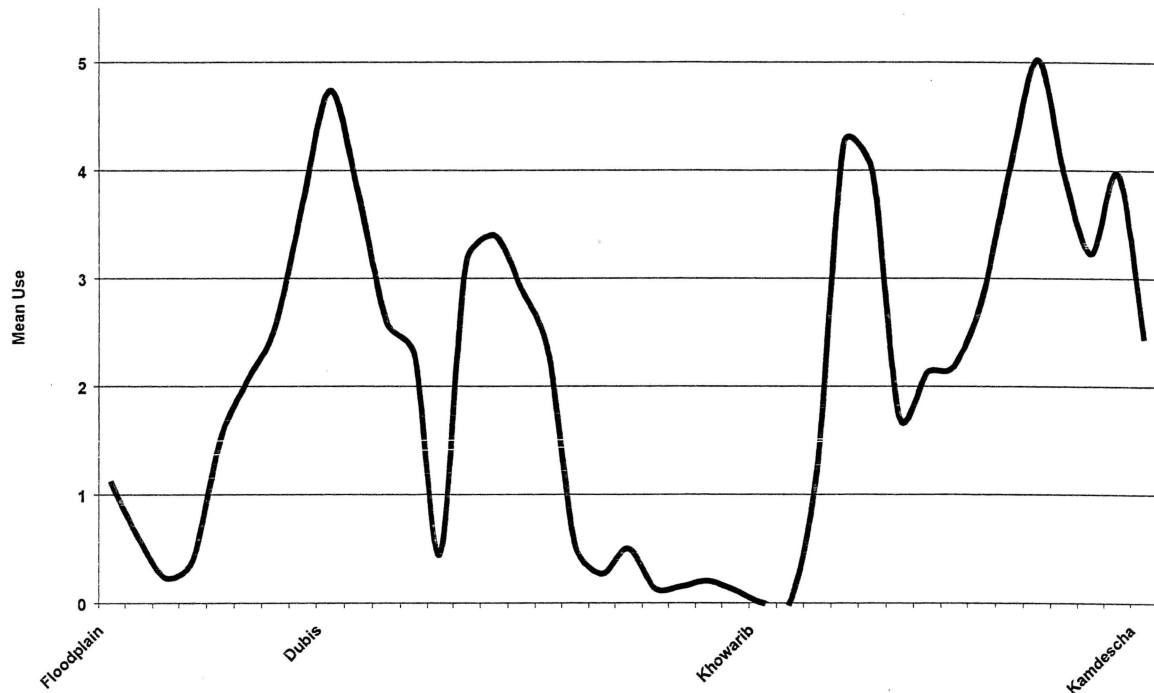


Fig. 11: Mean bark use of *Faidherbia albida* per 5km, Hoanib River, 1998-1999 ( $n = 3845$ )

A correlation was observed between the percentage of *Faidherbia albida* with bark damage and mean impact use (see Fig. 11). Higher percentages of bark damage were observed to correspond with a higher mean use of individual trees i.e. 95% bark damage correlated to 4.7 mean use, while 19.7% correlated to a mean use of 0.5. No sections of the river were observed to have a mean use greater than 5 (76-86%), though individual *Faidherbia albida* were observed to have a degree of damage as high as 7 (96-100%). Minimal use was observed in the western and eastern stretches (Khowarib village and the Schlucht), while highest mean use was observed in wildlife dominated areas (east and extreme west). The low mean use of bark in sections of the extreme west (0.38-1.1 mean use range) coincides with a lack of permanent elephant populations, though it was greater than that reported by Nott (1987) and Viljoen and Bothma (1990).

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In addition to the percentage of accumulated bark damage observed along the Hoanib River, the approximate time period that the damage occurred was also recorded (categories 1-3). The majority of *Faidherbia albida* bark damage observed was older than a year (see Table 3). This also correlated with a greater percentage of bark damage observed in trees with damage older than a year. Minimal 'recent' bark damage was observed in both the western and extreme western sections (4.7% and 5.6%, respectively). However, in the eastern section, 19.1% of observed damage was 'recent'.

**Table 3: Age of bark damage of *Faidherbia albida* (as percentage) in the Hoanib River, 1998-1999**

Section of River	Age of Bark Damage			$P < 0.001$
	Recent (%) (within last month)	Current Year (%)	Older than a Year (%)	
East (n=1028)	19.1	45.7	81.8	$r^2 = 0.99$
West (n=255)	4.7	59.6	89	$r^2 = 0.97$
Extreme West (n=880)	5.6	41.6	89.3	$r^2 = 0.99$

Scar or bark use reported by Viljoen and Bothma (1990) on the *Faidherbia albida* in the extreme western section was thought to represent eight year old damage or more, as bark re-growth was observed to be minimal. Therefore, the percentage of bark damage can be assumed to have increased compared to that reported by Viljoen and Bothma.

Furthermore, when comparing the damage observed with the numbers of *Faidherbia albida*, a negative correlation ( $r^2 = 0.776$ ,  $P < 0.001$ ) was observed in the extreme west (Hoanib Floodplain and Dubis). In the same stretch of the Hoanib River a negative correlation ( $r^2 = 0.63$ ,  $P < 0.001$ ) between the damage observed and the mean diameters of *Faidherbia albida* can also be inferred

## DISCUSSION

### HOANIB RIVER

#### *Faidherbia albida* numbers

The highest numbers of *Faidherbia albida* in the Hoanib River occur in the extreme western stretch, nearer the Hoanib Floodplain. Large numbers of trees were also observed in the semi-floodplain environment of the Khowarib plains. A higher density of trees was observed in both these floodplain areas and a trend of increased width correlating with the numbers of *Faidherbia albida* was observed. After the Khowarib Schlucht, the river branches out a few kilometres downstream resulting in a broader riparian forest and with high density of *Faidherbia albida*. The only other large stand was observed in the eastern section from the Khowarib Schlucht, where the river bows and loops. The banks along this section of the river are shallow and erosion by floodwaters is less than in the steep banked environment. Along the remainder of the river course the numbers of *Faidherbia albida* were observed at less than 20 trees/km.

The number and distribution of *Faidherbia albida* throughout the river appears not to be significantly affected by humans or domestic stock, but is rather a result of the river's natural course and minimal wildlife influences. Widening of the riverbed and floodplain areas has created environments that assist the establishment of *Faidherbia albida*. The accumulation of nutrient rich sediments in the extreme west and floodplain environments, combined with increased organic debris provide shelter for seedling establishment and a stable environment for growth.

#### *Size class distribution*

The size class distribution observed along the Hoanib Rivers indicates a relatively even age distribution with the lowest percentages of *Faidherbia albida* observed in the smallest size classes.

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The current recruitment rate of *Faidherbia albida* appears to be relatively healthy in the extreme western section of the river, from Dubis to the Hoanib Floodplain. The percentage declines towards the east, with the Khowarib to Kamdescha section recording the lowest rates of recruitment and established seedlings. This impact on recruitment rates has been observed elsewhere in Namibia (Ward and Breen, 1983), as domestic stock eat the majority of seedlings and new shoots, not only targeting *Faidherbia albida*. As trees increase in size they are less prone to large impacts by domestic stock. In the upper reaches of the river, the smaller age populations of *Faidherbia albida* were observed to be relatively stable compared to the other areas to the west and extreme west. Significant numbers of all other size classes of *Faidherbia albida* were observed throughout the river, including those >120cm diameter.

The even distribution of *Faidherbia albida*, indicative of a disequilibrium population, represents a population that is currently healthy. However, a change in preference feeding of large herbivores, periods of high aridity, or severe annual flooding events may inhibit the establishment of future populations (Laws, 1970; Ward and Breen, 1983; Jacobson and Jacobson, 1998).

### *Browse*

A significant correlation was observed between *Faidherbia albida* browse heights and wildlife densities (Leggett *et al.*, 2001). Approximately 80% of all browse heights in the lower Hoanib River were observed to be higher than 3m, a direct impact of elephants and giraffe. Of the remaining trees surveyed in the extreme west, all browse height percentages were less than 1.5m and attributed to the trees and seedlings in the younger age class categories. The browsing of domestic stock and wildlife (including giraffe *Giraffa camelopardalis*, gemsbok *Oryx gazella*, kudu *Tragelaphus strepsiceros* and elephant) upon young *Faidherbia* seedlings and coppices has been well reported throughout Africa, similar to impacts observed throughout the Hoanib River (CTFT, 1989; Jacobson and Jacobson, 1998).

In the western and eastern reaches of the river, approximately 40% of all browse heights were observed to be less than 1.5m. These low browse heights directly correlated with those areas predominantly populated by domestic stock and permanent or seasonal dwellings. Competition between domestic stock and wildlife has resulted in stretches of the river being under-used. In ephemeral river catchments to the south of the Hoanib, the fruits and pods of *Faidherbia albida*

are collected by subsistence farmers to help supplement dry times food availability (SDP 2, 1996; Jacobson *et al.*, 1995). The pods form a fodder base for the domestic stock at a time when food availability is otherwise minimal and nutrient low in dry grass (CTFT, 1989). In the Hoanib River catchment, domestic stock feed on the fallen pods of the *Faidherbia* trees during the dry times, though very few farmers actively collect and store them.

Low percentages of browse heights (1.5-3m) were observed along the river and this can be attributed to areas where there is a transition area between domestic stock and wildlife use. The browse heights are thus a little higher, though similar to the situation around villages, the trees are under-used, especially during the drier periods. Springbok *Antidorcas marsupialis*, kudu and gemsbok seasonally occupy the plains surrounding the Khowarib, Warmquelle and Sesfontein villages, and feed on *Faidherbia albida* pods in this stretch of the river.

A significant percentage of browse heights higher than 3m was observed in the extreme western and eastern sections of the river, with a slightly higher percentage observed in the eastern section where seasonal and resident populations of both elephant and giraffe occur. In the western section, from below Sesfontein to Dubis, an expansion of the elephant range to former seasonal feeding grounds was observed and resulted in a larger percentage of trees browsed above 3m (Viljoen and Bothma, 1990; Jacobson and Jacobson, 1998; Leggett *et al.*, 2001). As a result of this re-expansion, increasing competition for resources i.e. *Faidherbia albida* will continue, which in time may also have social and human implications (e.g. livestock, human and crop production conflicts).

In the extreme western and eastern stretches of the river higher mean browse heights were observed compared with the western reaches. The highest means were recorded in the extreme east (Kamdescha area), an indication of high use of *Faidherbia albida* by elephants and giraffe. Three sharp declines in mean browse heights were observed along the length of the Hoanib River; Khowarib Schlucht (east); east of the Dubis wetland (west); and east of the Khowarib Schlucht (east), the latter two both have characteristic steep embankments and narrow riverbeds.

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### *Bark Use*

Bark damage of *Faidherbia albida* was observed along the entire river, with the exception of the Khowarib Schlucht (eastern section) where no damage was recorded. The highest percentage damage was observed in the eastern section nearer Kamdescha, and in the extreme western section around the Dubis wetland. There was evidence of increased bark damage in areas populated by elephant, whether permanently or seasonally. In the eastern section, the percentage of bark damage was marginally higher than that in the extreme west, even though elephant reside in the area are assumed to be less reliant on the river than those in the extreme west (Legget *et al.*, 2001).

Bark damage occurring along the west stretch of river (nearest Khowarib) is not assumed to be a result of elephant, though previously described, they have and still do move throughout this area occasionally (Owen-Smith, 1971; Viljoen, 1987; Lindeque and Lindeque, 1991; Jacobson and Jacobson, 1998). This impact around human populations is not uncommon, as elephant prefer to use areas away from villages and people. However, if resources are limited, the elephant will encroach (i.e. near Kamdescha). Other wildlife and domestic stock have also been observed stripping bark from *Faidherbia albida*, though to a far lesser degree than elephant (CTFT, 1989).

### *Mortalities*

Mortalities of *Faidherbia albida* and population changes are thought to be the result of droughts and lack of flood events, while ground water extraction, as observed in the Kuiseb river, was reported to have a direct impact (Jobst, 1996; Jacobson and Jacobson, 1998; Le Maitre *et al.*, 1999). Furthermore, the velocity and frequency of floods, combined with changes in the river direction and erosion of riverbanks is assumed to be the major influence in the uprooting and mortalities of *Faidherbia albida* in the Hoanib River (Jacobson *et al.*, 1995).

Jobst (1996) reported that smaller *Faidherbia albida* (diameter <30cm) are less capable of handling water stress than larger trees, and thus are more threatened by a decrease in the water table and flood regime. Furthermore, Jobst reported that in the Kuiseb River there are more dying or dead young trees than older trees, indicating an inability of younger trees to reach the deep ground water source.

In contrast, Ward and Breen (1983) reported that the roots of younger trees are able to adapt better to a decrease in the ground water level and would be less water stressed. They also reported that during their study period a considerable number of large mature *Faidherbia albida* collapsed and died. Le Maitre *et al.* (1999) support the Ward and Breen hypothesis stating that *Faidherbia albida* mortalities occurred in mature trees that were not able to send out new roots if underground aquifer depths were lowered.

Therefore, research suggests that both the seedlings and the large mature trees are most susceptible to change in the water availability. During this study a large increase in uprooted mature trees occurred following seasonal flood events, 6% of the trees in the extreme western reaches succumbed to the impact. However, following the floods, an increase in seedling establishment was observed.

Reports of *Faidherbia albida* being uprooted (and dying) by elephant throughout other areas of Africa were not supported by this or previous surveys undertaken in the Hoanib River (Laws, 1970; Caughley, 1976; Nott, 1987; Viljoen and Bothma, 1990; Jacobson and Jacobson, 1998). During this study very low percentages of uprooting (UR) were observed throughout the Hoanib River. Elephant residing in the riverbeds of the west and extreme west are seasonal and the impact that they have on the trees is most likely not significant enough to observe large scale uprooting as observed elsewhere.

Low percentages of trees were observed to be standing dead (SD), with only marginally higher percentages observed in the extreme west. Those observed lying down dead (LDD) included a slightly larger percentage than SD, though the percentage was still negligible. Whether the mortalities were due to ring barking, flood events, or a change in the underground aquifer flow is unknown. It is evident that elephant do not have the same major impact on the age structures of *Faidherbia albida* in the Hoanib River as reported elsewhere in Africa.

## SECTION I

### MANAGEMENT IMPLICATIONS

*Faidherbia albida* are widely distributed along the Hoanib River as well as all other westerly flowing ephemeral river systems of Namibia. Its importance as a fodder source for both domestic stock and wildlife is invaluable, though increased use by humans (for livestock) for hard-times fodder is still viable.

The human impact on *Faidherbia albida* is minimal compared to that in other environments in Africa, thus its continued growth is dependent on animal influences and climatic variability i.e. flooding events. The population structure of *Faidherbia albida* in the Hoanib River indicates a relatively even sized distribution (dis-equilibrium), though climatic conditions and the continued re-expansion of elephant range could help relieve impact upon the riparian vegetation.

Dramatic changes in ground water through the abstraction of water from boreholes, springs and wetlands, and the damming of rivers can cause severe stress on and potential mortalities of large trees in a riparian forest. Seasonal changes throughout the Hoanib River have impacted and will continue to impact mature *Faidherbia albida*, as they are vulnerable to small shifts in groundwater availability and flood water events. It is important to understand the ecological implications on riparian vegetation of upstream use, existing or potential damming and extraction projects, and potential agricultural and tourist ventures. This knowledge could then be used to provide useful information for many people and their stock relying on *Faidherbia albida*.

Wildlife numbers in the Kunene Region have gradually increased since the early 1980s, predominantly due to the active participation and monitoring of MET and NGOs, including the implementation of the community game guard system (Leggett, 1998; Owen-Smith, pers.comm.). As numbers increase, so too does the food base needed to support the animals. A number of additional questions therefore need to be understood, in particular the notion of the sustainability of wildlife populations and their impact on the riparian vegetation. Have *Faidherbia albida* reached saturation levels as an available food source with respect to the Hoanib River's observed browse heights? If not, what is the longer-term availability of *Faidherbia albida* for the wildlife in the river? Movement patterns of wildlife have increased and re-expansion into areas occupied seasonally is occurring, but when conflict arises with communities, who will ultimately suffer? Active management through the emerging conservancy program may alleviate a number of these problems, while continued tolerance or lack of, may be the underlying influences.



Nott (1987) concludes that domestic stock should be restricted from entering the lower Hoanib River, as competition between wildlife and domestic stock for available water resources ultimately results in the domestic stock remaining (and exploiting) within direct proximity of water. This hypothesis is not without criticism, in particular from local natural resource users. However, across the northwest there is a long history of newly created boreholes and springs (seasonal or permanent) at which communal farmers have settled. The impact is evident in areas such as Palmfontein (wetland) near Erwee, which was a seasonal refuge for hard-times grazing but today has emerged into a permanent settlement for a number of families. Coupled with this Palmfontein is subject to large amounts of water abstraction which supplies the nearby village of Erwee with water (Fuller and Koujo, 2000).

Articles on and advertisements for Kaokoland and in particular, the lower Hoanib River, have recently appeared in numerous popular magazines, editorials and documentaries. This exposure has resulted in tourism within the northwest increasing exponentially over the last 5 years, as this 'last wilderness' has opened up. Discussions between Government ministries, NGOs, CBOs, tourism concessionaires and operators, traditional leaders and local communities have been held recently in an attempt to establish management options and plans for the lower Hoanib River's sustainable future. Escalating and uncontrolled tourism in this stretch of the river may not only impact upon elephant behaviour, but could also affect the river course, a pristine environment and potential world heritage site.

## CONCLUSION

*Faidherbia albida* are the dominant tree species in the Hoanib River. Predominantly a single-stemmed species, many multi-stemmed *Faidherbia albida* occur throughout the river.

The number of trees (per 5km) varied markedly along the length of the river with the highest numbers observed in the extreme west. Furthermore, a trend was observed between increased numbers and floodplains.

The size class distribution throughout the course of the river indicated a healthy population (dis-equilibrium) though changes in climatic conditions, groundwater levels and elephant impact can all have a detrimental impact. The greatest impact on *Faidherbia albida* populations was observed following flood events, when elephant damage was wide spread.

The mean heights of *Faidherbia albida* ranged from approximately 11m to 20m with the largest mean heights observed in the east. An exponential growth curve and significant correlation was observed when assessing the mean heights versus diameters i.e. smallest diameters equaled smallest heights, largest diameters equaled largest heights.

Areas dominated by wildlife were observed to have browse lines greater than three metres (elephant and giraffe) when compared to those in close proximity to settlements and domestic stock. Bark damage caused by elephants was also high throughout the river though again impact was greater in areas away from settlements.

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**APPENDIX A**

***FAIDHERBIA ALBIDA* FIELD SURVEY FORMS**

## SECTION I

***Faidherbia albida* (Anaboom) Survey - data sheet**

Date:

Recorder/Researcher:

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**APPENDIX B**  
**CASE STUDY: LOWER HOANIB RIVER**



## CASE STUDY: LOWER HOANIB RIVER

### RESULTS

#### SIZE CLASS DISTRIBUTION

Viljoen and Bothma (1990; 93) observed the size distribution of *Faidherbia albida* in the lower Hoanib River to be “conforming to a reverse J-shaped curve...(and) indicative of a climax population” ( $n = 206$ ) (see Fig. 12). Excluding dead trees and those less than 0.5m tall, their recruitment rate (diameter = 0-20cm) was observed to be 30.1% ( $n = 62$ ) of the population, while the 21-40cm size distribution class represented a further 25.2% ( $n = 52$ ). In contrast, the largest age class structure ( $>120$ cm) represented only 1.9% ( $n = 4$ ) of all surveyed trees.

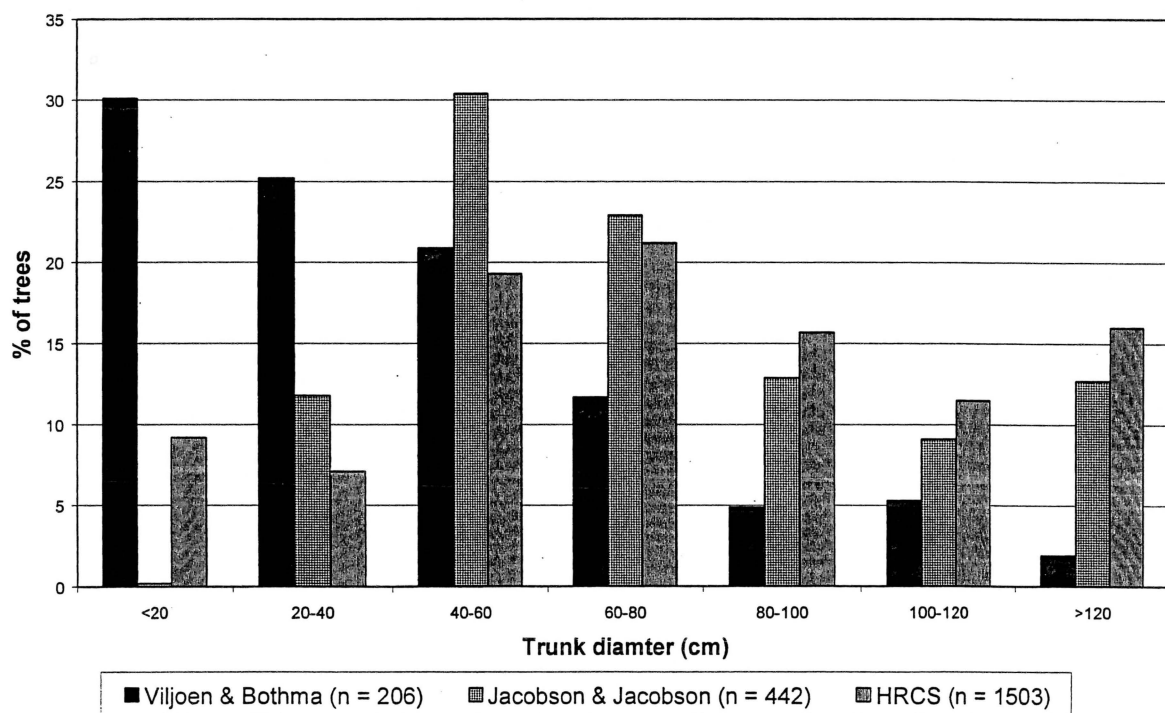


Fig. 12: Size class distribution of *Faidherbia albida*, lower Hoanib River, 1982-1999

Jacobson and Jacobson (1998) observed a marked variation in size class distribution to that of Viljoen and Bothma (1990). In Jacobson and Jacobson (1998), the size class distribution conformed more to a 'bell-shaped' curve or normal distribution, though no statistical variance was observed. The percentage of 2-20cm trees was observed at 0.2% ( $n = 2$ ), more than two orders of magnitude below the 30.1% observed by Viljoen and Bothma (1990). A substantial decline in the 21-40cm ( $n = 52$ ) size class distribution was also reported, adding to a lack of apparent recruitment in the river between 1982 and 1995.

During this study, *Faidherbia albida* in the lower Hoanib River ( $n = 1503$ ), indicated the 0-20cm size class distribution to be 9.2% of the population ( $n = 139$ ), a large increase from that of Jacobson and Jacobson (1998), yet approximately a third of the recruitment rate reported by Viljoen and Bothma (1990). The 21-40cm size class distribution was observed to be less than both previous surveys, 7.1% ( $n = 106$ ), with the last three size classes (81-100cm, 101-120cm and >120cm) observed to have greater densities than all previous surveys (15.7% ( $n = 236$ ), 11.5% ( $n = 173$ ) and 16% ( $n = 241$ ), respectively). The size class distribution of *Faidherbia albida* during this study indicates a less pronounced 'bell-shaped' curve and more even distribution across the size classes, when compared to the two previous surveys.

## DEBARKING

Viljoen and Bothma (1990) reported that 71.8% ( $n = 142$ ) of *Faidherbia albida* surveyed showed bark utilisation scars (see Fig. 13). Of those indicating damage, 31.6% ( $n = 45$ ) had been observed to have >20% bark removed (attributed to elephant use). Nott (1997) reported that elephants had removed >20% of the bark from 74% ( $n = 124$  of 168) of mature (>4m) *Faidherbia albida*.

This study observed that 42.2% ( $n = 619$ ) of *Faidherbia albida* displayed no signs of bark removal. Of the 57.8% ( $n = 847$ ) of *Faidherbia albida* which did, 35.1% ( $n = 514$ ) was observed between 0-25% of bark removal, while only 22.7% ( $n = 333$ ) displayed greater than 25% bark removal.

As first reported by Viljoen and Bothma (1990) in 1982, 100% of trees near Dubis wetland displayed signs of debarking (see Fig. 13). However, 20km west a reduction of 50% in the

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percentage of debarking was reported. From this stretch of the river coursing westward, a significant decline in the percentage of use was observed toward the Hoanib Floodplain where only 1% of damage was observed. Viljoen and Bothma (1990) further reported a significant linear correlation between the amount of bark utilised and mortalities ( $n = 5$ ) of *Faidherbia albida* ( $r = 0.92$ ,  $t = 5.14$ ,  $P < 0.01$ ,  $df. = 5$ ). However, Jacobson and Jacobson (1998) reported incidents of debarking occurring throughout the river, although the trees actually ring-barked ( $n = 5$ ) were low, though comparable to that reported by Viljoen and Bothma (1990).

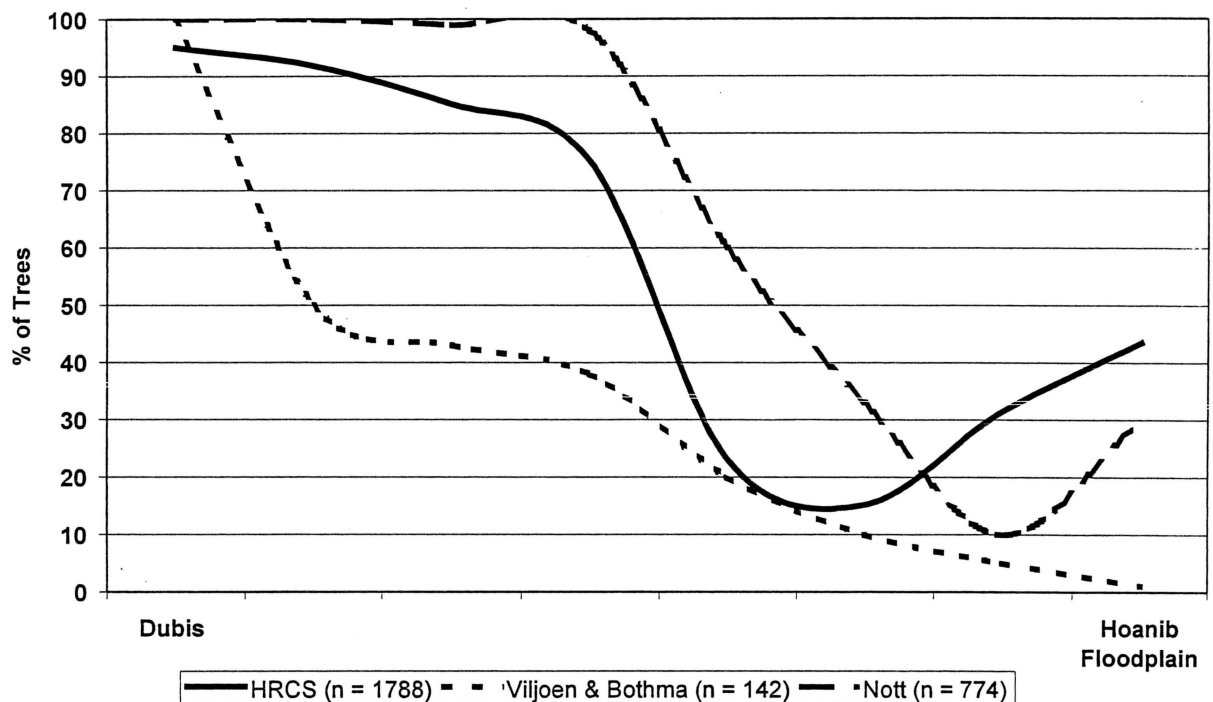


Fig. 13: Percentage of bark damaged *Faidherbia albida* per 5km, lower Hoanib River, 1982-1999

During this study a similar linear trend in the percentage of bark use to that reported by Nott (1987) was observed. However, this study observed a more pronounced increase in percentage use close to the Hoanib Floodplain. Though the observations nearly shadowed Nott's, a slight decrease in the percentage use of trees close to Dubis wetland was observed. An increased decline in the percentage use was observed at approximately 25-30km west of Dubis – from 75.2% to 23.2%, within a 5km stretch, similar to that reported by Nott.

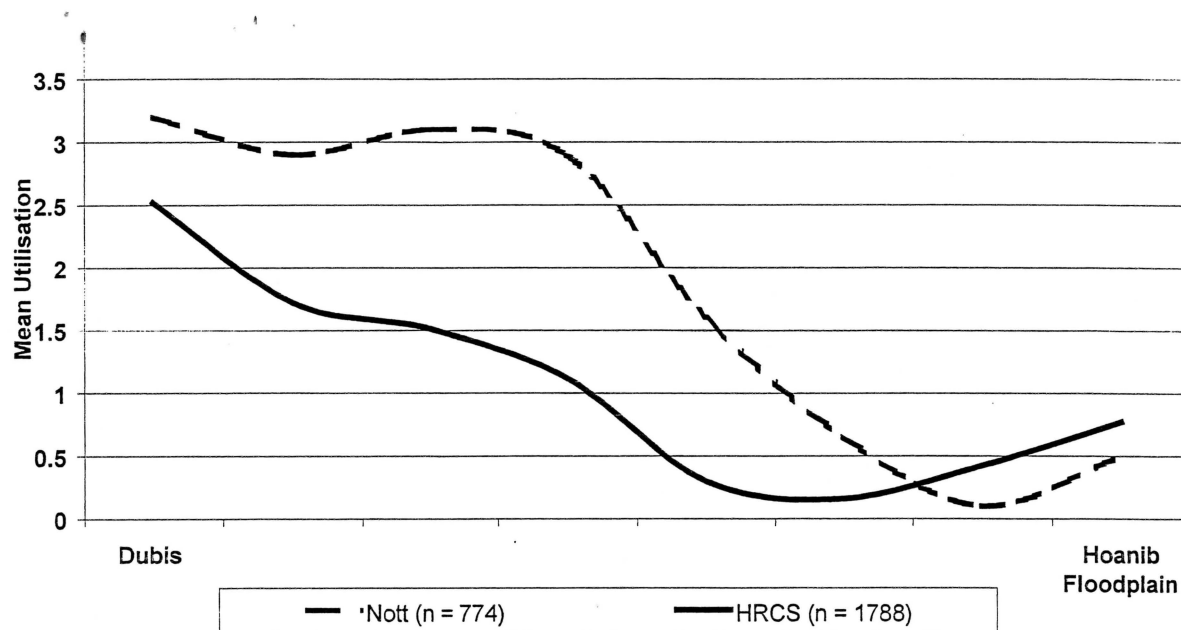


Fig. 14: Mean bark use of *Faidherbia albida* per 5km, lower Hoanib River, 1987-1999

The mean bark utilisation observed in this study indicated a linear correlation ( $r^2 = 0.718$ ,  $P < 0.001$ ) with that reported by Nott (1987) (see Fig 14). A lower mean bark use was observed in the lower Hoanib River, however, the mean use near the Hoanib Floodplain was observed to be slightly higher, as also observed in the percentage of bark used (see Fig 10). Nott reported that those trees closer to Dubis were more affected with the severity of use decreasing westward and only increasing slightly nearer the floodplain.

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### DISCUSSION

#### *Size Class Distribution*

Viljoen and Bothma (1990) postulated that '...the *Acacia albida* population in the Hoanib River is a healthy climax and stable population'. Over a decade later, Jacobson and Jacobson (1998) reappraised the impact of elephants on the *Faidherbia albida* in the lower Hoanib River and concluded that '...elephants have radically altered the age structure of the *Faidherbia albida* forest downstream of the Dubis wetland'.

Assessments of the *Faidherbia albida* population in the lower Hoanib River, documented over the past decade and a half, provide a valuable insight into the changing nature of the riparian forest. Previous authors' findings have indicated a shift in vegetation use since the early 1980s. Throughout other areas of Africa, similar impacts of elephant on vegetation to that observed by Jacobson and Jacobson (1998) have been reported. Laws (1970) reported on a number of studies within Uganda that indicated strongly skewed age class distributions of *Faidherbia albida* due to the preferential feeding impacts of elephant on younger trees.

The impact of flood events and periods of high aridity, as experienced in the 1980s, combined with resident populations of elephant, have all been causal effects in the changing size class distributions of *Faidherbia albida* in the lower Hoanib River. The lack of recruitment observed by Jacobson and Jacobson (1998) was attributed to a population that had been selectively destroyed by elephants, though they may only be part of the impact, as other wildlife including giraffe, gemsbok and kudu, also favor young trees and coppices (CTFT, 1989). However, in the few years since their study (Jacobson and Jacobson, 1998), observed recruitment rates (seedlings 0-20cm) have increased to approximately 10% of the total population. Though not comparable to the high recruitment rates reported by Viljoen and Bothma (1990), recent increases in recruitment may be attributed to favorable rainfall years and flood events in recent years. The pressure on the river's vegetation has been greatly reduced with reliable seasonal water sources both within and outside the river course, combined with re-expansion of elephant ranges, if only seasonally, into areas north and east of the lower Hoanib River (Legget *et al.*, 2001).

### *Bark Use*

A high percentage of bark use was observed around the Dubis wetlands, with a dramatic reduction approximately 20-25km downstream of this permanent/semi-permanent water sources (Nott 1987; Viljoen and Bothma, 1990; Jacobson and Jacobson, 1998). Furthermore, percentages of bark use increased nearer the Hoanib Floodplain and in turn, closer to the vicinity of the water sources of Gantias and Auses springs. This impact results from the arid environment of the lower Hoanib River, and where important water sources exist, greater impact around this environment results (piosphere effect). Areas away from this, i.e. between Dubis and the floodplain, are less affected and serve more as refuge areas.

A relationship between percentage of bark damage and permanent water as reported by Nott (1987) and Viljoen and Bothma (1990) was evident. Approximately 95% of all trees around Dubis were used, with a sharp increase towards the floodplain where approximately 45% of all trees were damaged. This assumption relates directly to the residence time of elephants in the Hoanib Floodplain, as accessibility is easiest to those sections of the river in close proximity to the floodplain. Following the rains, wildlife, including resident elephant herds, occupy the floodplain for several months, depending on the available resources. During these months the impact on vegetation in the floodplain and nearby riparian environment are at its highest due to the concentration of elephants.

Observed bark use of *Faidherbia* trees in the lower Hoanib correlated with that reported by Nott (1987), yet was significantly greater than that reported by Viljoen and Bothma (1990). Even though Nott's (1987) research was five years past Viljoen and Bothma's 1982 survey (1990), an increase in the percentage of bark use throughout the entire lower Hoanib River was reported: marginally lower around Dubis wetland, while increased toward the Hoanib Floodplain. Viljoen and Bothma's (1990) survey was undertaken in the height of an extreme arid period (drought), as well as at a time of extreme poaching pressure (Viljoen, 1987). The movement of elephant back to the safety of the riparian forest (of the lower Hoanib River) created an increased pressure on the river's vegetation at this time. Recent increase in use of the Hoanib Floodplain and nearby riparian environment may be due to more favorable rainfall conditions which have led to an increased impact on the vegetation. However, it is hoped that the increasing seasonal movements of elephant between other river courses will reduce the pressure reported on *Faidherbia albida* and other vegetation (Leggett *et al.*, 2001; J. Patterson pers. comm.).

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Jacobson and Jacobson (1998) also observed that debarking in the lower Hoanib River had caused an alteration of the outer bark (vascular cambium) in 33% of trees surveyed. They further postulated that these folds might offer some type of protection against ring barking, an adaptation to increased pressure by elephants. Though not specifically surveyed, numerous observations of these alterations were apparent throughout the middle and westerly stretches of the lower Hoanib River. Due to the brittle nature of *Faidherbia albida*'s bark, only small strips or chips can be removed at any one time (Dunham, 1990). This adaptive strategy may be favorable to the trees of the lower Hoanib River if the pressure by elephants, and to a lesser extent other wildlife increase to the detriment of the trees. For example, if an elephant feeds on a *Faidherbia albida*, the combined effect of the bark's brittle nature and the development of protection around old scars may increase the tree's ability from being ring-barked.

Previous surveys have concentrated on the impact in the lower Hoanib River and the influence elephant are having downstream of the Dubis wetlands. However, an assessment on the impact and damage to *Faidherbia albida* upstream from Dubis has never been reported. An impact on the *Faidherbia* trees 20-30km east of the Dubis wetlands was observed to be similar (80-90% bark use) to the impact as reported downstream (west) (Nott, 1987; Viljoen and Bothma, 1990; Jacobson and Jacobson, 1998).

The movement of elephants and their influence on the environment has not only been west of Dubis, but also to the east. Knowledge of their movements throughout the area has previously been reported, with frequent movement in and out of the Sesfontein and Khowarib plains and the river most likely acting as a corridor (Owen-Smith, 1971; Viljoen, 1987; Lindeque and Lindeque, 1991). Viljoen and Bothma (1990) suggested that '...most bark utilisation occurred on trees in the (lower) Hoanib River...(as there are a) greater density of elephants in this area' compared to the Hoarusib River to the north (Viljoen, 1987). Therefore future management options for *Faidherbia albida* and/or elephants must not only focus on the stretch of river downstream from Dubis, but at least 20-30km to the east, and preferably the entire Hoanib River.

### *Mortalities*

Mortalities and population changes are thought to be a result of flood events and droughts while extraction of groundwater, as observed in the Kuiseb river, is also understood to have a direct influence (Ward and Breen, 1983; Jobst, 1996; Le Maitre *et al.*, 1999). Throughout other areas in Africa *Faidherbia albida* mortalities due to elephants uprooting trees have been reported (Laws, 1970; Caughley, 1976), though this phenomenon was not supported by this or previous surveys undertaken in the lower Hoanib River (Nott, 1987; Viljoen and Bothma, 1990; Jacobson and Jacobson, 1998). Only 0.4% (n=6) of trees were observed to have been uprooted, though none could be directly attributed to elephant influences, even though the percentage use of trees was high in the lower Hoanib River. Following the rainy season, the river was surveyed and approximately 6% or 100 trees in the lower Hoanib River were found uprooted and lying down dead. Therefore, the impact of ephemeral flooding can assume to be greater in the Hoanib River than any other factor.

The impact of wood-borer insects on *Faidherbia albida* has been reported to negatively influence stands throughout Africa, though Viljoen and Bothma (1990) reported no infestations, even amongst severely debarked trees (Eltringham, 1980; Jacobson and Jacobson, 1998). Jacobson and Jacobson (1998) reported one incident of shot-borer beetle and a white-rot fungus colonising a broken trunk in the lower Hoanib River, while in the Kuiseb River they reported only 4 cases over a three-year study.



**SECTION II**

**THE SEASONAL AVAILABILITY OF  
GRAZING AND BROWSING  
IN THE HOANIB RIVER CATCHMENT,  
NORTHWESTERN NAMIBIA**

By: Keith Leggett\*  
Julian Fennessy  
Stephanie Schneider

Contact Address:  
Hoanib River Catchment Study  
Desert Research Foundation of Namibia  
P.O. Box 20232  
Windhoek  
Namibia  
E-mail: keithl@drfn.org.na

\* Person to whom all correspondence should be addressed

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## **ABSTRACT**

One of the main purposes of the vegetation study was to examine the roles of grass and woody vegetation in the maintenance of a viable ecosystem for both domestic stock and wildlife. In a variable rainfall zone such as the Hoanib River Catchment (HRC), the degree to which either woody vegetation or grazing will support domestic stock and wildlife varies from one season to the next. It is not uncommon to have several years in succession with below average rainfall and limited vegetation growth. The majority of animal species are grazers (i.e. feed on grass) and in seasons where available grazing is limited, animals that are traditionally grazers switch food sources to become either exclusively browsers (i.e. feed on trees and shrubs) or mixed browsers/grazers.

The Zurich-Montpellier method of vegetation assessment was used to assess the vegetation in the HRC during the 1999 and 2000 wet seasons and the 2000 dry season. The 2000 wet season had above average rainfall across all areas of the catchment, which induced copious vegetation growth. The annual and seasonal abundance of ground cover, bare earth, canopy cover, annual grass, perennial grass and annual forbs were measured in eight focus-study areas located across the catchment. The seasonality of vegetation was marked with the abundance of ground cover, canopy cover, annual grasses and annual forbs decreasing significantly during the dry season. The vegetation in the HRC appeared to be in a non-equilibrium state responding to annual rainfall rather than land use.

Seventy-five species of trees and shrubs, 49 species of annual and perennial grasses and 97 species of annual forbs were identified in the catchment. Dominant vegetation communities and their associated species were also identified.

The effect of land use on the number of species and abundance of vegetation was also investigated. It was observed that neither intensive cattle farming nor wildlife during an above average rainfall year had much impact on the vegetation. With a marked decrease in available grazing and browsing during the dry season, animals appeared to eat dried stalks of grass, fallen leaves, bark and buds of trees from the previous seasons growth and when available, seed pods of the *Faidherbia albida*.

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### KEY RESEARCH QUESTIONS

Due to the seasonal uncertainty of rainfall and the variable nature of land use within the catchment area, the research questions focused on the effect and resilience of vegetation to land use and climatic variability.

1. What are the main factors determining the seasonal availability of grazing and browsing in the catchment area?
2. What is the role of woody vegetation and how is it important to the domestic stock and wildlife especially during the dry season and periodic episodes of high aridity?
3. Is there a decline in diversity and abundance of vegetation closer to human settlements and water sources?
4. Does intensive pastoralism have a greater effect on the distribution and number of species of vegetation (both woody vegetation and grasses) than intensive wildlife farming?

## BACKGROUND

### EQUILIBRIAL OR NON-EQUILIBRIAL SYSTEM?

In order to manage rangelands, it is necessary first to understand how they function and what is the potential impact of the different management strategies. There are three proposed theories of how a rangeland functions, each relating to the degree and direction of linkage between plant and herbivore production. Linkages between biotic factors can be termed density-dependent or density-independent according to responses of one variable to the other. Definitions of equilibril, quasi-equilibril and non-equilibril systems are crucial if there is to be a clear understanding of how paradigms (system of concepts, generalisations or assumptions – Mentis *et al.*, 1989) such as these, affect arid and semi-arid lands (Behnke and Scoones, 1993; Behnke *et al.*, 1993; Robertson and Seely, 1998).

According to Behnke *et al.* (1993) the paradigms can be defined as follows:

- Equilibril means that the numbers of stock strongly affect the forage production from a particular area of land.
- Quasi-equilibril means the numbers of stock less strongly affect forage production in an area. Interactions are sometimes equilibril with biotic interactions, sometimes non-equilibril with abiotic climatic factors driving the system.
- Non-equilibril means that the numbers of stock do not significantly affect the total plant production in an area of land.

The question of whether or not traditional farming methods have contributed to degradation of the land has been the subject of a large amount of literature. According to Dodd (1994), the term 'degradation' was initially used to define the process of change in an ecosystem toward an 'arid' state. The modern use of the term usually refers to a decrease in productivity or unfavourable changes in species composition, but it does not infer that the changes are permanent or the result 'desert-like'. In addition, Dodd (1994) defines desertification as an irreversible change in the environment and should only be applied to areas where rainfall is between 50 and 300mm annually. Many authors (for example, Ellison, 1960; Downing, 1978; Danckwerts and Stuart-Hill, 1988; Mwalyosi, 1992; Dean and Macdonald, 1994; Dodd, 1994) attribute the main driving

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force of degradation and desertification to human influence, in conjunction with periods of aridity.

Other authors (for example, Standford, 1983; Ellis and Swift, 1988; Behnke, 1993; Behnke *et al.*, 1993; Dean *et al.*, 1995; Sullivan, 1996; Sullivan, 1999) have argued that many of the degradation processes and patterns attributed to people and domestic stock in arid environments, are masking natural variations in the climatic cycles. Sullivan (1999) states that previous analysis of these systems was based on temperate-zone ecology based on "equilibrium dynamics, emphasising density-dependent interactions". Sullivan further postulates that any analysis of vegetation systems in an arid environment should be by a "non-equilibrium model, focusing on abiotic sources of variation and non-linear interactions between biotic and abiotic components".

## EFFECT OF DOMESTIC STOCK AND WILDLIFE IN SEMI-ARID AND ARID ENVIRONMENTS

### Domestic stock

Several authors (Bourliere and Hadley, 1970; Walker and Noy-Meir, 1982; Frost *et al.*, 1986; du Toit and Cumming, 1999) have reported that rainfall, fire and herbivory, and in some areas, frost are the prime driving variables in African savannas. Walker (1993) reported that the impact of livestock management on savannah rangelands varied and depended on stocking rates and the interaction of rainfall, soil properties, topography and the occurrence of drought. Kruger and Rethmann (1999) reported that in the Camel Thorn Savannah (*Acacia erioloba* Savannah) of eastern Namibia, variation in rainfall appeared to have a greater impact on the productivity of both veld and livestock than stocking rate alone. Other authors (e.g. Jameson, 1960; Ellison, 1963; Dodd, 1994) suggested that heavy grazing pressure in an arid and semi-arid environment affects rangeland plant communities and the abundance of individual plants. The most dramatic changes in species composition and productivity have been reported to occur near water points and human habitation. This area corresponds to a "sacrifice zone" (Standford, 1983; Perkins and Thomas, 1993). High densities of domestic stock have been reported to induce changes in infiltration rates (Tarkar *et al.*, 1990) and soil nutrient levels (Dean and Macdonald, 1992).

However, the effect on bulk rangeland (more than a kilometre away from either water point or human habitation) was reported to be rare (Jameson, 1960; Ellison, 1963; Dodd, 1994).

Bayer and Waters-Bayer (1994) reported that fluctuations in yields of natural forage in dryland areas are caused more by variability in rainfall than by grazing pressure. The authors state that in systems where annuals predominate in a seasonal rainfall pattern, grazing pressure will have an effect on rangeland yield. Further, in areas where higher rainfall with more herbaceous perennials, higher grazing pressure can lead to the replacement of perennial grasses by annuals.

"This may not mean that less forage is produced in a given year, but as annuals respond more slowly to rainfall and disappear faster in the dry season, annual fluctuations in forage availability may increase with higher grazing pressure" (Bayer and Waters-Bayer, 1994).

There appears to be a similar effect on woody species. While most woody species are well adapted to being defoliated, severe browsing or cutting can cause disappearance of woody species, affecting yields in subsequent years (Bayer and Waters-Bayer, 1994).

A study in the semi-arid region of South Africa by Fynn and O'Connor (2000), looked at the effect of stocking rates and rainfall on rangeland dynamics, with particular emphasis being placed on cattle performance. They found that changes in botanic composition were strongly influenced by rainfall variability, with a dramatic compositional shift induced by the 1991-92 drought. High rainfall and light grazing promoted tufted perennial grasses; heavy grazing and low rainfall promoted some annuals and weakly tufted perennial grasses; while other annuals were favoured by heavy grazing and high rainfall. They also concluded that long-term heavy grazing did not reduce cattle performance (gain animal<sup>-1</sup> and gain ha<sup>-1</sup>). However, during drought, cattle were less productive at high stocking rates on poor (heavily stocked) condition rangeland than on good (lightly stocked) rangeland. One of the implications for management was that grazing can induce pronounced changes in herbaceous species in a semi-arid savanna during and subsequent to drought years. However, Kruger (1998) reported that stocking rate appeared to have no significant influence on the percentage basal cover and frequency of occurrence of grass species over a seven year period in the Camel Thorn Savannah of eastern Namibia. In this environment, changes in seasonal rainfall appeared to have a significantly greater impact on basal cover and grass species.

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### Wildlife

Wildlife, particularly elephants, have been regarded as significant agents in changing vegetation in arid and semi-arid systems (van Wyk and Fairall 1969; Laws *et al.*, 1975; Barnes 1983; Trollope *et al.*, 1989; Ben-Shahar 1996; Du Plessis 1998a and 1998b). The larger migratory ranges of wildlife have been considered to be less damaging on vegetation than domestic stock that generally kept at higher stocking densities (Krueter and Workman, 1992).

Du Plessis *et al.* (1998a and 1998b) reported that high wildlife grazing intensities and drought are perceived to have the same long-term effect on species composition and abundance. From their study it was reported that the effects of grazing intensity or rainfall amount on environmental degradation was not clearly distinguishable. They described the accumulated effects of rainfall and grazing as a 'degradation gradient', which includes the effects of rainfall and climatic cycling rather than a 'grazing gradient' as it was not possible to separate the effects of herbivory exclusively. This study was carried out in Etosha National Park under 'natural' environmental conditions.

### DRY SEASON GRAZING

The long dry season in semi-arid and arid areas of the world can produce long intervals of nutritional deprivation for ungulates (Coppock *et al.*, 1986; Mosi *et al.*, 1976; Pratt and Gwynne 1977). Studies conducted in North America under similar environmental constraints to arid areas of Africa showed that livestock could endure up to 6 months on 'sub-maintenance' grazing (Schwartz and Ellis, 1981). Coppock *et al.* (1986) reported a similar behaviour for African livestock from the Turkana region of Kenya. The food habit of livestock from here ranged from grass-dominated (96%) for cattle, to browse-dominated (95%) for camels, while goats, sheep and donkeys tended to be mixed feeders of herbaceous and non-herbaceous vegetation. The same authors also reported that during the dry season, domestic stock were able to survive for up to six months on below-minimum standards for growth recommended by the National Research Council (1975, 1976, 1978, 1981). Cattle survived on 70% of the minimum nutritional requirements, while donkeys, sheep and goats survived on 80%, 83%, 95%, respectively (Coppick *et al.*, 1986). Livestock were thought to obtain their crude protein and bulk feed from dry grass with supplementary protein from browsing. Sheep and goats increased their nitrogen intakes by eating

### *The Seasonal Availability of Grazing and Browsing*

seedpods of the *Acacia tortilis*. No comparable studies have been reported from Southern Africa, although Skarpe (1986), reported that cattle and wildlife browse *Boscia albitrunca*, *Lycium namaquensis*, *Grewia flava* and *Rhus tenuinervis* towards the end of the dry season in Botswana.



## INTRODUCTION

The Hoanib River Catchment (HRC) is one of twelve major ephemeral river catchments that occupy the semi-arid areas of north-western Namibia. All twelve rivers flow into the Atlantic Ocean or end in the Namib Sand Sea. Many originate in commercial farmlands, flow through communal farming areas and, near their mouths, traverse a protected conservation area. The HRC in particular occupies an area of 17 200 km<sup>2</sup>, 3% of which lies in private farm lands, 91% in communal farm lands, and 6% is protected in Etosha National Park and Skeleton Coast Park (Jacobson *et al.*, 1995).

The Hoanib River constitutes the boundary between the former Damaraland and Kaokoland. Since Namibia's independence in 1990 these two areas have been incorporated into the Kunene and Erongo Regions (see Figure 1). The catchment area of the Hoanib River can be divided into three broad geographic sections. The eastern section (east of the Khowarib Schlucht) is relatively densely vegetated with mopane woodland dominant. The middle section of the Hoanib River (from the Khowarib Schlucht to Skeleton Coast Park eastern boundary) is sparsely vegetated. Virtually no vegetation exists outside the river course in the western section of the river (from the Park boundary to the coast). A broad flood plain (70km<sup>2</sup>), east of the moving dunes of the coast, offers substantial grazing for wildlife after flood events during the wet season.

One of the main purposes of this study was to investigate the effect of land use on vegetation distribution and abundance. An in-depth study was undertaken to examine the effect of wildlife and domestic stock on the veld in the eastern section of the catchment. While several studies exist on the effect of domestic stock on the vegetation in communal lands (e.g. Van Warmelo, 1962; Loxton Hunting Associates, 1974; Nærva *et al.*, 1993, Sullivan and Konstant, 1997; Sullivan 1996, 1998; Becker and Jurgens, 2000) and the effect of wildlife on the vegetation of Etosha National Park (Du Plessis, *et al.*, 1998a, 1998b) no comparative studies from the north-west have been reported.

The focus area for this study had an average rainfall of about 250mm a year (the highest average rainfall in the HRC area). Vegetation transects from Otjokavare, Hobatere, Kaross and Palmfontein were compared. All have similar rainfalls, geographic and geological conditions. However, the main difference between the areas was the type of land use to which the vegetation is subjected. Palmfontein and Otjokavare are communal lands under heavy livestock grazing

pressure with very little management input from local communities. Hobatere was subjected to heavy livestock grazing pressure up until the early 1980s when it became a hunting and game concession and has since been subjected to limited management by rangeland ecologists with the Ministry of Environment and Tourism (MET). While Kaross has long been part of Etosha National Park, since the late 1970s it has functioned as a protected species game reserve and is moderately to heavily stocked with endangered species, namely black rhino (*Diceros bicornis*), sable (*Hippotragus niger*), roan (*Hippotragus equinus*) with additional numbers of Hartmann's mountain zebra (*Equus zebra hartmannae*), blue wildebeest (*Connochaetes taurinus*), giraffe (*Giraffa camelopardalis*) and gemsbok (*Oryx gazella*) (MET, 1998). Kaross has been the subject of intensive management by the MET over many years.

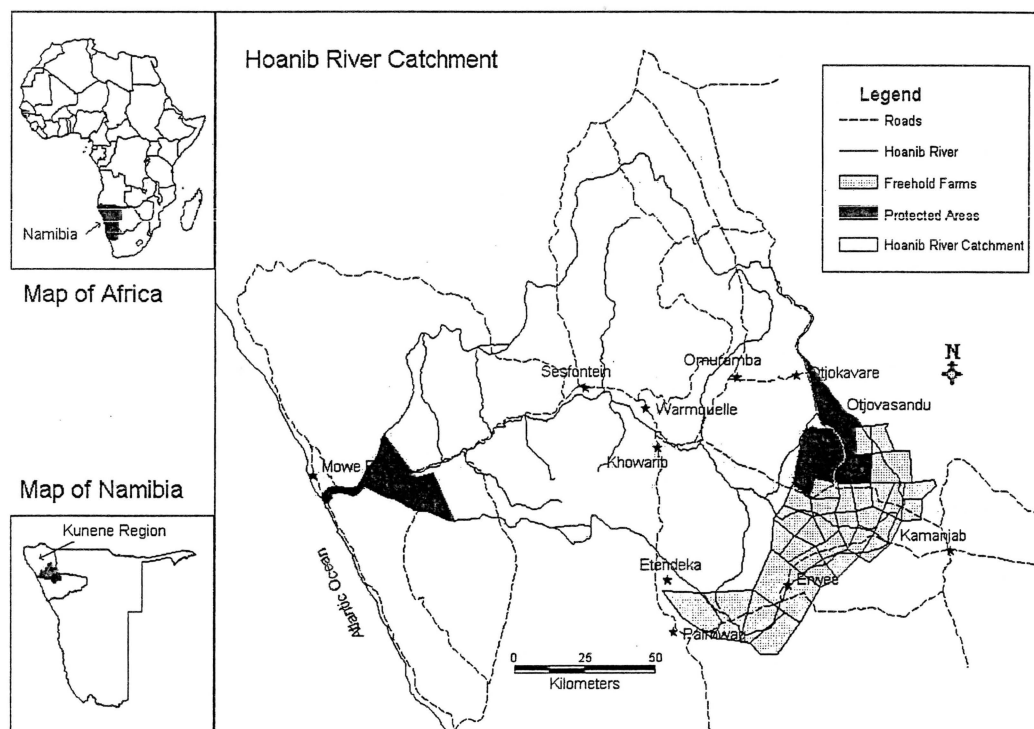


Figure 1: Map of Hoanib River catchment area

The vegetation gradient from east to west in Kaokoland was studied by Becker and Jurgens (2000). In addition, they looked at the effect of grazing on vegetation type and degradation of the land. They identified 45 major plant communities and derived four identifiable main vegetation units, these were:

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- (a) *Colophospermum mopane* – *Terminalia prunioides* – *Combretum apiculatum* savanna, which corresponds approximately to the 250-350mm rainfall zone.
- (b) *Colophospermum mopane* – *Terminalia prunioides* savanna, which corresponds approximately to the 150-250mm rainfall zone.
- (c) *Colophospermum mopane* savanna and ephemeral grasslands dominated by *Stipagrostis hirtigluma*, which corresponds approximately to the 100-150mm rainfall zone.
- (d) More permanent grasslands dominated by *Stipagrostis uniplumis*, which corresponds approximately to the 50-100mm rainfall zone.

Sullivan (1999) reported that the floristic communities, diversity, density, cover and population structure of woody vegetation in the Sesfontein, Warmquelle and Khowarib areas were not degraded by local herders except on a local scale close to settlements. The Sesfontein area has long been regarded by researchers as 'degraded' (for example, Van Warmelo, 1962; Loxton Hunting Associates, 1974; Nærua *et al.*, 1993) as a result of over-use by local herdsman. However, Sullivan theorises that previous researchers failed to take into account a number of factors that include:

- (a) the spatial and temporal scale interpretations of ecological data;
- (b) a conceptual adherence to equilibrium dynamics which stress the density-dependent impact of people and livestock over and above the abiotic factors in constraining and driving primary productivity; and
- (c) modern ideology which tends to view "...traditional communal farming practices as environmentally degrading".

Sullivan studied the woody vegetation based on a method developed by Leithead (1979), known as the zig-zag transect method. This method requires that each consecutive individual tree/shrub be sampled according to its proximity to the preceding individual, providing it is within 45° on either side of a stated compass-bearing from this individual. According to Sullivan, this method is well-suited to arid environments, as it makes no assumption regarding the density or distribution of species because the vegetation itself dictates the length of each transect. Additional features such as soil type, terrain, geomorphology and distance from nearest permanent settlement are also taken into account.

The purpose of this study was not to map the vegetation of the Hoanib River catchment area as this has been reported by previous authors (Giess, 1971; Viljoen, 1980; Becker and Jurgens,

2000), but rather to categorise the area by the dominant vegetation species found along the transects.

Similarly, this study has not set out to create a checklist of vegetation species in north-western Namibia which has already been compiled by other authors (for example, Maggs *et al.*, 1994; Maggs *et al.*, 1998; Craven, 1999). The enthnobotany of the region has also been reported by other authors (Malan and Owen-Smith, 1974; Sullivan, 1998) and was not investigated during this study.

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# METHODS

## VEGETATION TRANSECTS

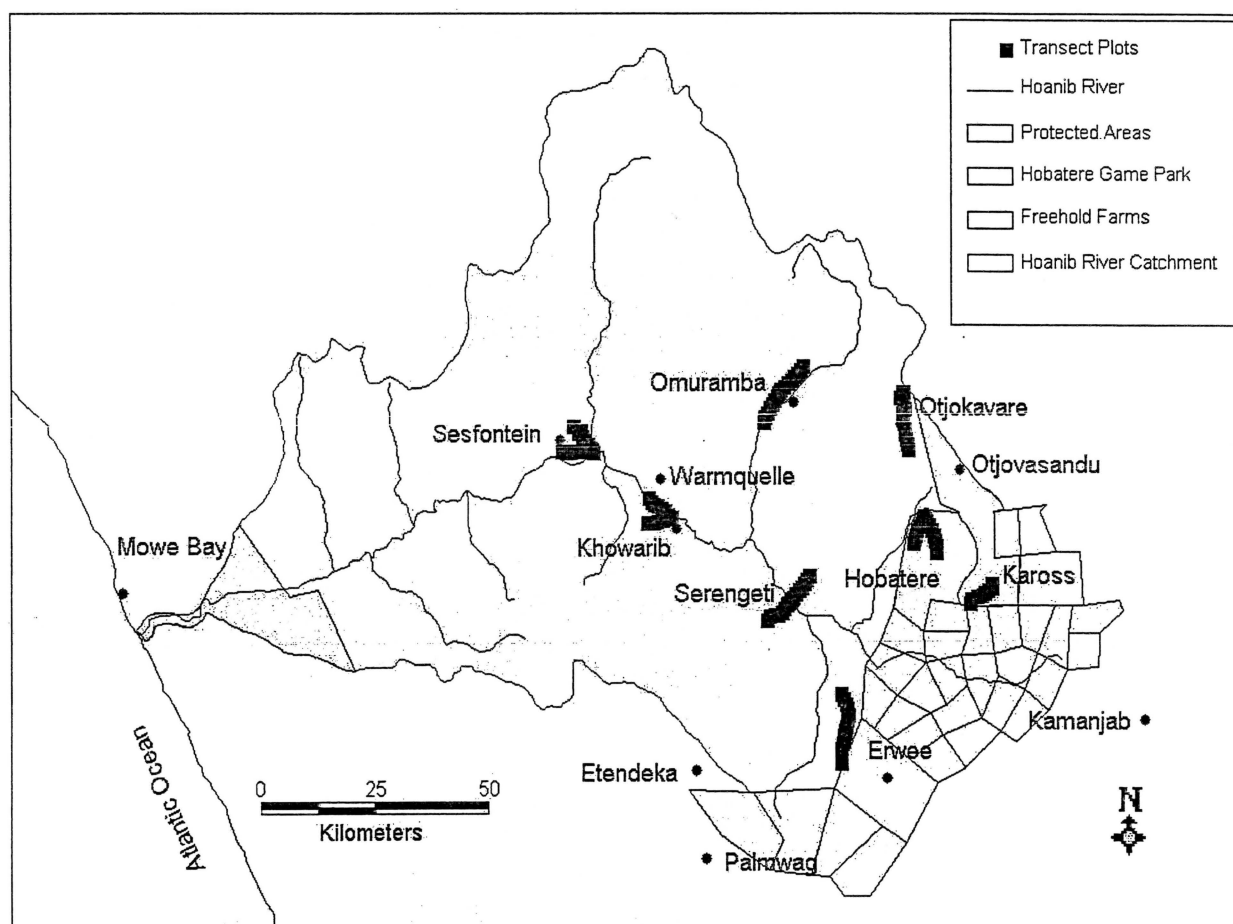
Vegetation transect lines were established in eight focal areas of the catchment (see Table 1. for the GPS location of point of origin for transect lines and Figure 2. for the location of transects). The point of origin for the transects was chosen as the major permanent water source (either borehole, wetland or spring) in six of the focal areas, with the only exception being the Serengeti transects where point of origin was the riverbed of the Hoanib River. Two 7-km transects were taken from each water source (the exception being Kaross where only one transect was taken). The direction of each transect was deliberately chosen to exclude the influence of any other water point. At nine plots (geology and geography permitting), data was recorded at 0m (water source), 500m, 1km, 2km, 3km, 4km, 5km, 6km and 7km along each of the transect lines. Plots were assessed for vegetation species and abundance using the Zurich-Montpellier method (Braun-Banquet, 1932; Mueller-Dombois and Ellenberg, 1974; Werger, 1974; Bonham, 1989; McAuliffe, 1990). All fertile specimens of trees, shrubs, grasses and forbs were submitted to the National Botanic Research Institute (NBRI) of Namibia for identification. Data sheets were also submitted to the NBRI for inclusion in the Namibian Tree Atlas.

The transect lines were located in areas of high, medium and low grazing pressure from both domestic stock and wildlife. The western section of the catchment from Sesfontein to the coast was not investigated as the vegetation abundance in this area is low and few domestic stock use this zone.

**Table 1: Location of water sources at the start of each vegetation transect**

Location	GPS of water source	
	°S	°E
Khowarib	-19.25601	13.86680
Sesfontein	-19.13543	13.70391
Omuramba	-19.02357	14.09054
Otjokavare	-19.06341	14.34785

Hobatere	-19.25325	14.39414
Serengeti	-19.41268	14.11416
Palmfontein	-19.65406	14.22580
Kaross (Etosha National Park)	-19.06341	14.53519



*Figure 2: Location of transects in the catchment area.*

One dry- and two wet season surveys were undertaken at each of the plots along the transect lines. The wet season in the Hoanib River catchment can begin as early as October and finish as late as April the following year. For the purposes of this study the wet season is named in the year that the last rains fell. For example, if the rains began in October 1999 and ended in April

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2000, this period would be referred to as the 2000 wet season. All observations on each plot were recorded on sampling sheets (Appendix A).

### THE ZURICH-MONTPELLIER METHOD

The Zurich-Montpellier or Braun-Blanquet method has been widely used to provide rapid, floristically complete descriptions of vegetation (Braun-Banquet, 1932; Mueller-Dombois and Ellenberg, 1974; Werger, 1974; Bonham, 1989; McAuliffe, 1990). Recently, Loutit (1998) has used this method to characterise large areas of the former Damaraland and Kaokoland, including sections of the HRC. The National Botanic Research Institute (NBRI) of Namibia as the government authority mandated to manage the botanical resources of Namibia, recommended this method for the study as it was considered to be the most suitable for covering a large number of sites with different habitat types and with a standard reproducible method. In addition, it is rapid and effective, although it has showed a tendency to be subjective.

#### Field sampling technique

##### Site Selection

The sites were selected subjectively. The area in which the survey was to be carried out was first visually surveyed and then chosen to be representative for the surrounding vegetation type - homogenous representation of the vegetation present in the whole area.

##### Representativeness

According to Werger (1974), "stands for sampling should be selected in such a manner that each is representative of the vegetation of which it is part and that each plot sampled therein should yield more or less typical description of that vegetation in terms of both floristic composition and structure".

Based on this method, sites were selected to represent the 'average' vegetation of an area. For example, if a clump of trees was only evident in a small section of a sample area and the surrounding area was sparsely vegetated, the plot was located in the area of sparse vegetation as this was a better representation of the vegetation as a whole.

### Homogeneity

A working definition of homogeneity is given by Godron (1968), in Weger (1974) as: "a stand is homogeneous when every species experiences equivalent living conditions throughout the entire extent of the stand and not necessarily every point of it".

According to Werger (1974), the statistical testing of homogeneity can be difficult. However, a practical approach toward homogeneity is probably more appropriate and sites were therefore selected where the environmental conditions and vegetation homogeneity appeared to be similar over the entire plot (i.e. the plot was not influenced by irrigation or part of an irrigation project).

### Minimum area or plot size and plot form

Two basic approaches were taken to determine the size of the plot to be analysed:

- (a) One was based on the community-unit theory (Werger, 1974) that ensures that the entire vegetation community is represented. The determination of the size of the plot is important. If too small an area is selected, the plot will not be representative and too large a plot would result in wasted effort.
- (b) Based on the statistical approach to vegetation which would determine whether or not a community exists. If the community exists, then a minimum size is automatically set.

After consultations with Loutit (MET) (1998), it was decided that each plot size ought to be 50m x 50m, in normal heterogeneous vegetation areas. However, along riverbanks where vegetation is not as heterogeneous, it was decided to use 100m x 25m plots to ensure that all plant communities were represented. In all cases plot size was 2500m<sup>2</sup>.

### Structure

In the semi-arid and arid areas, two layers of vegetation can often exist. Low trees and shrubs are often scattered, singly or in small groups, over a vegetation of dwarf shrubs, forbs and grasses. This can be considered as a homogeneous layer because; "if there is a stable ecological-sociological equilibrium of different growth forms, that constitutes an inseparable entity" (Werger, 1974). Knowledge that certain species occur only under shrubs or low trees, should be interpreted as a consequence of their specific ecological amplitude and the impact they have on the microclimate and local soil moisture conditions.



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Within the Hoanib River catchment area, *Colophospermum mopane* was observed to occur in both tree and shrub forms in the same area. As long as the plot had been selected for its homogeneity it was possible to separate each layer and assign a cover abundance to both the tree and shrub growth form.

### Floristic lists

For each sample plot, a complete list of species that occurred there was compiled (inclusive of grasses, forbs, shrubs and trees). The study attempted to obtain species composition over time, since the later extraction of syntaxa in phytosociological tables was dependent on species numbers and the correct identification of the species. In the arid and semi-arid environments it was not always possible to identify individual species due to the survey either being conducted in the dry season or variable rainfall throughout the catchment resulting in different growth forms of species. Complete species lists, as far as possible, were collected during the three surveys.

### Cover abundance

The density of individual species provide important information on species dominance in an environment, especially when comparing transects and individual sites along a gradient. The relative importance of each species in the plot was assessed visually by a cover abundance scale and was based upon the following (Werger, 1974):

- + Present but not abundant and with a minimal cover value (less than 1% of plot area)
- 1 Numerous, but covering less than 1% of the plot area, or not so abundant and covering between 1-5%
- 2a Covering between 5 and 12.5% of the plot area and independent of abundance
- 2b Covering between 12.5 and 25% of the plot area and independent of abundance
- 3 Covering 35-50% of the plot area and independent of abundance
- 4 Covering 50-75% of the plot area and independent of abundance
- 5 Covering 75-100% of the plot area and independent of abundance

### Ground cover

Ground cover was assessed visually in the same manner as cover abundance, but represented the total coverage of species within the plot.

#### Bare ground

Bare earth was assessed in the same manner as cover abundance and recorded as a 'species', but relating to the lack of vegetation cover within a plot where the ground was exposed.

#### Location

The location of each plot was obtained via a Geographical Positioning System (GPS) and recorded in the north-west corner. The size of the plot, predominantly 50m x 50m, though sometimes 100m x 25m along riparian environments, was also recorded.

#### Photographs

Photographs were taken at all sites along the transect plots as a visual method for seasonal comparisons.

### **VELD CONDITION**

In addition to the Zurich-Montpellier method, the researchers used an evaluation method for appraising grass species in terms of veld condition. This method was developed by Du Plessis *et al.* (1998b) for the evaluation of veld condition using selected grass species in the Etosha National Park. This involved the classification of grass species into either 'Decreasers' or 'Increasers' (after Trollope, 1990) depending on how the species responded to grazing pressure.

#### **Grass species and grazing indicators**

The grass species (annuals and perennials) present in each plot were recorded, as mentioned above, to help assess relative abundance. 'Increaser' or 'decreaser' grass species, as described by Du Plessis (1998a), were defined for the Etosha National Park and used to help identify the species throughout the catchment. These species have been categorised as follows:

- Category 1: Species dominant in under utilised veld ('Increaser 1' species)
- Category 2: Species abundant in lightly grazed veld, decreasing with under- or over-utilised veld ('Decreasers')

## SECTION II

- Category 3: Species with low abundance in under-utilised or lightly-grazed veld which tends to increase in abundance when vegetation is moderately grazed ('Increaser 2a')
- Category 4: Species that are more abundant in moderately over-utilised veld ('Increaser 2b')
- Category 5: Species becoming dominant in severely over-utilised veld ('Increaser 2c')

### **Annual and perennial grasses and annual forb definitions**

For the purposes of this study, an annual was defined as a grass that grows and seeds seasonally (i.e. it does not usually survive the dry season). In contrast a perennial grass generally forms tufts and retains its leaf throughout the year. Growth, flowering and seeding in both the annual and perennial grasses occurs primarily during the wet season.

Annual forbs are defined as those species of herbaceous plants that germinate, flower and then die again in one season, generally not surviving the dry season.

## RESULTS

The results presented were averaged from all eight focus study areas within the catchment. Variations in vegetation across the catchment, including rainfall gradients, land-use type and intensity are discussed in each of the case studies.

The following figures representing wet (1999, 2000) and dry season (2000), cover abundance, bare earth, trees and shrubs, annual grasses, perennial grasses and annual forb abundance over the entire catchment, have been graded according to the Zurich-Montpellier method. For the purposes of this presentation the Zurich-Montpellier abundance scale was converted to a graphing scale (see Table 2).

**Table 2: Zurich-Montpellier conversion to a graphing scale**

Zurich-Montpellier abundance	Percentage abundance scale (%)	Graphing scale (see Figure 3)
0	0	0
+	0 – 1	0.5
1	1 - 5	1
2a	5 - 12.5	2
2b	12.5 - 25	2.5
3	25-50	3
4	50-75	4
5	75-100	5

Note: A Zurich-Montpellier abundance of '2a' represents an abundance of 5-12.5% in the plot and is presented as 2 in the following figures (where the average value from several plots has been used, '2a' is taken between 2 and 2.5 on the figures). In a similar way a Zurich-Montpellier abundance of + would be presented on the graphs as 0.5 (or between 0-1 for average values).

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### GROUND COVER ABUNDANCE

The average ground cover abundance observed throughout the Hoanib River catchment during the 1999, 2000 wet season and the 2000 dry season is presented in Figure 3.

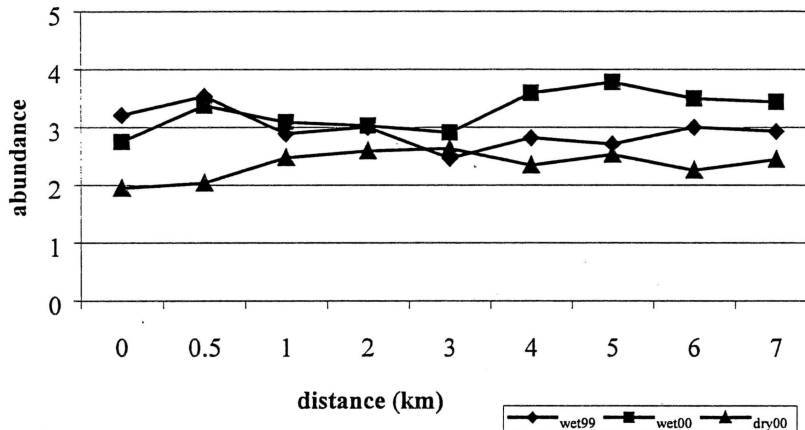


Figure 3: Average wet and dry season ground cover abundance across the Hoanib River catchment, 1999-2000

The average ground cover abundance in the 1999 wet season was between 1-4 (5- 75%), while during the 1999-2000 wet season, ground cover abundance was observed as between 2.5-4 (25- 75%). The average dry season ground cover abundance across the catchment was lower, between 1-2 (5-12.5%). During both wet seasons (1999 and 2000), the average ground cover (grass, trees and shrub) abundance was significantly greater than in the dry season (from *t*-test analysis for a one-tailed distribution for paired samples of unequal variance,  $p < 0.005$  for 1999, and  $p < 0.001$  for 2000). The 2000 wet season produced a greater ground cover abundance than the 1999 season ( $p = 0.0254$ , *t*-test). In most cases, ground cover abundance was observed to be at its least nearest to the water point (0km).

## BARE GROUND ABUNDANCE

The average bare ground abundance observed throughout the Hoanib River catchment during the 1999, 2000 wet season and the 2000 dry season is presented in Figure 4.

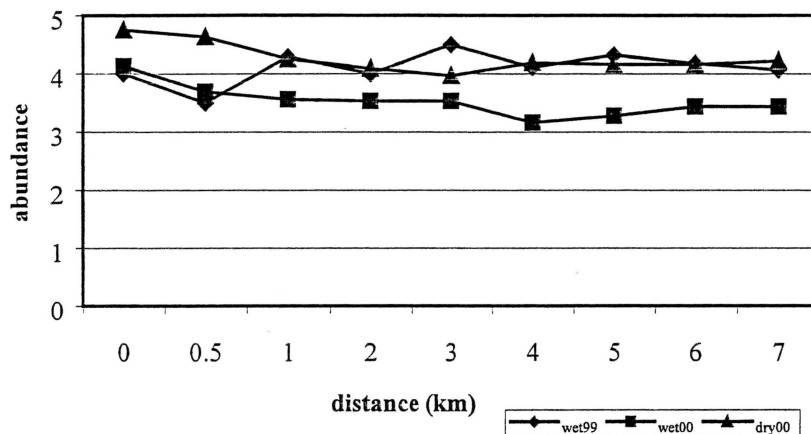


Figure 4: Average wet and dry season bare ground abundance across the Hoanib River catchment, 1999-2000

The abundance of bare ground varied across the catchments and was seasonally dependent. The average abundance of bare ground across the catchment during the 1999 wet season was between 3 and 5 (50-100%). This abundance was reduced during the 2000 wet season to between 3 and 4 (50-75%). The average dry season bare ground abundance increased to between 4 and 5 (75-100%). A significant decrease was observed in the average abundance of bare earth during the 2000 wet season compared to the 2000 dry season ( $p < 0.001$ ,  $t$ -test for 2000). However, there was no significant decrease between the bare earth dry season abundance in 2000 and the 1999 wet season ( $p = 0.1101$ ,  $t$ -test).

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### TREE AND SHRUB CANOPY COVER ABUNDANCE

The average tree and shrub canopy cover abundance observed throughout the Hoanib River catchment during the 1999, 2000 wet season and the 2000 dry season is presented in Figure 5.

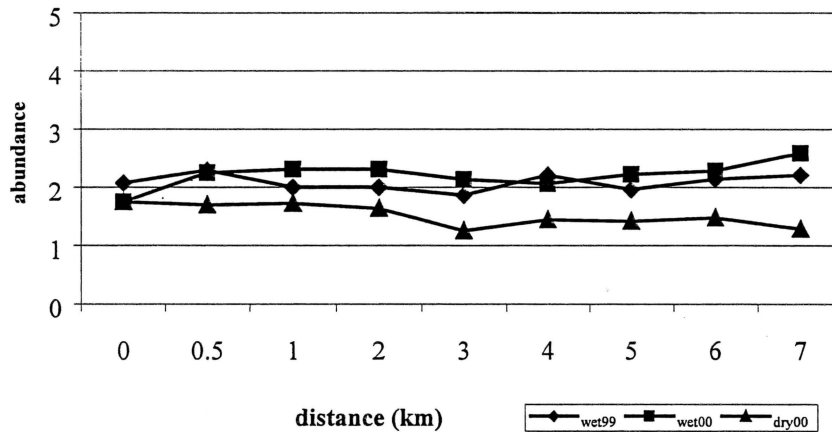


Figure 5: Average wet and dry season tree and shrub canopy cover abundance across the Hoanib River catchment, 1999-2000

There appeared to be very little seasonal variation in the average canopy cover abundance of trees and shrubs across the catchment. During the 1999 wet season the average canopy cover abundance was between 0.5 and 2 (1-12.5%), while the 2000 wet season had an observed average abundance of 1-2 (5-12.5%). The dry season canopy cover abundance was observed to be between 0.5 and 1 (1-5%) which was significantly lower than both the 1999 and 2000 wet season ( $p < 0.001$ ,  $t$ -test for both 1999 and 2000). There was little significant difference in the canopy cover abundance between the 1999 and 2000 wet seasons ( $p = 0.085$ ,  $t$ -test). In addition there appeared to be little difference in canopy cover abundance across the eight focus study areas.

## DRY SEASON STANDING 'DEAD GRASS' ABUNDANCE

The average standing 'dead grass' cover abundance observed throughout the Hoanib River catchment during the 2000 dry season is presented in Figure 6.

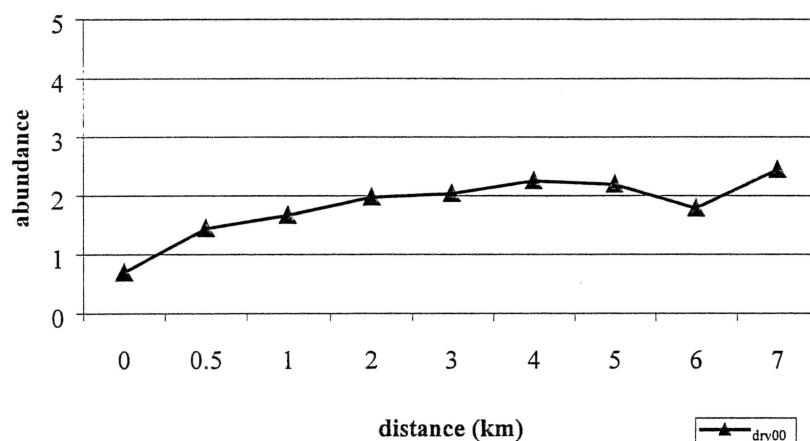


Figure 6: Average dry season 'dead grass' abundance across the Hoanib River catchment, 1999-2000

The standing 'dead grass' (dried stalks of annual and perennial grasses) abundance was surveyed during the 2000 dry season after the above average rainfall recorded during the 1999-2000 wet season (Leggett *et al.*, 2001). The average standing 'dead grass' abundance across the catchment varied from between 0.5-2 (0.5-12.5%). The minimum standing 'dead grass' abundance was observed closest to water points (0km) and maintained a relatively constant abundance after 2km distances from the water point.



## SECTION II

### ANNUAL GRASS ABUNDANCE

The average annual grass cover abundance observed throughout the Hoanib River catchment during the 1999, 2000 wet season and the 2000 dry season is presented in Figure 7.

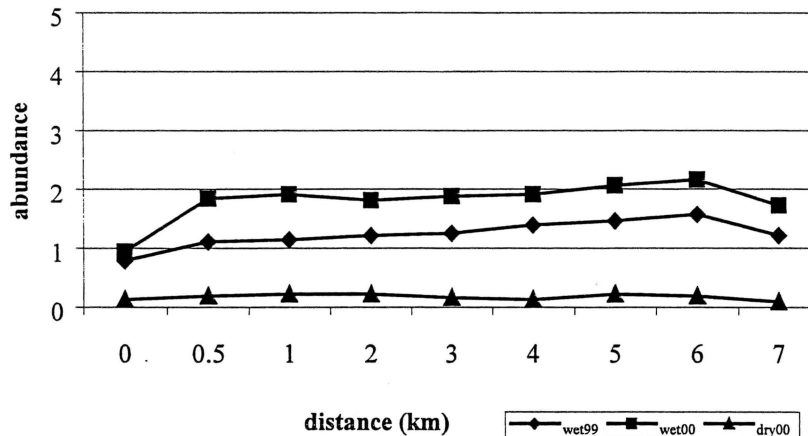


Figure 7: Average wet and dry season annual grass abundance across the Hoanib River catchment, 1999-2000

The abundance of the annual grasses varied both annually and seasonally. During the 1999 wet season the average annual grass abundance was between 0.5-1 (1-5%), while during the 2000 wet season it was between 0.5-2 (1-12.5%). The average abundance of annual grasses during the 2000 dry season was between 0-0.5 (0-1%). Both wet season average abundances were significantly greater than the dry season abundance ( $p < 0.001$ ,  $t$ -test for both 1999 and 2000). The abundance of annual grasses also varied significantly from season to season ( $p < 0.001$ ,  $t$ -test). There also appeared to be a significant decrease in the average abundance of annual grasses within 0.5km of the water point.

## PERENNIAL GRASS ABUNDANCE

The average perennial grass cover abundance observed throughout the Hoanib River catchment during the 1999, 2000 wet season and the 2000 dry season is presented in Figure 8.

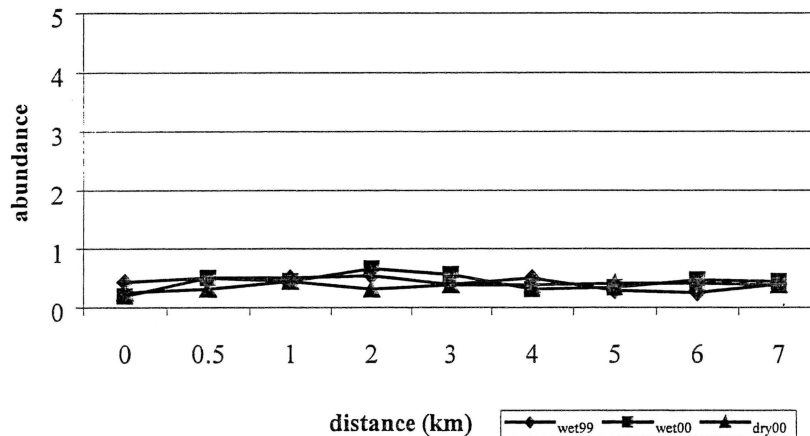


Figure 8: Average wet and dry season perennial grass abundance across the Hoanib River catchment, 1999-2000

There appeared to be little difference between the seasonal average abundance (between 0-0.5 (0-1%)) of perennial grasses across the catchment. The average abundance of perennial grasses across the catchment was relatively low, however, local abundance of perennial grasses within the catchment were observed (for example; Serengeti plains, Khowarib, Sesfontein). The abundance of perennial grasses did not appear to vary over the transect distances.

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### ANNUAL FORB ABUNDANCE

The average annual forb cover abundance observed throughout the Hoanib River catchment during the 1999, 2000 wet season and the 2000 dry season is presented in Figure 9.

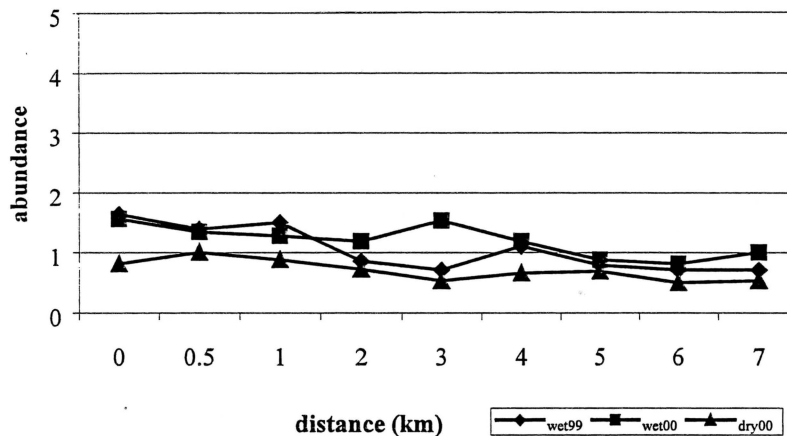


Figure 9: Average wet and dry season annual forb abundance across the Hoanib River catchment, 1999-2000

The average annual forb abundance across the catchment during the 1999 wet season was between 0.5-1 (0.5-5%), while a similar average abundance was observed during the 2000 wet season. However, the average abundance of annual forbs during the 2000 dry season was between 0-0.5 (0-1%), which was significantly different from both the previous wet season average abundance ( $p = 0.01428$ ,  $t$ -test for 1999 and  $p < 0.001$ ,  $t$ -test for 2000). There appeared to be little difference in average abundance observed between wet seasons ( $p = 0.1693$ ,  $t$ -test). The abundance of annual forbs appeared to be greatest nearer the water points.

## SEASONAL VARIATIONS IN VEGETATION ABUNDANCES

The seasonal relationship between ground cover, bare earth and tree and shrub (canopy) cover abundance is presented in Figures 10 to 12. See Figures 13 to 15 for the seasonal relationship between annual grasses, annual forbs and perennial grasses.

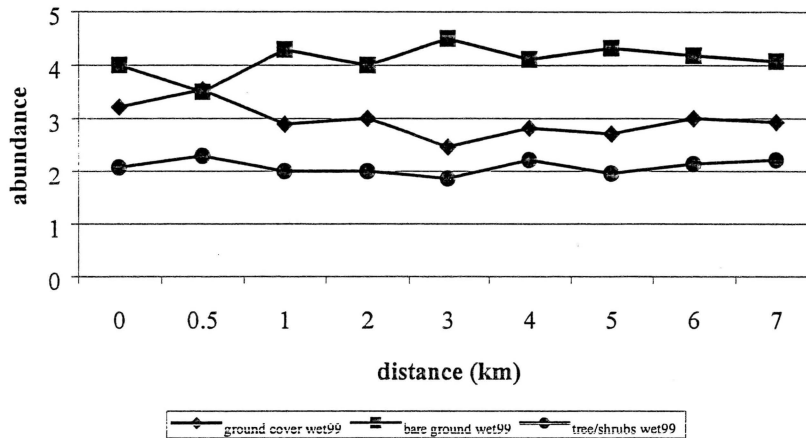


Figure 10: Comparison between ground cover, bare earth and tree and shrub canopy cover abundance during the 1999 wet season

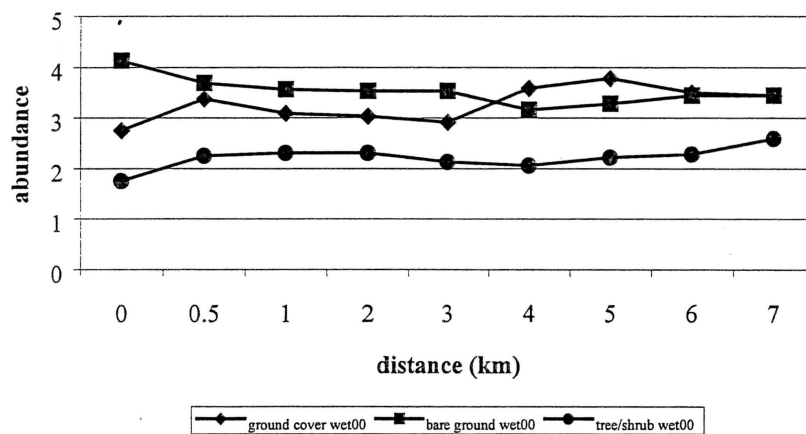


Figure 11: Comparison between ground cover, bare earth and tree and shrub canopy cover abundance during the 2000 wet season

## SECTION II

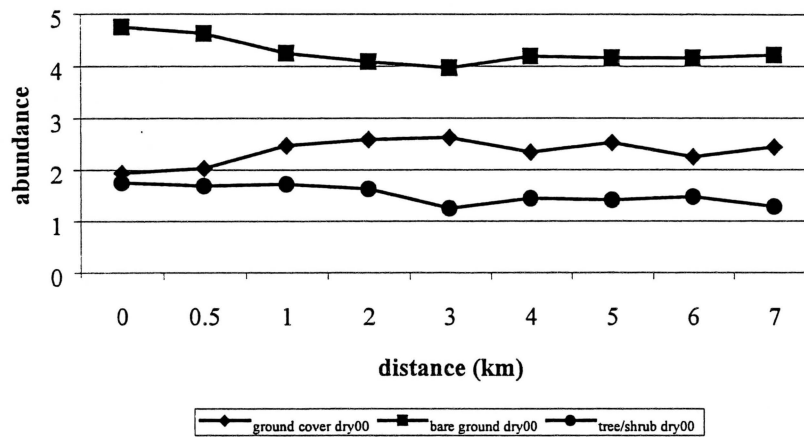


Figure 12: Comparison between ground cover, bare earth and tree and shrub canopy cover abundance during the 2000 dry season

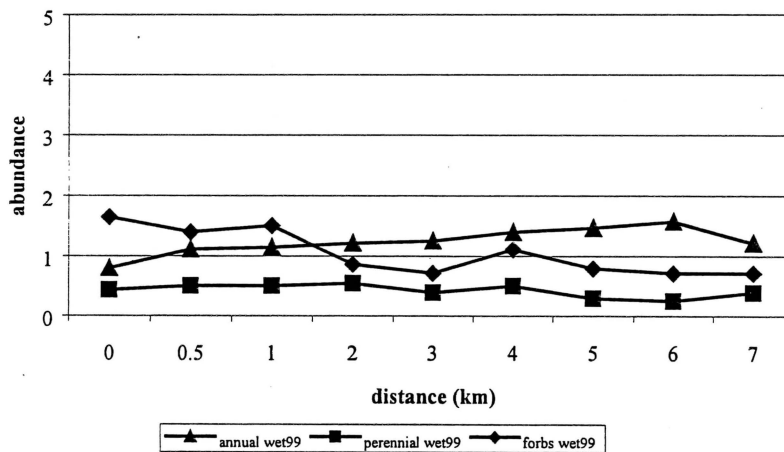


Figure 13: Comparison between annual grasses, annual forbs and perennial grass abundance during the 1999 wet season.

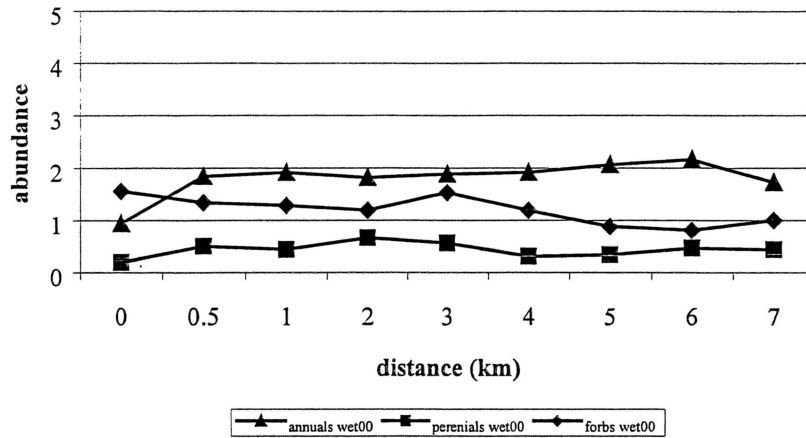


Figure 14: Comparison between annual grasses, annual forbs and perennial grass abundance during the 2000 wet season.

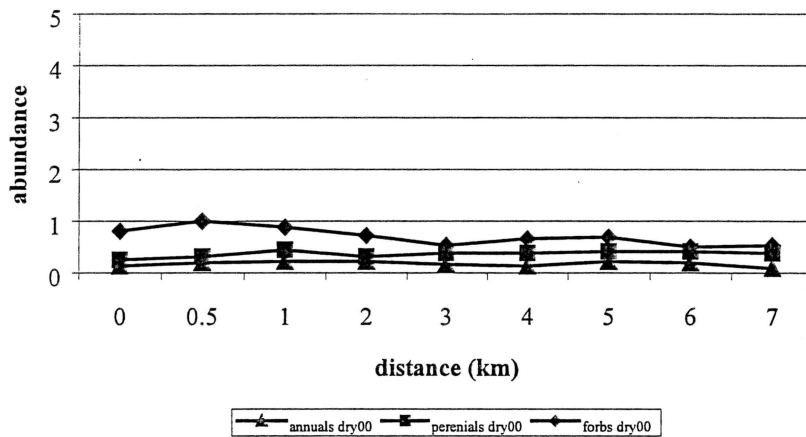


Figure 15: Comparison between annual grasses, annual forbs and perennial grass abundance during the 2000 dry season.

During the 1999 wet season there appeared to be a significantly larger bare ground fraction than was observed during the 2000 wet season. The tree and shrub canopy cover distribution did not appear to vary significantly on a seasonal time scale. However, there was a significant decline in ground cover abundance and tree and shrub canopy cover abundance between the wet season and the dry season. The reverse was observed for bare ground abundance, which was at its greatest during the dry season and at its least during the wet season.

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During both the 1999 and 2000 wet seasons, the abundance of annual forbs was greatest closest to the water points. In the 1999 wet season, forbs were more abundant closest to the water point than annual grasses, then abundance decreased slowly to about the 2 km mark where the abundance of annual grasses increased to greater than the forbs. During the 2000 wet season, forbs were again in greater abundance than annual grasses closest to the water point. However, annual grass abundance increased at the 0.5km plots to be greater than the forb abundance. Perennial grass abundance varied little between the two wet seasons. However, during the 2000 dry season, perennial grasses showed the greater abundance, varying little from the observed wet season abundance. Both annual grass and forb abundances decreased to less than the perennial grass abundance and significantly less than the wet season abundances.

### VEGETATION SPECIES PRESENT

For a detailed list of species observed growing in the eight focus area transect plots during the wet and dry season see Appendix B. The abundance (Zurich-Montpellier scale) of individual species and the number of plots the species occupied is also shown in Appendix B.

The same plots were used for vegetation studies during both wet and dry season surveys. Only those species that were carrying leaf were identified and analysed. Those trees and shrub species that are normally deciduous and become dormant during the dry season were not taken into account during the surveys. However, even species known to be deciduous were counted if they were carrying any leaf at the time of the surveys.

A summary of the number of species of trees and shrubs, grasses and forbs found in the transect plots is presented in Table 3.

**Table 3: A summary of the number of species of trees and shrubs, grasses and forbs found in transect plots in the Hoanib River catchment during the 1999 and 2000 wet seasons and the 2000 dry season**

	No. of species of trees and shrubs		No. of species of grasses		No. of species of forbs	
	Wet season	Dry season	Wet season	Dry season	Wet season	Dry season
Otjokavare	36	18	24	3	76	10
Hobatere	30	19	27	6	70	32
Kaross	28	21	24	2	37	15
Palmfontein	21	17	14	4	35	29
Omuramba	21	12	32	2	39	13
Serengeti plains	17	13	24	5	36	12
Khowarib	15	13	15	1	37	6
Sesfontein	20	15	18	3	32	8
Mean and STD (in brackets)	23.5(±7.2)	16.0(±3.3)	22.3(±6.2)	3.3(±1.7)	45.3(±17.3)	15.6(±9.6)

### Trees and shrubs species abundance

Seventy-five species of woody trees and shrubs were identified in the Hoanib River catchment during the 1999 and 2000 wet seasons.

The most dominant tree and shrub species throughout the catchment was *Colophospermum mopane*. In the higher rainfall sections of the eastern catchment *Colophospermum mopane* forms stands with both *Terminalia prunioides* and *Combretum apiculatum* (Otjokavare, Hobatere, Kaross, Palmfontein). As the rainfall decreased, *Colophospermum mopane* formed stands with *Terminalia prunioides* (Serengeti plains and Omuramba). In the drier areas of the Khowarib and Sesfontien basin, *Colophospermum mopane* formed stands with both *Terminalia prunioides* and *Acacia tortilis*. For a complete list of associations with these dominant vegetation communities see Appendix B.

Of the species listed in Appendix B, only a few carried leaf during the entire dry season. The only trees and shrubs that were found to carry substantial amounts of leaf during this period were:



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*Acacia erioloba*, *Boscia albitrunca*, *Boscia foetida*, *Faidherbia albida*, *Maerua parvifolia*, *Maerua schinzii* and *Salvadora persica*. All other species observed bore the previous season's leaf and for the most part, were denuded of most of their leaves.

There appeared to be little annual variation in trees and shrub abundance, although a greater canopy cover and greater retention of leaf was observed after the above average rains of the 1999-2000 wet season.

### Grass species abundance

The identified grass species, their abundance and distribution in transect plots in the Hoanib River catchment are shown in Appendix B.

Generally, the highest species diversity of grasses occurred in the higher rainfall areas of the eastern section (the exception being Palmfontein), with a lower diversity observed in the western section of the catchment.

The most abundant species of grasses in the catchment were the annuals (*Antheophora schinzii*, *Eragrostis porosa*, *Kaokochloa nigrirostis*, *Stipagrostis hirtigluma*). The four annual grass species listed above had greater abundances in order of magnitude, than other observed annual species. According to the range assessment method developed by Du Plessis *et al.*, (1998a), all of these grasses would be categorised as either 'Increaser 2b' (Category 4) or 'Increaser 2c' (Category 5). This correlates to the species of grasses, some dwarf shrubs and annual forbs that are more dominant in moderately to severely over-utilised veld.

The abundance of annual grass species also appeared to change with the amount of rainfall. For example, during the 1999 wet season (rainfall approx. 100 mm), the dominant annual grass on the Serengeti plain was *Kaokochloa nigrirostis* (Avg. abundance = 4) with lesser amounts of *Stipagrostis hirtigluma* (Avg.abundance = 2b). However, in the same plots during the 1999-2000 wet season (rainfall approx. 300mm), *Kaokochloa nigrirostis* and *Stipagrostis hirtigluma* had a similar average abundance of 3.

Of the 49 grass species listed in Table 5 the only perennial grasses are *Stipagrostis hochstetteriana*, *Stipagrostis namaquensis*, *Stipagrostis uniplumis*. Though several of the

species list in Appendix B (for example: *Cenchrus ciliaris*) are thought to be perennial in other areas of Namibia (Muller, 1984), they were observed to behave more like annuals in the Hoanib River catchment as they do not usually survive through the dry season. In the eastern section of the catchment the abundance of perennial grasses was low. However they formed a significant proportion of the grass abundance on the Serengeti, Khowarib and Sesfontein plains. These three perennial grass species were classified as 'Decreasers' (Category 2) by the Du Plessis *et al.*, (1998a) assessment method. This means that these species are abundant in lightly grazed veld, decreasing with under- or over-use.

The dwarf shrub species of *Leucosphaera bainesii* (bitter bush), *Monechma salsola* and *Petalidium engleranum* were common throughout the catchment. All of these dwarf shrubs are classified by Du Plessis *et al.* (1998a) as an 'Increaser 2c' (Category 5) which inferred that these species are dominant in severely over-used veld. *Leucosphaera bainesii* was most dominant around water points and highly disturbed areas (e.g. Omuramba water point, 0km), while *Monechma salsola* and *Petalidium engleranum* were more common on the plains (e.g. Omuramba and Serengeti plains).

### **Annual Forbs**

Ninety-seven different annual forbs species were collected from the transect plots during this study. Of these only 41 species were identified by the NBRI, while the remaining 56 species remain unidentified. For a detailed list of identified forbs see Appendix B. Du Plessis *et al.*, (1998a) classified all annual forbs 'Increaser 2c' (Category 5) inferring that these species become dominant in severely over-used veld.

Annual forbs were found to be abundant in all plots across the catchment during the wet season. They were most abundant in plots around water points and in highly disturbed areas (human settlements and areas of intensive agricultural activity). *Tribulus zeyheri* and *Zygophyllum spp.* were the most abundant of the annual forb species and were encountered in nearly all transect plots.

During the dry season, very few of the wet season forbs survived, most having seeded and 'died off'. Large reductions in the number of species and abundance of forbs were observed across the catchment during this time.

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### EFFECT OF LAND USE

A comparative study was undertaken in Otjokavare, Hobatere, Kaross and Palmfontein to look at the effect of land use on vegetation species and abundance. The effect of the wet and dry season on the abundance of ground cover, bare ground, canopy cover of trees and shrubs, annual grasses, perennial grasses and annual forbs was investigated in each of the study areas.

#### Ground cover abundance

The ground cover abundance in transect plots in Otjokavare, Hobatere, Kaross and Palmfontein is presented in Figures 16(a) and 16(b).

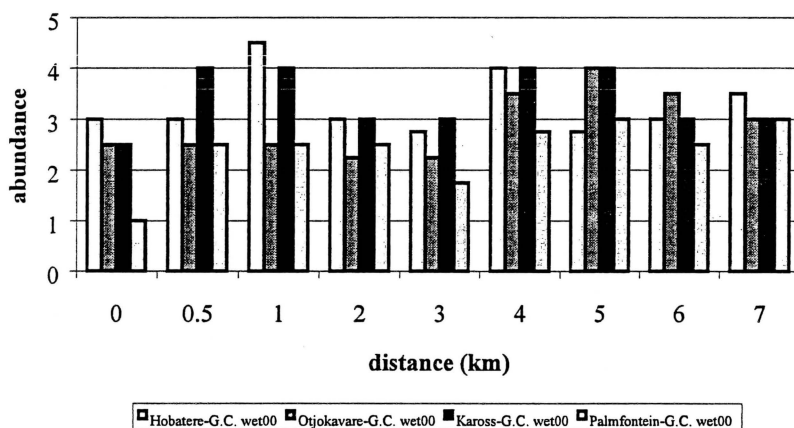


Figure 16(a): Ground cover abundance observed in transect plots in Otjokavare, Hobatere, Kaross and Palmfontein during the 2000 wet season

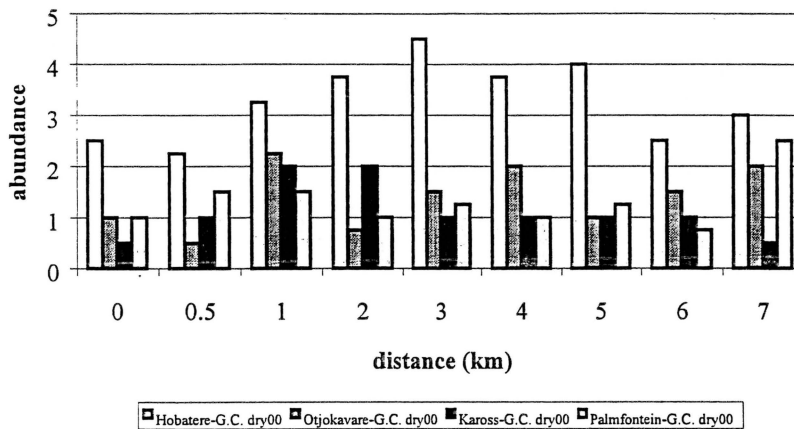


Figure 16(b): Ground cover abundance observed in transect plots in Otjokavare, Hobatere, Kaross and Palmfontein during the 2000 dry season

The ground cover abundance in all areas decreased within 0.5 km from a water source to less than 12.5%. Further along the transect, the canopy cover increased to between 12.5 and 75%. Similar trends were observed for each site during both the wet and dry seasons. During the dry season the ground cover abundance at Otjokavare, Kaross and Palmfontein decreased to less than 12.5% in all plots. Hobatere Game Park had a substantially higher abundance (12.5% to >75%) of ground cover in the dry season.

### Bare ground abundance

The bare ground abundance in transect plots in Otjokavare, Hobatere, Kaross and Palmfontein is presented in Figures 17(a) and 17(b).

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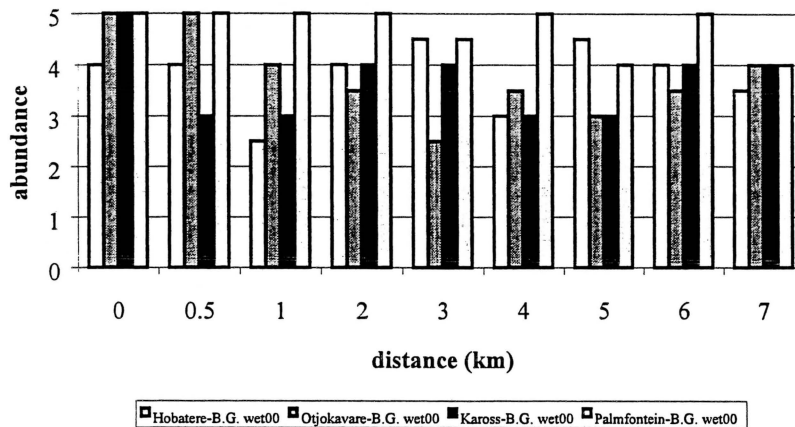


Figure 17(a): Bare ground abundance observed in transect plots in Otjokavare, Hobatere, Kaross and Palmfontein during the 2000 wet season

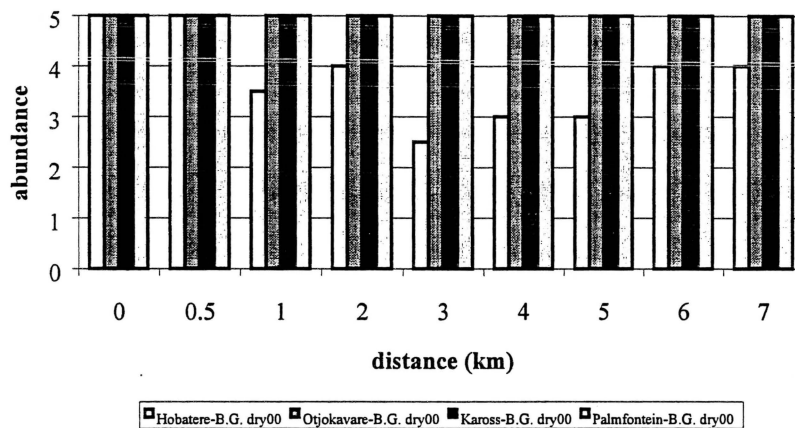


Figure 17(b): Bare ground abundance observed in transect plots in Otjokavare, Hobatere, Kaross and Palmfontein during the 2000 dry season

The bare ground abundance during the wet season was variable at all sites. Palmfontein has the highest abundance of bare ground across the transect plots, although all sites had bare ground abundances of greater than 50%. During the dry season the bare earth abundance increased to between 75 and 100% in all transects except for Hobatere Game Park where the bare ground abundance was still in excess of 50%, but lower than the observed abundances (75-100%) in other study areas.

### Tree and shrub canopy cover abundance

The tree and shrub canopy cover abundance in transect plots in Otjokavare, Hobatere, Kaross and Palmfontein is presented in Figures 18(a) and 18(b).

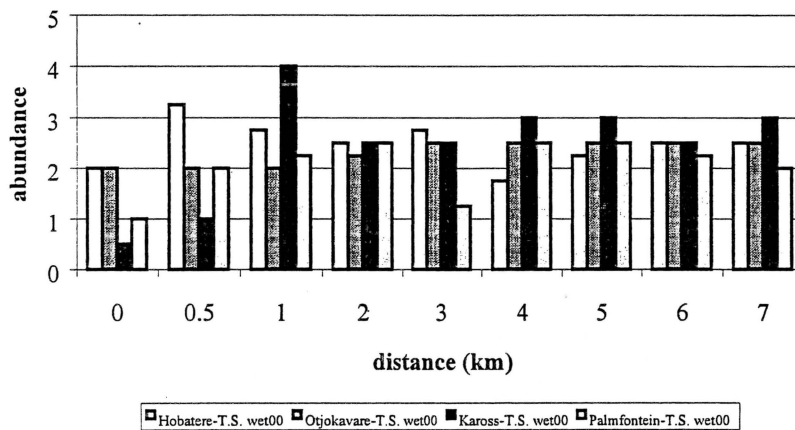


Figure 18(a): Tree and shrub canopy cover abundance observed in transect plots in Otjokavare, Hobatere, Kaross and Palmfontein during the 2000 wet season

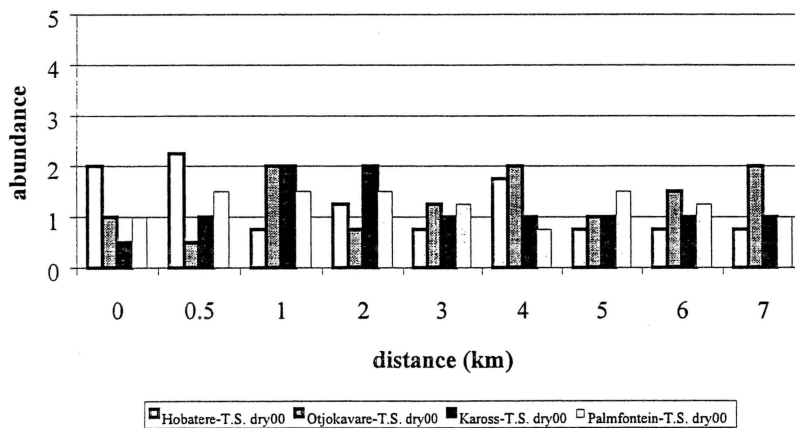


Figure 18(b): Tree and shrub canopy cover abundance observed in transect plots in Otjokavare, Hobatere, Kaross and Palmfontein during the 2000 dry season

With the exception of the first 0.5km around the water sources, the canopy cover abundance of trees during the wet season was variable but ranged for all sites from 5 - 50% (most plots were

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between 5 and 12.5%). However, during the dry season, the canopy cover abundance decreased at all sites to less than 5%.

### Annual grasses

The annual grass cover abundance in transect plots in Otjokavare, Hobatere, Kaross and Palmfontein is presented in Figures 19(a) and 19(b).

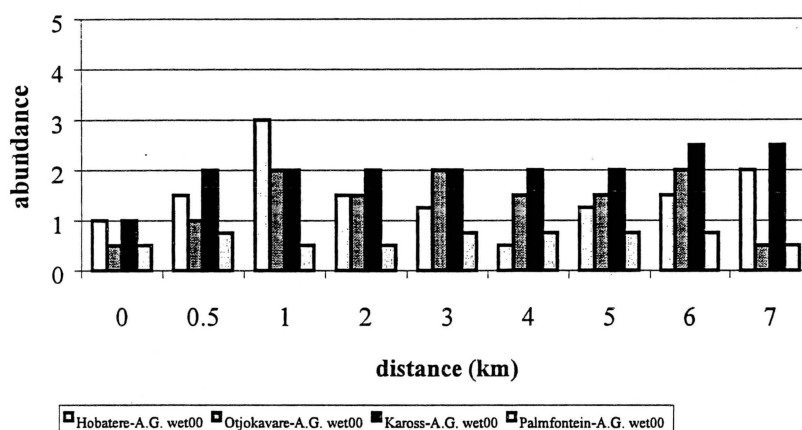


Figure 19(a): Annual grass abundance observed in transect plots in Otjokavare, Hobatere, Kaross and Palmfontein during the 2000 wet season

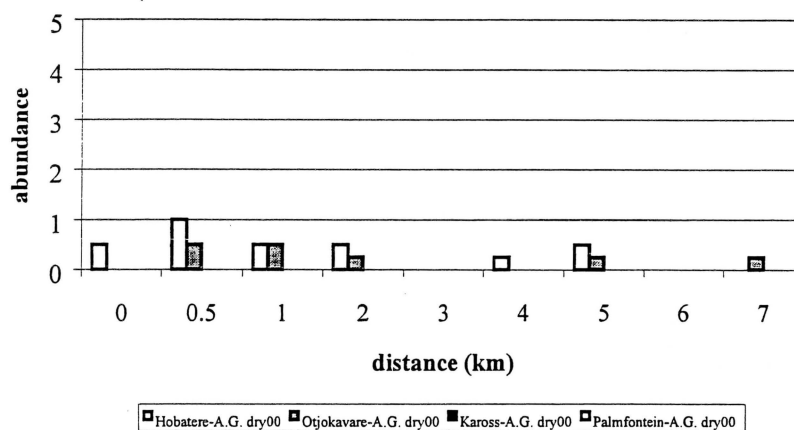


Figure 19(b): Annual grass abundance observed in transect plots in Otjokavare, Hobatere, Kaross and Palmfontein during the 2000 dry season

The abundance of annual grasses varied from area to area. All sites showed low abundance of between 0 and 1% around the water sources. However, in Kaross and Hobatere Game Park the abundance increased with distance from a water source to between 5 and 12.5%, at 7km from the water source. Both Otjokavare and Palmfontein showed annual grasses of lower abundance (1-12.5%) over the transects. During the dry season the abundance of annual grasses decreased to <1% in all plots.

### Perennial grasses

The perennial grass cover abundance in transect plots in Otjokavare, Hobatere, Kaross and Palmfontein is presented in Figures 20(a) and 20(b).

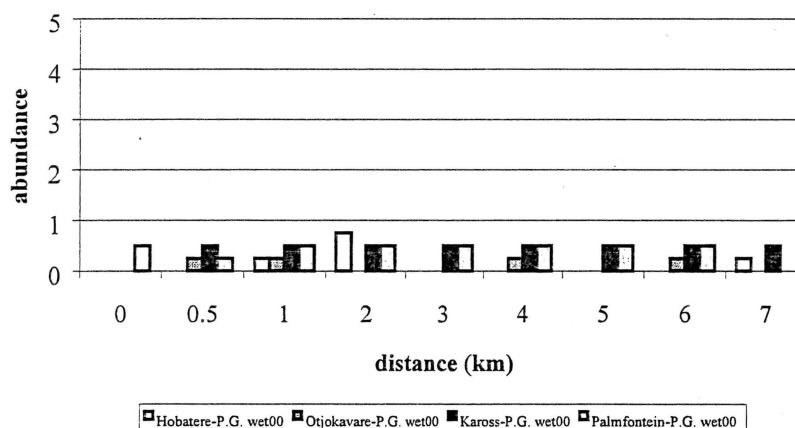


Figure 20(a): Perennial grass abundance observed in transect plots in Otjokavare, Hobatere, Kaross and Palmfontein during the 2000 wet season



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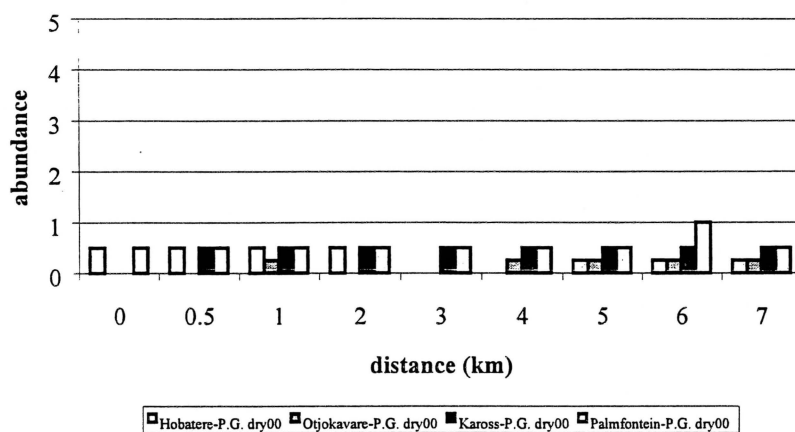


Figure 20(b): Perennial grass abundance observed in transect plots in Otjokavare, Hobatere, Kaross and Palmfontein during the 2000 dry season.

The abundance of perennial grasses was consistent during both the wet and dry season. The abundance was low along all transects and never amounted to more than 1% in any plot.

## Annual forbs

The annual forb cover abundance in transect plots in Otjokavare, Hobatere, Kaross and Palmfontein is presented in Figures 21(a) and 21(b).

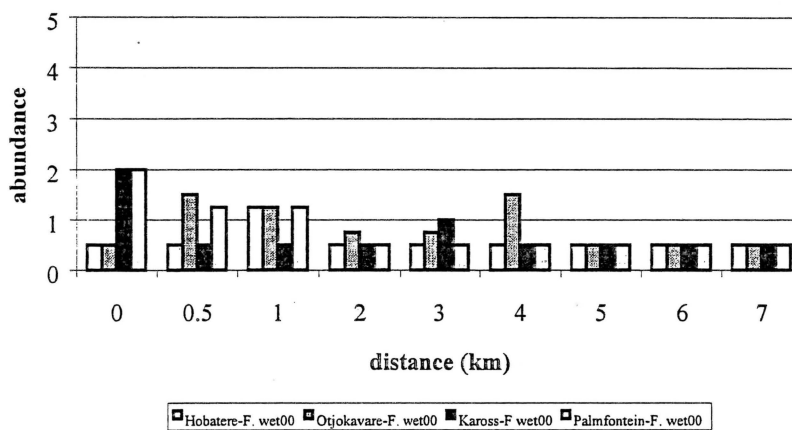


Figure 21(a): Annual forb abundance observed in transect plots in Otjokavare, Hobatere, Kaross and Palmfontein during the 2000 wet season

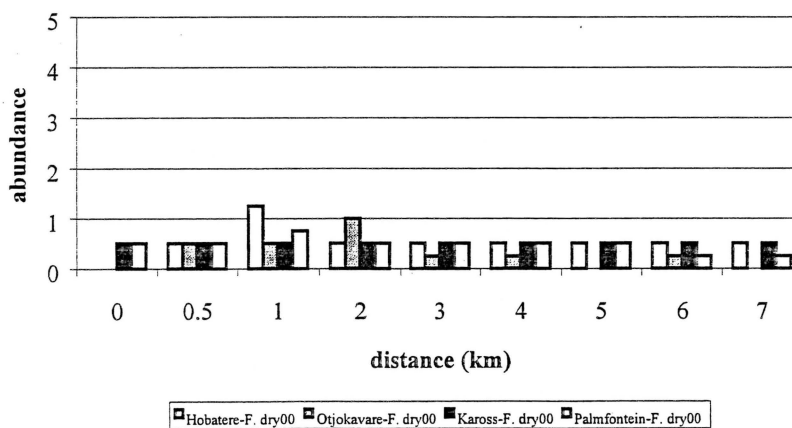


Figure 21(b): Annual forb abundance observed in transect plots in Otjokavare, Hobatere, Kaross and Palmfontein during the 2000 dry season

During the 2000 wet season the annual forb abundance was greatest around the water sources (between 5 and 12.5%) at both Kaross and Palmfontein. While in Hobatere and Otjokavare,

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abundance remained low (<1%). At the 2.0 km plot, the abundance of forbs at all sites was approximately the same (<1%) and stayed at this abundance for all other transect plot sites. During the dry season the abundance of annual forbs had decreased in most sites, often not being recorded.

### Species Diversity

The highest canopy cover abundance for all tree and shrub species occurred during the wet season and decreased during the dry season as many of the species drop their leaves. The dominant tree and shrub vegetation type was *Colophospermum mopane* – *Terminalia prunioides* – *Combretum apiculatum* (as defined by Becker and Jurgens 2000). For other species of associated shrubs and trees see Appendix B.

During the wet season, the most abundant annual grasses across the study areas were *Antheophora schinzii*, *Eragrostis porosa*, *Kaokochloa nigrirostis*, all of which are species that are abundant or dominate in moderately and severely utilised veld. Throughout the catchment, some areas had locally abundant annual grasses that dominated (for example, Hobatere where *Sorghum verticilliflora* dominated for 3 plots), but the majority of other annual species were in low abundance (<1%). During the dry season very few annual grass species were observed in the plots.

A similar pattern to annual grasses is observed for annual forb species. There were high abundances of forbs in the wet season, particularly *Tribulus zeyheri* that had an abundance of between 5 and 12.5%. Most other forb species had an abundance of <1% throughout the plots.

For a complete list of species, abundance and distribution see Appendix B. For a summary of the number of species in each transect see Table 3. The results of vegetation distribution and abundance have been discussed in detail in a previous section.

## ANNUAL RAINFALL

The rainfall in the catchment for the 1999 and 2000 seasons is shown in Table 7 (for a detailed discussion of rainfall in the catchment, see Leggett *et al.*, 2001b).

**Table 7: 1999-2000 rainfall data from the Hoanib River catchment.**

Location	Distance from the coast (km)	Rainfall 1998-1999 (mm)	Rainfall 1999-2000 (mm)	Long-term mean (mm)
Möwe Bay <sup>1</sup>	0	20.9	2.9	13.45
Sesfontein	100	N/a	106.5	107.9
Khowarib	120	115.5	310.5	N/a
Warmquelle	125	N/a	232.5	N/a
Erwee <sup>2</sup> (Atlanta Post)	150	159	N/a	N/a
Omuramba <sup>2</sup>	155	N/a	N/a	N/a
Etendeka Mountain Camp <sup>1</sup>	150	92.5	288	N/a
Hobatere Game Park	180	182.5	432	251.38
Otjokavare	185	211.0	431.5	N/a
Otjovasandu	190	N/a	N/a	299.8
Kamanjab <sup>1</sup>	210	85	345	305
Opuwo <sup>1</sup>	215	209	559.4	289.14

<sup>1</sup> - Located outside the Hoanib River catchment

<sup>2</sup> - Insufficient data collected

N/a – not available

In most areas of the catchment either average or above average rains fell during the 1999-2000 wet season.

## DISCUSSION

### Annual variation in vegetation

There appeared to be a strong correlation, catchment-wide, between abiotic factors (mainly rainfall) and vegetation growth. In particular, the abundance of annual grasses and annual forbs seemed to be dependent on seasonal rainfall. The abundance of perennial grasses and cover abundance of trees and shrubs appeared less dependent on seasonal variability, although increased growth and flowering in all species was observed after higher rainfall events. The increased growth of annual grasses provided a significant standing 'dead layer' of grasses that was observed during the following 2000 dry season. This 'dead layer' was not observed during the 1999 dry season as the growth of annuals was significantly less. Most of the observed dead layer was thought to be *Stipagrostis hirtigluma* sub. *hirtigluma* which had formed large stands of grasses during the 2000 wet season.

There appeared to be little difference in the abundance of perennial grasses over much of the catchment, while in most areas and during most seasons, the abundance was relatively low. However, a relatively high abundance of perennial grasses (*Stipagrostis uniplumis* and *Stipagrostis hochstetteriana*) was observed on the Serengeti, Khowarib and Sesfontein plains after the above average rains of the 2000 wet season. These two species are regarded as 'decreasers' (Category 2) (Du Plessis *et al.*, 1998a) i.e. they are only found in under-used or slightly-used veld. The Serengeti plains could be described as under-used veld as there are few water points in this area and it is only grazed seasonally by domestic stock and wildlife. However, the Khowarib and Sesfontein plains have long been regarded as an over-used and degraded area (Van Warmelo, 1962; Loxton, Hunting and Associates, 1974; Nærua *et al.*, 1993; MAWRD, 1997) and the presence and abundance of 'decreaser' species would indicate a disparity with previous researchers. A possible explanation could be the growth behaviour of the perennial grasses in this arid environment. In the western section of the Hoanib River catchment, where below-average rains are regularly recorded for several consecutive seasons, perennial grasses are thought to behave in a similar manner to annual grasses. They 'die back' soon after seeding if insufficient moisture is available to maintain growth throughout the dry season. During the 1999 wet season a small percentage of perennial grasses on the Khowarib and Sesfontein plains was observed to sprout new leaf (in comparison to the 2000 season). Few of those that

sprouted leaf were observed to carry this leaf through to the following wet season. Therefore when the rains fell, both perennial grasses and annuals grew at approximately the same rate. However, the wet season provided above-average rains, in the 2000 wet season and the perennial grasses retained leaf (i.e. not die back to a tuft) throughout the dry season. This observation would appear to cast doubt upon Sullivan's hypothesis that "extreme rainfall and flooding events can be expected to play a defining role in constraining opportunities for recruitment" (Sullivan, 1999).

The seasonal dependence of vegetation growth on variable rainfall supports the non-equilibrium argument that has been proposed by numerous authors in arid lands (e.g. Ellis and Swift, 1988 and specifically Sullivan, 1996; 1999) for this area.

### **Seasonal variation in vegetation**

The seasonal variation in vegetation was marked. The abundance of bare ground increased dramatically during the dry season to be the most abundant ground cover. The abundance of all vegetation species decreased to its lowest at this time. Several tree and shrub species lost their leaves and in many areas, only *Bosica spp.* and *Maerua spp.* remained with leaf in the plots. The same was true for annual grasses and forbs with low abundance observed for both vegetation types.

Only perennial grasses retained leaf into the dry season, but again this only occurred due to the above average rainfalls of the 2000 season.

Within the 'sacrifice zone' (Perkins and Thomas, 1993) normally associated with between 0 and 1km around a water point, all vegetation species - with the exception of forbs and large trees - were affected by the disturbance caused by constant animal movement in both the wet and dry seasons. The zone tended to be larger during the dry season and contracted during the wet season. However, over the study period the zone existed in all areas, regardless of rainfall. Annual forbs dominated this zone, mainly because forbs could establish themselves rapidly and domestic stock did not find them particularly palatable. Only annual grass species that could cope with disturbed environments were observed here (for example, *Eragrostis porosa*, *Monelytrum luederitzianum*). Very few perennial grasses, shrubs and trees were found in the immediate area around the water source. Large trees (>10m height) were found in this zone. As a result of their

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size, domestic stock did not knock over these trees and neither did they significantly browse their foliage. These results were similar to those observed by Perkins and Thomas (1993) in Botswana.

Outside the 'sacrifice zone' there appeared to be little change in vegetation abundance and number of species. There tended to be a decrease in the abundance of annual forbs and an increase in annual grass abundance. Perennial grasses, shrub and tree abundance appeared to remain relatively constant for the remainder of the distance plots. The term 'over-grazed' has often been used to describe the communal areas of north-western Namibia (Van Warmelo, 1962; Loxton, Hunting and Associates, 1974; Nærua *et al.*, 1993; MAWRD, 1997), and the most abundant species of grasses occurring in the Hoanib River catchment are symptomatic of moderately to severely over-used veld. Perennial grasses that are generally associated with 'lightly' grazed veld (Du Plessis, 1998a), exist in areas normally associated with over-grazing (Khowarib and Sesfontein). A possible explanation for the relative stability of grass species and abundance is probably because all the grass species (annual and perennial) behave similarly in a below-average or average rainfall year i.e. they germinate or sprout quickly at the onset of rain, have a short growing season, seed and then 'die-off' when the land dries out. It is only in the exceptional, above average rainfall years that the perennials retain some leaf growth throughout the dry season. This could be a special adaptation of certain perennial grasses to survive in low and erratic rainfall regimes.

The almost constant abundance and number of species of both annual and perennial grasses across the study area casts doubt on the theory, especially in non-equilibrium conditions, that traditional pastoralism leads to a decrease in species within a climatic zone (Du Toit and Cumming, 1999). This will be discussed in more detail in the wildlife and domestic stock section.

### **Dry season grazing and browsing availability**

The question of what domestic stock and wildlife are feeding on during the dry season and during periods of aridity, where below average rainfall occurs during several consecutive wet season, remains unsolved in the Hoanib River catchment. Certainly, in the areas where there were higher concentrations of domestic stock (Otjokavare, Omuramba) there was little grazing, with even standing 'dead grass' remaining on the ground during this season. At this time of the year, both domestic stock and wildlife were observed grazing on dead *Colophospermum mopane* leaves and

seedpods of the *Faidherbia albida* trees. In particular, wildlife congregated in the riverbed during the dry season, primarily feeding on the seedpods and leaves of *Faidherbia albida*. Elephant (*Loxodonta africana*), giraffe (*Giraffa camelopardalis*) and gemsbok (*Oryx gazella*) were observed eating the bark of *Faidherbia albida* and *Colophospermum mopane* trees (Leggett *et al.* 2001a). Goats were seen browsing extensively on the *Faidherbia albida* trees and numerous shrub species (for example, *Grewia spp.*) over all areas of the catchment around settlements. However, in most areas along the Hoanib River the browse height of *Faidherbia albida* was too high for goats to browse extensively on it.

Immediately before and just after the first rains of the wet season some tree species (for example, *Colophospermum mopane*, *Grewia spp.*, *Terminalia prunoides*, *Combretum appiculatum* and some *Commiphora spp.*) sprouted leaves that were readily browsed by both domestic stock and wildlife. This new vegetation was usually available before the annual and perennial grasses had germinated or sprouted leaf. Wildlife was observed to leave the riverbeds and trek many kilometres into the hills to browse on other more palatable species (for example; *Commiphora spp.*), immediately after the onset of the first rains (Leggett *et al.*, 2001a).

This behaviour has been observed in other arid areas in Africa. Coppick *et al.* (1986), reported that livestock - cattle, goats, sheep and camels in particular - survived for six months on the nutrition gained from dried stalks of the previous season's grass, seed pods and dried leaves in the arid Turkana region of Kenya. Skarpe (1986) suggested that animals in the Kalahari also obtained a great deal of nutrition at the end of the dry season by eating the buds of new leaves from sprouting trees. In addition, Skarpe (1986) also reported that many of the trees and shrubs in the Kalahari have the habit of sprouting in advance of the wet season to take advantage of any early rains, depending on the 'carry over' moisture from the previous seasons.

However, during periods of aridity in the Hoanib River catchment when below-average rains fall (for example, during the 1981 season no rain fell in Sesfontein), very little grazing was available to animals but some managed to survive for long periods. During the 1981-82 drought, 90% of the domestic stock and 80% of some wildlife species died (Viljoen, 1982). Many of the animals did not die in the first season of the drought but survived well into the second year feeding entirely on available browse (R. Loutit, pers.com., 1998). Trees and shrubs normally sprout leaves even during arid years and therefore browse would be available to sustain many of the animals. However, during the second year of the drought very few trees sprouted new growth (R.



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Loutit, pers.com., 1998; D. Gilchrist pers.com., 1998) depriving the animals of nutrition, resulting in large mortality. Therefore, in an arid system like the Hoanib River catchment, it is the browsing that sustains the domestic stock and wildlife during arid periods (dry seasons or dry years). The grazing, only available for short periods of time, is a bonus to the system.

### Species Diversity

The number of species of vegetation across the climatic gradient of the Hoanib River catchment follows a similar pattern to that described by Becker and Jurgens (2000). The vegetation type *Colophospermum mopane* - *Terminalia prunioides* - *Combretum apiculatum* dominates the wetter, eastern section of the catchment (Otjokavare). As the rainfall decreases *Colophospermum mopane* - *Terminalia prunioides* vegetation type dominates (Omarumba) and in the ephemeral grasslands of the Serengeti plains *Stipagrostis hirtigluma* and *Kaokochloa nigrirostis* species dominate. While in the west around Sesfontein, grasslands of perennial *Stipagrostis hochstetterana* (also smaller amounts of *Stipagrostis uniplumis*) become the dominant grass type with *Colophospermum mopane* – *Terminalia prunioides* – *Acacia tortilis* becoming the dominant woody vegetation.

### The impact of wildlife and domestic stock on the veld

Of the four focus areas (Otjokavare, Hobatere Game Park, Kaross, Palmfontein), only Hobatere Game Park appeared to have a significant difference in ground cover and bare earth abundance during the 2000 dry season. However, this was probably due to a high abundance of standing 'dead grass' from the previous wet season as the abundance of trees, shrubs, annual grasses, perennial grasses and annual forbs was not significantly different from any other area. That there was standing 'dead grass' is probably due to the fact that the fence enclosing Hobatere Game Park has numerous holes (caused by elephants) along its western boundary allowing the seasonal movement of wildlife (Leggett *et al.*, 2001a). Wildlife tends to move out of Hobatere Game Park during the dry season and into the hills around the game park, returning in the wet season. This tends to reduce the pressure on the land during the dry season possibly resulting in the higher annual grass abundance observed here. Kaross is fully enclosed by an electric fence and no movement of animals either into or out of the 14 000ha area is possible. Grazing pressure is maintained year round in this area. This situation is similar to that occurring in the communal

areas around Otjokavare and Palmfontein. Although there are no fences, grazing pressure is maintained year round by domestic stock. During the wet season pastoralists keep some domestic stock close to the villages for monitoring purposes. During the dry season, the domestic stock are limited in their movements by available water and tend to be concentrated around permanent water points and human settlements. As a result, the vegetation does not get a chance to rest and recover.

In an arid area, drought is normal, and, generally, if animals cannot migrate out of an area to another with better climatic conditions, a large percentage of the animals will die from lack of sufficient grazing and browsing. These episodic droughts enforce a natural 'resting period' on the veld. The vegetation is generally better adapted to drought and can recover more rapidly than the wildlife and domestic stock populations (Dankwerts and Stuart-Hill, 1988).

Palmfontein was observed to have the lowest diversity of trees, shrubs and grasses (annual and perennial). This area has traditionally been used as a 'hard times' grazing area by pastoralists of the eastern catchment (Leggett *et al.*, 2001a). 'Hard times' grazing areas are only used when traditional grazing areas have been exhausted. These areas are generally characterised by poor grazing and inadequate water supplies for large numbers of domestic stock. This combination is abnormal in the catchment area, where it is more usual to have grazing where there is no water and water where there is no grazing. This area generally supports relatively small numbers of domestic stock (approx. 800–1000, Leggett *et al.*, 2001a) during 'normal' rainfall years, however during arid years when no other grazing is available large numbers of stock (up to 5000 individuals) are pushed into this area (R. Loutit, pers.com., 1998). The level of use by pastoralists supports the data that showed the Palmfontein area to have generally poor quality browsing and grazing even in years of above-average rainfall. This is probably caused by the absence of a resting period for the veld.

From the results, it would appear that the intensive grazing of either domestic stock or wildlife has a similar impact on the number of species and abundance of vegetation during above average rainfall years.

## CONCLUSION

Vegetation across the catchment varied both seasonally and annually. The abundant vegetation growth, catchment wide, resulting from the above-average rainfalls of the 1999-2000 wet season, tends to support the concept of a non-equilibrium system. This vegetation response during years of below-average and normal rainfall will be different from those observed during this study. Some of the conclusions that can be drawn from this study are:

- The number of species and abundance of trees and shrubs appeared not to be closely related to annual rainfall (except in times of exceptionally arid climatic cycles).
- The number of species and abundance of annual grasses depends on annual rainfalls. There are indications that dominant species in an area change with relation to the amount of annual rainfall.
- Perennial grasses in below-average rainfall years behave similarly to annual grasses: they seed and do not retain leaf during the dry season. It is only during years of above-average rainfall that perennial grasses retain their leaf during the dry season.
- Domestic stock and wildlife appear to survive on very little during the dry season mainly by browsing, eating seedpods, dried leaves and dried stalks from the previous season's crop.
- During arid years, when the abundance of both annual and perennial grasses is low or non-existent, wildlife and domestic stock survive by browsing buds and leaves on trees and shrubs.
- There appears to be little difference on the effect of intensive grazing by either domestic stock or wildlife on vegetation species or abundance during years of above average rainfall.

The implications for management from this study are that, catchment-wide, the vegetation (in particular annual and perennial grasses) responds more to climatic cycles and not to the intensity of land-use. This is evident for both domestic stock and wildlife populations with off-take recommended during years where below average rainfall occurs and stocking of the land during above average years. In addition, there appears to be merit in keeping an 'open range' system in operation allowing freedom of movement of wildlife and domestic stock during the wet and dry seasons. Although the sacrifice zone appears to be relatively small around a water source, the addition of further water sources in an arid area would have the effect of intensifying grazing and browsing, possibly leading to an increase in the sacrifice zone. A better management option

would probably be to include a better distribution of water sources, together with a co-ordinated, highly flexible and adaptive grazing management system.

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## **SECTION III**

### **RAPID VELD ASSESSMENT**

DEVELOPMENT AND IMPLEMENTATION  
OF A RAPID VELD ASSESSMENT METHOD  
FOR LOCAL NATURAL RESOURCE USERS

By: Stephanie Schneider\*  
Keith Leggett  
Julian Fennessy

Contact Address:  
Hoanib River Catchment Study  
Desert Research Foundation of Namibia  
PO Box 20232  
Windhoek  
Namibia  
E-mail: [stephanies@drfn.org.na](mailto:stephanies@drfn.org.na)

\* Person to whom all correspondence should be addressed

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## **ABSTRACT**

Rapid Veld Assessment (RVA) provides an easy and visual method for a quick assessment of grazing conditions. It has been designed for field use by local natural resource users and can be mastered with minimal training and material. The RVA is comprised of six category sheets, each containing four photos depicting a certain grazing condition, categorised from zero to five. These sheets require the user to match the observed grazing condition with one of the photos and thereby with one of the categories. The photos representing the six categories were chosen in a participatory manner in conjunction with members of local communities and a range land ecologist. Field trials and comparative assessments, as described in this paper, suggest that a degree of standardisation has been achieved with the RVA. However, individual bias cannot be totally avoided. The RVA has the potential to become a valuable tool for local communities in the long-term monitoring of their local veld conditions.

## INTRODUCTION

Rapid Veld Assessment (RVA) aims to provide an easy and visual method for a quick assessment of grazing conditions, while at the same time achieving a certain degree of standardisation. This paper sets out to describe how the RVA was developed for use in the Hoanib River catchment and its field-test by the Community Researchers in six focus communities of the Hoanib River catchment Study (HRCS). The RVA is comprised of six category sheets, each containing four photos depicting a certain grazing condition, categorised from zero to five. These sheets can easily be used in the field and only require the observer to match the grazing condition at hand with one of the photos and thereby with one of the categories (see Appendix A).

The RVA concept was developed by the project team, in collaboration with Mr. Colin Nott, who had previously established a simple photo-evaluation method for veld assessment as one method used in part of his MSc. thesis. During his fieldwork Mr. Nott found this method to be both the simplest and most effective of all the veld assessment methods he used. Since completing his thesis, his involvement in Community Based Natural Resource Management (CBNRM) in north-western Namibia has led to the idea of developing a similar method for local communities in that area (pers. comm., 1999). Milton and Dean (1996) also described a veld assessment method, using photographs to establish grazing records over time. Their method, however, requires not only visual comparison between photos and the actual veld condition, but further observations and recordings according to an established scoring system, e.g. forage value of veld, grazing intensity, disturbance indicators, seedlings of perennials, and soil and habitat health. Hence, this method is more time-consuming and is more difficult to use - especially in a field situation with respect to local natural resource users.

The RVA method does not aim to identify different grass species and/or their individual nutritional values, but rather looks to assess the overall abundance of vegetation cover in an area. It is intended for use by local natural resource users and conservancies, and eliminating the need for extensive training. Due to its simplicity, it is easy to apply and does not require any expensive or complicated measuring equipment. Therefore, the RVA method is applicable and cost effective, and gives the local communities the ability to assess their local grazing conditions over time. Its use can help local communities to better manage their land, i.e. move their domestic stock throughout the season according to changes in grazing conditions.

## HOANIB RIVER CATCHMENT STUDY (HRCS) AREA

The Hoanib River Catchment (HRC) is one of twelve major ephemeral river catchments occupying the semi-arid areas of north-western Namibia. All twelve rivers flow into the Atlantic Ocean or end in the Namib Sand Sea. The Hoanib River originates in the western edge of Etosha National Park, flowing through freehold and communal farming areas and, near its mouth, traverses the protected Skeleton Coast Park. The HRC occupies an area of 17 200 km<sup>2</sup>, 3% of which lies in freehold farm lands, 91% in communal farm lands and 6% is protected in both the Etosha National Park and Skeleton Coast Park.

The Hoanib River constitutes the boundary between the former Damaraland and Kaokoland, although since Namibia's Independence in 1990, these two areas have been incorporated into the Kunene and Erongo Regions (see Figure 1). With an estimated 8 000 people, the area is sparsely populated. The whole area is classified as rural and most people in the HRC are Otjiherero- or Damara/Nama-speaking, living from subsistence farming (predominantly domestic stock) on communal land.

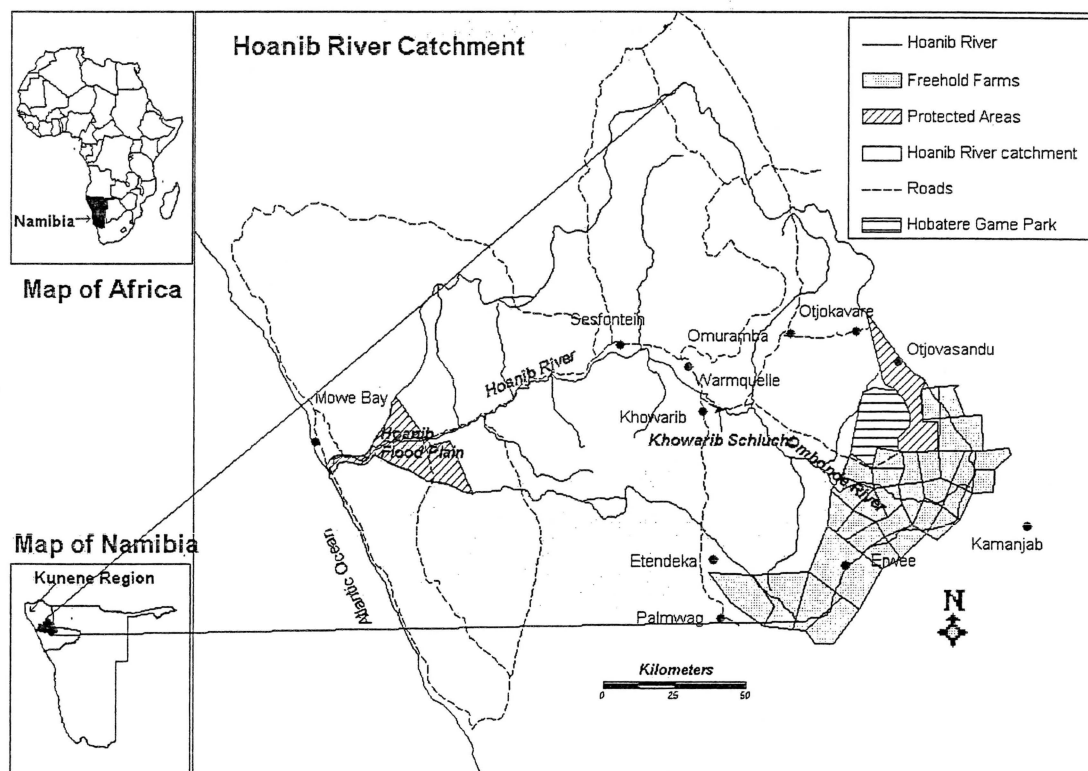


Figure 1: The Hoanib River catchment



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The rainfall within the HRC is highly variable (coefficient of variation from 50% to 90%) and unpredictable, with a mean rainfall of approximately 350mm in the east of the catchment to less than 15mm at Möwe Bay, on the Atlantic coast (Jacobson *et al.*, 1995; MWTC 2000). Drought in such an environment is normal in comparison with other areas of the world and, to be more accurate, one should refer to periods of high aridity (Jacobson *et al.*, 1995). Grazing throughout the catchment is dependent upon the variability of seasonal rainfall. Although grazing might be abundant after good rainy seasons, it is predominantly a limited resource, especially during periods of low rainfall. Sound management of grazing is therefore very important for livestock farmers in the HRC, in order to maintain a reliable food source for animals throughout the year.

## METHODS

### DEVELOPING THE CATEGORY SHEETS

Over a period of 18 months, the HRCS team developed a photo library of various veld conditions from different areas throughout the HRC. The photos were taken randomly, with the aim of covering as many grazing conditions and environments as possible, e.g. wet and dry seasons. From this library, 44 photos were singled out as representative of the HRC throughout the varying seasons. These photos were then shown to and discussed with individuals and small groups of community members in the HRC for their categorisation into groups. Ten different evaluations were undertaken (see Table 1).

**Table 1: Community Consultations for RVA Photo Categorisation**

Village	Number of People	Sex-Distribution		Language Group	
		Female	Male	Damara/ Nama	Otjiherero
Erwee*	1	1		1	
Khowarib*	1		1	1	
Khowarib	3	2	1	3	
Khowarib	3	1	2	2	1
Omuramba*	3		3		3
Otjokavare*	2		2		2
Sesfontein*	1	1		1	
Sesfontein	7	3	4	5	2
Warmquelle*	1		1		1
Warmquelle	9	2	7		9

\* including the local Community Researcher

With input from the local natural resource users and after final consultation with a range land ecologist, Mr. Bertus Kruger, six category sheets were developed (laminated A4-sheets with four representative photos for each category). These category sheets and their photos represent the following categories (see Appendix A):

Category 0: Bare Ground (no grass)

Category 1: Extremely Poor Veld (large sections of bare ground, very little grass)

Category 2: Poor Veld (small sections of bare ground, little grass)

Category 3: Moderate Veld (less bare ground, more grass)

Category 4: Good Veld (little observable bare ground, abundant grass)

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Category 5: Excellent Veld (no observable bare ground, abundant grass)

## FIELD TRIAL OF RVA

During individual training sessions, the RVA was introduced to the six Community Researchers, working for the HRCS (see Table 2). Fixed walking and vehicle points were established together with the respective Community Researcher in each of the focus communities. The Community Researchers were then expected to visit these fixed walking points during the first week of every month and categorise the veld condition in the immediate vicinity, according to one or several of the photos on the category sheets. The results observed were then recorded on a special recording sheet (see Figure 2).

**Table 2: List of Community Researchers and their Focus Communities**

<b>Focus Community</b>	<b>Name of Community Researcher</b>
Erwee	Magdalena Eises
Khowarib	Willy Ganaseb
Omuramba	Theodor Tjizembisa
Otjokavare	German Muzuma
Sesfontein	Flora !Haradões
Warmquelle	Uaongarisa Vella Tjiumbua

As RVA was developed for long-term monitoring of changes in veld conditions, its value for isolated observation is limited. Since it is important to use the RVA repetitively over a long period of time and at the same points, fixed points were established.

**Rapid Veld Assessment (RVA)****Recording Sheet**

Erwee

Name	Type	Description	GPS co-ordinates	Recording Date	Category
Fix 1	walking	sewage dam	S 19.68585° E 014.31012°		
Fix 2	walking	500m West	S 19.68591° E 014.307°		
Fix 3	walking	1km West	S 19.68662° E 014.30284°		
Fix 4	vehicle	on road to Palmfontein	S 19.68589° E 014.298°		
Fix 5	vehicle	beyond Palm Post 1	S 19.67774° E 014.28023°		

Figure 2: Example of RVA recording sheet for the Community Researcher in Erwee

**Establishing Fixed Walking Points**

Fixed walking points were established with each of the Community Researchers, in the vicinity of their respective villages. As starting points, water sources most frequented by domestic stock were chosen. The immediate surroundings of these water points (WPs) represented the first fixed point (Fix 1). In a perpendicular direction two further fixed points were established at distances of 500m (Fix 2) and 1km (Fix 3) from the water points. These directions were chosen in order to minimise human impact along the distance gradients.

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The Global Positioning System (GPS) co-ordinates of these fixed points were taken. However, to facilitate repetitive surveying, each point was chosen either close to or at a significant landmark, e.g. a rock, tree or stones (see Table 3).

**Table 3: Fixed Walking Points in HRC – location, distance and GPS co-ordinates**

Community	Name	Distance from Water Point	GPS co-ordinate	
			Latitude [°S]	Longitude [°E]
Erwee	Fix 1	WP	-19.68585	14.31012
	Fix 2	500m W	-19.68591	14.307
	Fix 3	1km W	-19.68662	14.30284
Khowarib	Fix 1	WP	-19.25643	13.87105
	Fix 2	500m S	-19.26092	13.87021
	Fix 3	1km S	-19.26495	13.86872
	Fix 4	500m N	-19.253	13.86873
	Fix 5	1km N	-19.24818	13.86654
Omuramba	Fix 1	WP 1	-19.07112	14.07898
	Fix 2	500m S	-19.07471	14.07931
	Fix 3	1km S	-19.07795	14.07948
	Fix 4	WP 2	-19.02369	14.09065
	Fix 5	500m S	-19.0277	14.0906
	Fix 6	1km S	-19.03171	14.09108
	Fix 7	WP 3	-19.02525	14.10059
	Fix 8	500m SE	-19.02727	14.10527
	Fix 9	1km SE	-19.02846	14.10923
Otjokavare	Fix 1	WP	-19.06318	14.348
	Fix 2	500m WSW	-19.06562	14.34457
	Fix 3	1km WSW	-19.06796	14.34117
	Fix 4	100m ENE	-19.06313	14.34836
	Fix 5	500m ENE	-19.05979	14.35026
	Fix 6	1km ENE	-19.05557	14.35185
Sesfontein	Fix 1	WP 1	-19.12084	13.6133
	Fix 2	500m W	-19.12081	13.60858
	Fix 3	1km W	-19.12029	13.60439
	Fix 4	WP 2	-19.12169	13.6274
	Fix 5	500m NE	-19.11747	13.6294
	Fix 6	1km NE	-19.1129	13.63127
	Fix 7	1.5km NE	-19.10866	13.63243
Warmquelle	Fix 1	WP	-19.18479	13.81759
	Fix 2	500m SW	-19.1895	13.81636
	Fix 3	1km SW	-19.19338	13.81451
	Fix 4	1.7km SW	-19.19916	13.81284

## Establishing Fixed Vehicle Points

The fixed vehicle points were established together with the local Community Researchers during the fixed vehicle patrol surveys with either Ms. Schneider and/or Mr. van der Linde. These points were chosen at intervals along the established fixed routes for wildlife surveying, which had previously been established for each of the six focus communities. Their GPS co-ordinates were recorded and Erwee's fixed vehicle points are shown in Table 4. Significant landmarks were chosen to help identify the sample area for repetitive surveying. The HRCS set out to conduct these fixed vehicle patrols at least once per month, however, due to transport problems, fixed vehicle points were only regularly visited in Erwee.

**Table 4: Fixed Vehicle Points in Erwee**

Name	GPS co-ordinate		Description
	Latitude [°S]	Longitude [°E]	
Fix 4	-19.68589	14.29800	road to Palmfontein, 2. metal cage
Fix 5	-19.67774	14.28023	beyond Palm Post 1 (right track)
Fix 6	-19.66563	14.26830	beyond Palm Post 2, after dip
Fix 7	-19.66028	14.25720	beyond Palm Post 2, before vet fence
Fix 8	-19.65523	14.24980	Palmfontein Springs
Fix 9	-19.68563	14.28170	road from Palm Post 1 to Makalani, single tree
Fix 10	-19.70120	14.27943	road Palm Post 1 to Makalani, succulent tree
Fix 11	-19.72115	14.27081	Makalani, flat rock
Fix 12	-19.73396	14.27060	Makalani

## COMPARATIVE ASSESSMENT

An attempt was made to verify the degree of standardisation that was achieved by using the category sheets of the RVA. Fixed points were visited by a number of people (HRCS team, Community Researchers, Polytech student) at the same time, which then individually assessed the grazing condition and filled in their recording sheets for later comparison.

## RESULTS

### DEVELOPING THE CATEGORY SHEETS

The community assessment of categories represented by the 44 photos are shown in Table 5, as well as the assessment by the range land ecologist. The accumulated choice of the consulted community members is shown in columns two to seven and the mode of the community choices is given in column eight. The last column indicates the photos that were finally chosen by the HRCS team as representative for each category on the RVA sheets. The final decision for photos chosen as representative of the six categories was undertaken by a range land ecologist in co-operation with the HRCS team.

**Table 5: Community members' and range land ecologist's assessment of photos representing six veld conditions for RVA category sheets**

Photo	Accumulated categorisation by community members						Mode	Category by Ecologist	Final choice for category sheets
	0	1	2	3	4	5			
1	10						0	0	0
2	10						0	0	0
3	10						0	0	
4	10						0	0	0
5	8	2					0	0	
6	1	8	1				1	0	
7		3	3	2	2		1	1	1
8	2	4	4				1	1	1
9	2	4	4				1	1	
10			2	2	2	4	5	5	
11	1	1	3	2	2	1	2	4	
12		1	3	2	2	2	2	4	4
13		1	3	4	1	1	3	4	4
14			3	2	1	4	5	5	
15			3	2	2	3	5	5	
16		1	4	1	2	2	2	5	
17			3	4	2	1	3	3	3
18	5	5					0	0	
19			3	2	4	1	4	2	2
20				1	6	3	4	4	4
21		4	2	2	2		1	1	
22		1	5	2	1	1	2	1	
23			3	5	2		3	2	
24		6	3	1			1	1	1
25		7		2	1		1	1	
26					6	4	4	5	5
27				3	4	3	4	4	
28			4	1	3	2	2	2	2

29				1	4	5	5	3	3
30				2	5	3	4	4	4
31					2	8	5	5	5
32			3	4	2	1	3	2	2
33		4	1	4	1		3	5	
34			3	2	3	2	2	2	
35		6	3	1			1	1	
36			2	3	2	3	3	2	
37			4	3	3		2	2	2
38				6	2	2	3	3	3
39				3	2	1	3	5	5
40	3	2	1				0	1	
41	1	4	1				1	1	1
42				3	2	1	3	3	3
43	6						0	0	0
44			2	1	1	2	5	5	5

## FIELD TRIAL

Table 6 shows the RVA surveying and results conducted by the Community Researcher in Erwee between April and October 2000. The results show that, with the RVA method, changes in available grazing can be observed. The Community Researcher frequently used in-between scales, which are allowed by the method, in order to best match the veld condition to the RVA sheets.

**Table 6: RVA Results from Community Researcher in Erwee.**

Fixed Point	Date									
	02/04	04/05	14/05	26/05	01/06	23/06	03/08	22/08	21/09	16/10
Fix 1	0	1			2-3		3			2
Fix 2	1	3			3		2-3			1-2
Fix 3	1	3			4		3			2-3
Fix 4	2		3-4	4		3-4		3	3	3-4
Fix 5	3		4-5	4-5		4-5		5	5	5
Fix 6	1-2		3	3-4		4		3-4	2-3	3-4
Fix 7	1-2		3-4	3		4		3	3	3
Fix 8	0		0	0		0		0	0	0
Fix 9	3-4		4	4-5		5		4-5	5	5
Fix 10	2		3	3-4		4		4	2-3	3
Fix 11	1		3	3		3		3-4	2	2-3
Fix 12			1-2			1-2		1	1	1



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## COMPARATIVE ASSESSMENT

Tables 7.1 to 7.6 present the results of the comparative assessment undertaken in the six focus communities. These assessments were conducted by the Community Researchers and the HRCS team between 15 and 21 September 2000. Fix 1 to 16 identify the various established fixed points in the respective villages that were visited. The letters A to D indicate different persons who assessed these points.

**Table 7.1: Comparative RVA Results; Erwee (n=3: 2 females, 1 male)**

	Fix 4	Fix 5	Fix 6	Fix 7	Fix 8	Fix 9	Fix 10	Fix 11	Fix 12
A	4	4	3	3	0	4	2	2	1
B	3	5	2-3	3	0	5	2-3	2	1
C	3-4	4	2-3	2-3	0	4	2	2	1

**Table 7.2: Comparative RVA Results; Khowarib (n=3: 1 female, 2 males)**

	Fix 6	Fix 7	Fix 8	Fix 9	Fix 10	Fix 11	Fix 12
A	3	2	5	1	3	3	0
B	3	2	5	2	4	3	2
C	3	2	5	1	3	2-3	0

**Table 7.3: Comparative RVA Results; Omuramba (n=3: 1 female, 2 males)**

	Fix 1	Fix 2	Fix 3
A	0	2	2
B	0	1	1
C	0	1	1-2

**Table 7.4: Comparative RVA Results; Otjokavare (n=4: 1 female, 3 males)**

	Fix 7	Fix 8	Fix 9	Fix 10	Fix 11	Fix 12	Fix 13
A	1	0	0	1	1	2	3
B	0-1	0	0	1	0-1	2-3	2-3
C	1	0	0	1	1	2	2-3
D	0-1	0	0	1	1	2-3	2-3

**Table 7.5: Comparative RVA Results; Sesfontein (n=4: 2 females, 2 males)**

	Fix 8	Fix 9	Fix 10	Fix 11	Fix 12	Fix 13	Fix 14	Fix 15	Fix 16
A	0	0-1	1-2	2-3	4-5	1-2	0	3	0-1
B	0	1	1	2	4	1	0	0-1	1
C	0	1	1	2	4	1	0	1	1
D	0	0-1	1	1-2	3-4	1	0	1-2	1

**Table 7.6: Comparative RVA Results; Warmquelle (n=2: 2 males)**

	Fix 5	Fix 6	Fix 7	Fix 8	Fix 9	Fix 10	Fix 11
<b>A</b>	0	1	2	0	0	1	1-2
<b>B</b>	0	1	3	0	0	1	1

At the majority of fixed points throughout the HRC, the deviation of the individual assessments was low, only differing by one category. The highest correspondence seems to occur in the “poorer” veld conditions (category 0 and 1), whereas distinguishing between categories 2 to 4 proved to be a little more subjective.

## DISCUSSION

### DEVELOPING THE CATEGORY SHEETS

As can be seen in Table 5, the assessments of local community members and of the range land ecologist differed to some degree. In some cases, it was difficult to explain that only the abundance of grass cover was of interest when evaluating the photos, rather than grass species and in turn their nutritional value. This was the case with experienced farmers, who have a detailed knowledge on grazing issues in their area. Local perception might have been influenced by the location shown on the photos, since, on several occasions, discussions seemed to focus on where the photo was taken rather than the actual grazing conditions shown on it. Some placements in categories were preceded by heated debates. Furthermore, once community members had identified the area shown on the photo, e.g. Khowarib plains or Omuramba, they tended to categorise them according to the area’s grazing value as a whole, rather than the actual veld condition shown on the photo.

The knowledge of, and interest in, grazing conditions varied widely between different people involved in the evaluation process. An attempt was made to include members of both genders and both predominant language groups (Damara>Nama and Otjiherero) in the HRC. Community members were chosen randomly with a focus on the local Community Researchers. Male community members showed a greater interest in the evaluation process than their female counterparts. A wide range of local people were represented in the survey - from experienced farmers with a deep knowledge of their area, its environment and grazing conditions to young adults with relatively little interest in their local

### SECTION III

environment. However, since most of the assessments were not done by individuals but rather in groups no exact statistics identifying language groups or gender are available.

#### **FIELD TRIAL**

The RVA method has been developed and tested in the field by the HRCS and offers a relatively consistent method for quick assessment of grazing conditions. Field-testing of the RVA proved the method to be simple and usable in the field. All six Community Researchers mastered the RVA after minimal training. A wide variety of people – community members, farmers, ecologists etc. – should, after a short introduction, be able to apply the RVA method in any field situation by a great variety of people (community members, farmers, ecologists, etc.). The method is quick and requires only a pen and paper (recording sheet) and six RVA sheets.

The results of the field trial in Erwee over a period of six months suggested that the grass abundance at some fixed points increased even in the dry season. This is not feasible and it is suggested that even when the veld was assessed by the same person over time, the individual's perception cannot be taken as independent from the overall grazing situation in the area.

During the field trial and photo evaluation sessions, the community members showed a strong interest in the process, in particular the photos. This indicated the popularity of this new and visual method. The use of colourful photos made it attractive to use even on a regular basis. The routine grass assessment was further facilitated by developing simple recording sheets (see Figure 2) that do not require unnecessary writing.

The success of the RVA method will depend on monitoring and continued use in the field. Training on the assessment method to be used is important and once the results have been obtained and seasonal variability in grass cover abundance observed, it is then the responsibility of the natural resource user or committee to implement grazing management practices based on the results observed. To achieve long-term success it is important that users of the RVA method take ownership of the method.

## **COMPARATIVE ASSESSMENT**

Some degree of standardisation of veld assessment has been achieved as can be seen in Table 7.1 to 7.6. However, during field-testing some Community Researchers remarked that it was sometimes difficult to distinguish between categories 2, 3 and 4 and that some of the photos seemed to show a more dense grass cover than others. If the assessment of certain fixed points is conducted by the same person on a regular basis, the task should become easier. A person's individual assessment categorisation should not change over time and should be minimised through the use of the example photos. This can be seen in the Erwee Community Researcher's field survey (Table 6), which shows a more consistent assessment over time.

## CONCLUSION

The RVA method seems to have the potential of becoming a valuable tool for local communities in long-term veld assessment and monitoring. Regular assessment of fixed vegetation points in an area can assist individual natural resource users and/or bodies (e.g. the Grazing Committee) to allocate seasonal grazing areas and monitor veld conditions over time. As a quick and simple method, the RVA can easily be used at 'grass roots' level.

One problem that became obvious during field-testing in the HRC was, that the vast size of the area with its various environments and topography, made it difficult to choose photos representing the entire area. It is therefore recommended to develop local versions of the category sheets and not to use standardised sheets created for the HRC. This experience suggested that the smaller the target area of individual RVA category sheets, the potentially better and easier it will be to apply for the people of the specific area. The method can easily be duplicated, as it is only a matter of photos taken at varying veld conditions throughout the seasons. A brochure on how to develop your own RVA is available at the Desert Research Foundation of Namibia (DRFN) in both English and Afrikaans (Rapid Veld Assessment – RVA) and has been handed out to the communities in the HRC.

There is, however, room for improvement of the method. The RVA was recently adapted by the Rural Institute for Social Empowerment (RISE), in collaboration with the LIFE Programme (Living in a Finite Environment), for their work with conservancies in the Erongo Region. They are trying to assign grass weights to individual photos in order to increase the scientific value of the RVA, by collecting and measuring grass samples at the same time as taking the photos (Rod Krick, pers. comm. 2000).

## REFERENCES

Jacobson, P., Jacobson, K., and Seely, M. (1995) *Ephemeral Rivers and their Catchments*. DRFN. Windhoek.

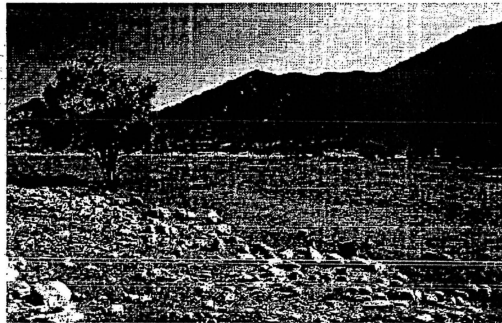
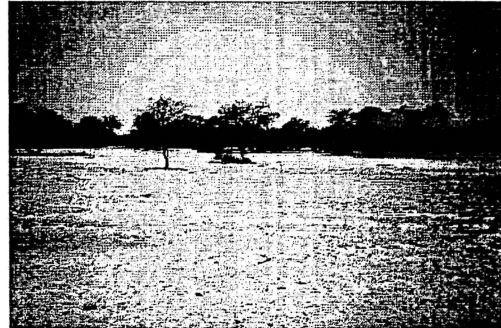
Milton, S.J. and Dean, W.R.J. (1996) *Karoo Veld – Ecology and Managent*. ARC-Range and Forage Institute. RSA.

MWTC (Ministry of Works, Transport and Communication), Meteorological Services. (1999/2000) *Rainfall Data*. Government of Namibia. Windhoek.

**APPENDIX A**  
**RVA SHEETS, CATEGORY 0-5**

Rapid Veld Assessment (RVA)

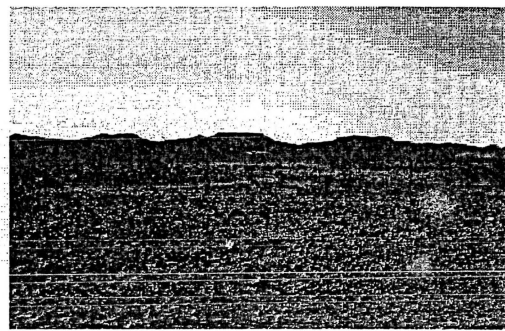
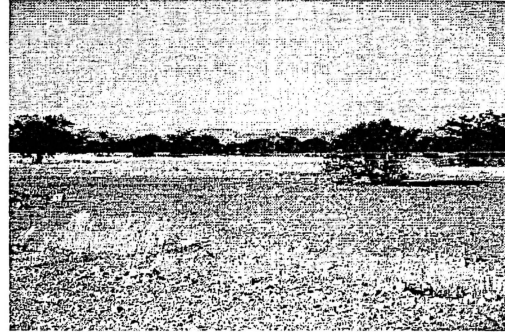
**Category 0 - Bare Ground**





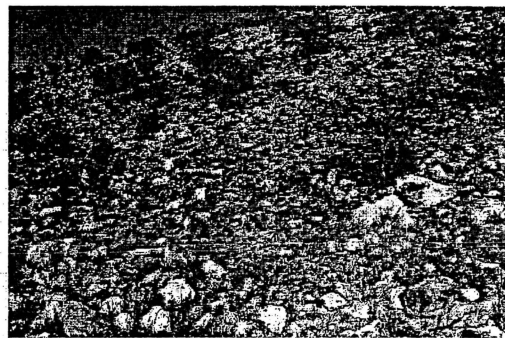
Rapid Veld Assessment (RVA)

**Category 1 - Extremely Poor Veld**



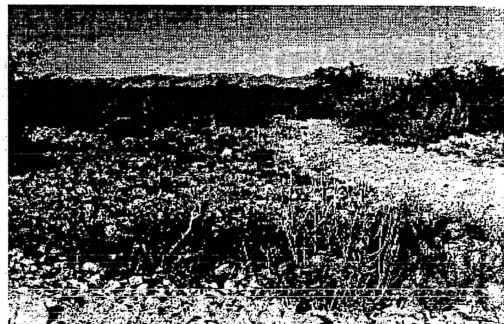
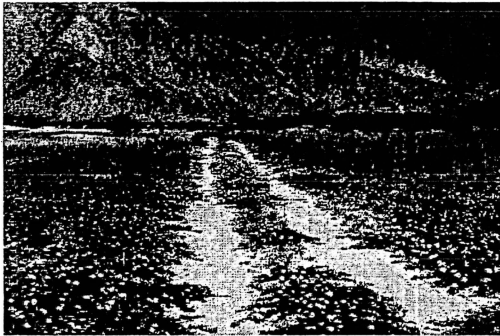
Rapid Veld Assessment (RVA)

**Category 2 - Poor Veld**



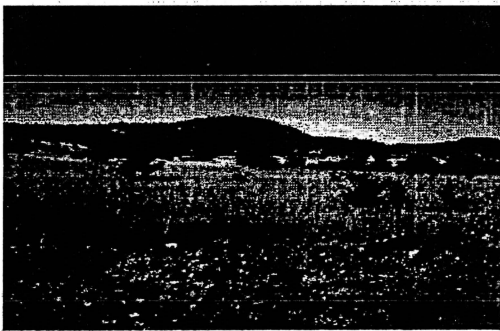
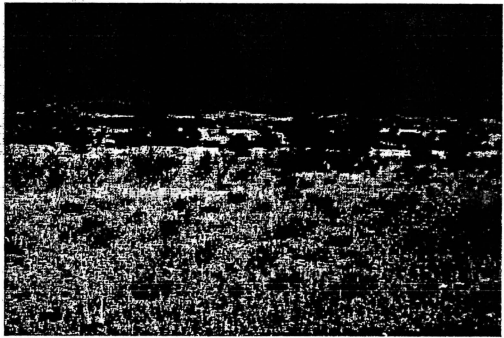
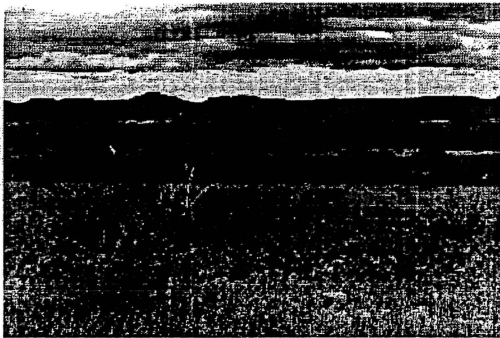
Rapid Veld Assessment (RVA)

**Category 3 - Moderate Veld**



Rapid Veld Assessment (RVA)

**Category 4 - Good Veld**



Rapid Veld Assessment (RVA)

**Category 5 - Excellent Veld**

