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Human impacts on woody vegetation, and multivariate analysis: a case study based on data from Khowarib settlement, Kunene Region.

Sian Sullivan* and Tracey L. Konstant**

Abstract

The effects of human and livestock utilisation on woody vegetation communities in close proximity to Khowarib settlement, Kunene Region, were assessed. Vegetation sampling of individuals of 2cm diameter was carried out using transects located in different topographic categories and at different distances from Khowarib. Species, branch removal, and height of browse line were recorded for each individual, while distance from the settlement and topographic category (reflecting substrate) were recorded for each sample. For purposes of analysis, values for branch removal and browse line were averaged for each sample and, together with distance from settlement, treated as measures of utilisation impact. Community data were related to the environmental variables, including the utilisation measures, using a suite of multivariate techniques, namely classification using the program TWINSPAN, and indirect and direct gradient analyses (Detrended and Canonical Correspondence Analyses), using the program CANOCO. This indicated a significant, but small-scale, negative impact of these use measures on the species richness of the samples. The study provides a focus for discussion regarding the appropriateness of such numerical analytical techniques in assessing human and livestock utilisation impacts on dryland vegetation. This is particularly relevant in the context of initiatives within Namibia to 'combat desertification', which are generally hampered by a lack of quantitative or standardised information concerning patterns and impacts of vegetation resource use, especially in communal farming areas.

Keywords: Sesfontein-Khowarib Basin, multivariate analysis, classification, ordination, gradient analysis, scale, degradation.

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Introduction

This paper is based on previously unpublished work conducted in Namibia in 1992 (see Sullivan, 1993a, 1993b). It is presented here in response to recent interest regarding the use of multivariate methods to explore and analyze community data from the pro-Namib and Semi-Desert Savanna Transition Zone, as identified by Giess (1971), (see, for example, Cowlishaw & Davies, forthcoming; Jürgens, 1995). More specifically, it addresses the advantages and disadvantages of this methodology as an appropriate tool for assessing vegetation degradation caused by human and livestock impacts in a dryland area. This is the focus for vegetation work currently being conducted by Sullivan in and around the so-called Sesfontein/Khowarib Basin on a much expanded data set.

Study area

Khowarib settlement (S 19°15', E 13°15') is situated on the southern bank of the ephemeral and westward-flowing Hoanib River, in west-central Kunene Region, formerly northern Damaraland (see Figure 1).

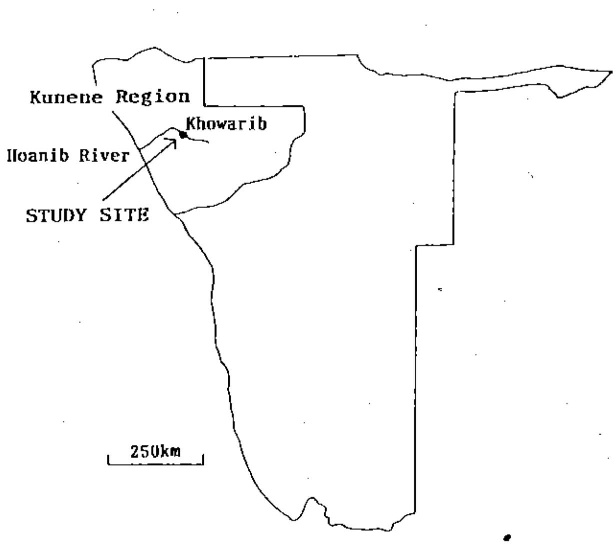

Figure 1: Map of Namibia indicating study area.

Climate

The single most important climat
and the associated unpredictabili
series rainfall data* for the nearb
and 1957-1986 has a Coefficient
(1973), Caughley (1987) and Elli
rainfall in this area, and ecologica
their variability than by average va

Accompanying this low and varia
rates, estimated as in the region o
bination of factors means that, as
productivity is primarily moisture,

Temperatures are characterised b

Topography

Khowarib is situated on the easte
Plains between the Namib Desert
the East (cf. Mabbutt, 1952: 335-3
flowing rivers traversing these m
valley with many large tributaries.
constrained by the uplands of the
the Khowarib 'Schlucht' or gorge.
schists and calcrete are characteri
Khowarib settlement, however, str
and silts.

Vegetation*** *(see Appendix 1 for*

The vegetation of Kunene can be
nomy and species distribution, ref
and micro-climate characteristics.
the Karoo-Namib biogeographical
culent life-forms (Werger, 1978a:
individual having many taxa of t
wider ephemeral river valleys (We

* Rainfall data from the Weather Bureau,
glia; and the National Meteorological Libr
** i.e. the standard deviation expressed as
*** Nomenclature follows the current spec
Namibia. See also Kolberg, *et al.* (1992).

(Moraceae), *Plicosepalus kalachariensis* (Loranthaceae), *Acacia erioloba*, *Faidherbia albida*, and *Mundulea sericea* (Fabaceae), *Ziziphus mucronata* (Rhamnaceae), *Salvadora persica* (Salvadoraceae), *Grewia bicolor* (Tiliaceae), *Cordia sinensis* (Boraginaceae), *Sterculia quinqueloba* (Sterculiaceae), *Boscia albitrunca* (Capparaceae), and *Combretum apiculatum* and *C. imberbe* (Combretaceae) (Nordenstam, 1974: 57). Many of these are characteristic of the riparian forest supported by the Hoanib River.

Jürgens (1991: 21, 30-32) has redefined the area as the 'Damaraland-Kaokoland Domain' within his Nama-Karoo phytogeographical Region. Characteristic species include *Maerua schinzii* and *Boscia foetida* (Capparaceae), *Moringa ovalifolia* (Moringaceae), and *Euphorbia virosa* (Euphorbiaceae), while the numerous endemic or near-endemic elements include *Acacia robynsiana* and *A. montis-usti* (Fabaceae), *Commiphora giessi* and *C. kraeuseliana* (Burseraceae), and *Sesamothamnus guerichii* (Pedaliaceae).

Nordenstam (1974: 58) describes the 'Kaoko element' as an interesting phytogeographical group confined to southern Angola and north-west Namibia, comprised of well-defined species which can be considered as 'epibiotic relic elements'. Taxonomically isolated, monotypic genera include *Welwitschia* (Welwitschiaceae), *Phlyctidocarpa* (Apiaceae), and *Kaokochloa* (Poaceae). Other well-defined species with their phytogeographic centre north of the Brandberg include *Acacia robynsiana* (Fabaceae), *Balanites welwitschii*, and many *Petalidium* spp. (Acanthaceae). More than 25 species recorded by Nordenstam (1974: 60, 63) for the Brandberg Mountain, some distance south of Khowarib, are probably the remains of an old Afro-arid flora, and have a markedly disjunct distribution between the arid areas of both the Karroo-Namib region and the Sahalian-Oriental domain of the Sudano-Zambesian region, or in the adjacent Saharo-Sindian region.

According to Giess' Vegetation Map of Namibia Khowarib is located in the Mopane Savanna typical of the north-west, and characterised by *Colophospermum mopane* (Fabaceae) (1971: 9-10). This species occurs as a tree or shrub depending on local conditions and, with its relatively shallow root system, is able to compete in areas where moisture accumulates at shallow depth (cf. Cole, 1986: 116; Giess & Tinley, 1968: 251-252). Within this broad vegetation zone there is a wide variety of habitats, including a uniquely high diversity of the genus *Commiphora* (Burseraceae) on rocky substrates. A significant habitat in the Sesfontein-Khowarib Basin is the fertile alluvial sands and silts deposited by the Hoanib River and dominated by tall *Acacia tortilis* subsp. *heteracantha* (Fabaceae) savanna woodland.

Animal wildlife

The area is host to a high diversity of animal wildlife and is well-known for its desert-dwelling populations of elephant (*Loxodonta africana*), black rhino (*Diceros bicornis*), and the endemic Hartmann's zebra (*Equus zebra hartmannae*). Communal farmers in the area currently have no legal entitlement to these animal resources. The

Ministry of Environment and T
which will confer use rights to
income generation from wildlife (

Settlement and land use

It is likely that Khowarib, and
Khowarib Schlucht, has been a
rently settled by a predominantly
herding, grow vegetables and gra
garden established by the previou
tion resources for a variety of p
Khowarib itself, and at several
Warmelo, 1962: 37).

In recent historical times, the ar
related primarily to two interrela
Malan, 1973: 83; Malan, 1974: 1
north of Nama and Oorlam Af
horses through their trade relati
tribute in the form of livestock fr
ment south by Herero pastoralis
west Namibia and latterly to thei
their impoverishment due to Oo
1896-1897. Today the area is sub
to the new freedom of movem
pendence and following the extre

Human history associated with la
the potential for conflicting claim

Vegetation use

Indigenous vegetation resources
important sources of food, hous
building, household utensils and
access to alternative resources a
supplementary, significance to pe
species utilised by the inhabitan
authors indicated that the prod
purposes, as summarised in Tab
33).

Table 1: Numbers of woody plant species recorded for different forms of utilisation at Khowarib settlement, Kunene region.	
type of utilisation	numbers of species recorded (total used = 37)
food: fruit resin	19: 12 7
household medicines	11
household utensils	10
leather dyes/tanning agents	6
browse for livestock	14

Objectives

This study had two main objectives:

1. To define the impact of human and livestock use on woody vegetation in the vicinity of a permanent settlement in a dryland area, using a variety of indicators (e.g. species diversity and composition, and relationships of these with environmental variables including measures of utilisation).

2. To assess the value of using multivariate analytical techniques in pursuit of objective 1; i.e. to explore and describe community data in relation to utilisation impacts, and to statistically test the relationships between particular communities and specific environmental variables or combinations of variables.

Methods

Field methods

Sampling strategy

In a semi-arid environment such as Kunene, indigenous perennial woody species, adapted to conditions of low and irregular rainfall, can act as longer-term indicators of environmental change caused by settlement impacts. The woody vegetation surrounding Khowarib was surveyed using a 'zig-zag' transect method (following Leithead, 1979: 29-30) (Figure 2). In this method each consecutive individual is sampled according to its proximity to the preceding individual, providing it is within

45° on either side of a stated com
this technique lies in the fact th
distribution of species, the vegeta
feature of the technique is extrem
species distributions are character

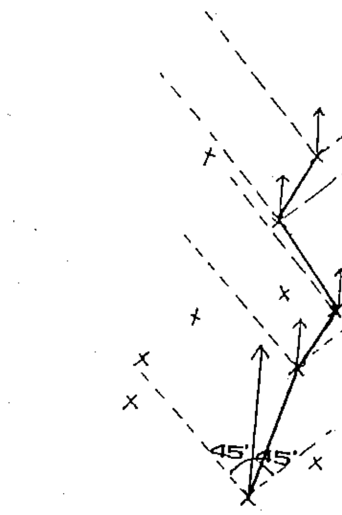

Figure 2: Schematic diagram of
Leithead, 1979).

In order to take into account the s
the area was split into three topo
plant physiognomic characteristic
were sampled separately and at
The resulting stratified sample is
this information):

Plains:

The Khowarib settlemen
and the vegetation sampl
category. A total of 12 t
consisting of 4 within the
4 located 5 km away fro
radiated out from the cen

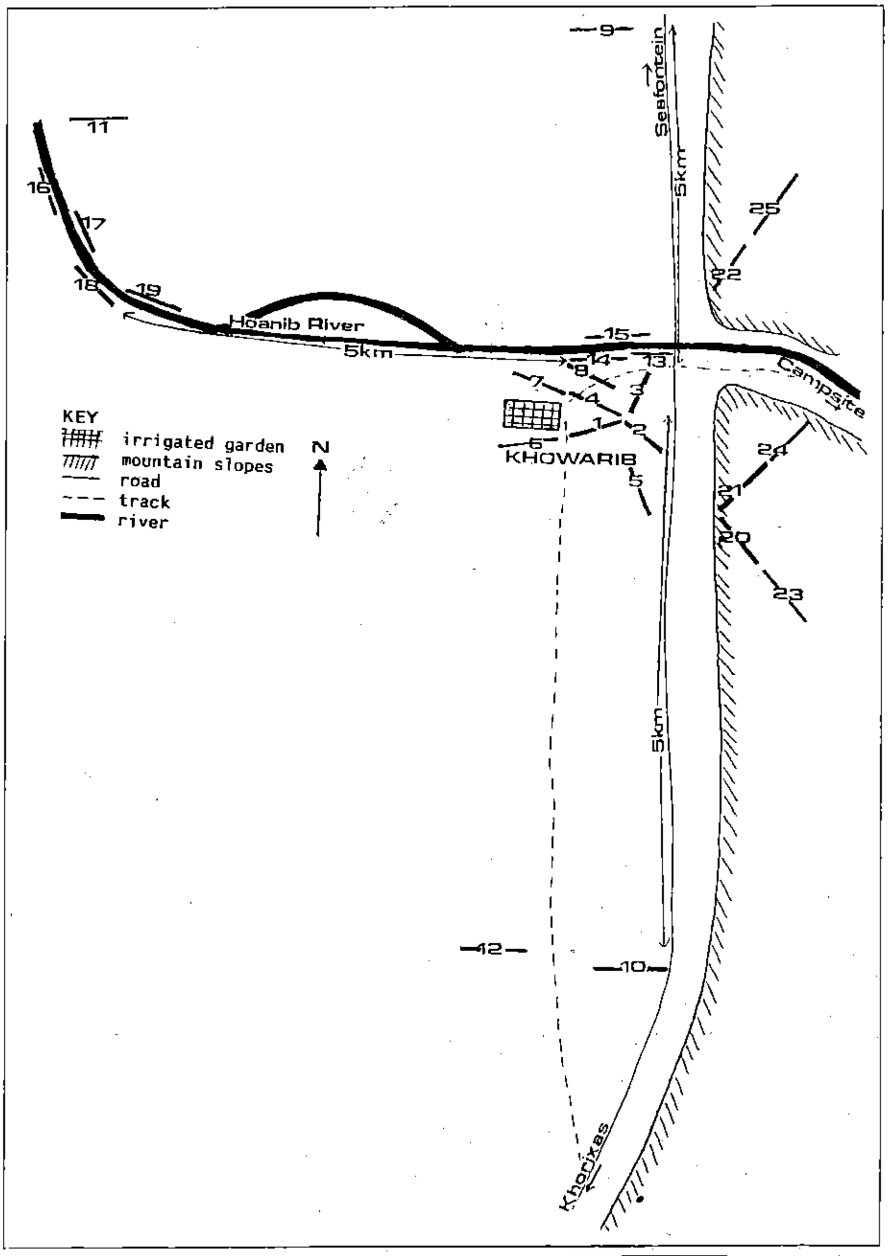

Figure 3: Sketch-map showing location of transects (1-12 = plains; 13-19 = riverine; 20-25 = mountain).

Riverine:

These transects were lo
Seven transects were car
settlement and 4 located

Mountain:

The eastern side of Kho
Highlands which at thi
Schlucht. Six shorter tra
lower slopes and 3 on the
to substantial heights i
legitimately replace the e

In each transect in the **plains** an
were sampled, while the **mountai**
individuals. A total of 635 individu

Table 2: Samples and individu
settlement.

Topographic category	Proximity to se
Plains:	within Khowa outskirts 5 km away
Riverine:	outskirts 5 km away
Mountains:	lower slopes (upper slopes (
Totals:	

Individual attributes

For each individual of 2cm diame

• the species was identified. Plant nomenclature follows the current species list of the NBRI species (see also Kolberg *et al.*, 1992). A full list of species and families recorded in this study, together with author citations, is presented in Appendix 1. Where species could not be identified to species level (only one incidence), the local Damara name is given to facilitate future identification. Assistance with species identification was provided by Ms G.L. Maggs of the National Herbarium, Windhoek.

Measures of human and livestock impact:

• the degree of branch removal or **lopping** for human use, identified by the occurrence of clean cut marks through the branches or main stem, was classified according to the following scale:

0	no lopping
1	slight lopping; 1-2 large branches or only small ones removed
2	moderate lopping; 25-50% of branches removed
3	severe lopping; > 50% of branches removed
4	cut through the main stem/s so that the height of the tree was substantially reduced

• the height of the **browse line**, when one could be easily discerned, was measured.

Analysis

A suite of exploratory and analytical techniques were used to assess the relationship between the species diversity and composition of each sample, and the physical location and average utilisation measures recorded as 'environmental variables' for each sample.

Classification

The data set was used for the construction of a samples-by-species matrix, presented in Table 3, which was 'classified' using the TWINSPAN (Two-Way Indicator Species Analysis) program (Hill, 1979b). This is a polythetic divisive classification technique which uses information on all the species data to successively divide the samples into a hierarchy of smaller and smaller groups based on indicator species and floristics (Goldsmith *et al.*, 1986: 494). In TWINSPAN the data are first ordinated by reciprocal averaging and the samples are divided or polarised through emphasizing the species that characterise extremes on the reciprocal averaging axes (Gauch, 1982: 201-2). The values presented in the resulting table are new values or 'pseudospecies' based on levels of abundance for each species in each sample.

Table 3. Original samples-by-spe
classification, DCA ordination and

Species	01	02
Acacia erioloba	-	-
Acacia senegal	-	-
Acacia tortilis	26	28
Boscia albitrunca	-	-
Boscia foetida	-	-
Catophractes alexandri	-	-
Ceraria longipedunculata	-	-
Colophospermum mopane	-	-
Combretum apiculatum	-	-
Combretum wattii	-	-
Commiphora multijuga	-	-
Commiphora pyracanthoides	-	-
Commiphora virgata	-	-
Commiphora sp. (/aba/hub)	-	-
Faidherbia albida	-	-
Gossypium cf. *anomalum*	-	-
Lycium[5] sp.	-	-
Maerua schinzii	1	-
Pechuel-loeschea leubnitziae	-	-
Salvadora persica	-	1
Tamarix usneoides	-	-
Terminalia prunioides	-	-

Recent fieldwork indicates that /al
obs.).
The Genus *Lycium* is under taxono

Ordination: Detrended Correspond

Ordination techniques are multiva
the basis of species abundance b
sional space such that similar spec
(Gauch, 1982: 109, 115; Gaillard e
data to a low-dimensional space
mensions or axes are normally co

fore, the location of species and samples along these axes is likely to reflect the underlying structure of the data (Gauch, 1982: 116). Relationships between community patterns and known environmental variables can then be inferred to produce an ecological interpretation of the community data, which can be tested using other methods. As such, ordination is an indirect gradient analysis method from which species-environment relationships can be explored and described in a qualitative manner (ter Braak, 1986: 1167).

Detrended correspondence analysis (DCA) is an ordination technique which assumes the unimodal distribution of the data and from which, by using weighted averages for both samples and species, relationships between the two can be inferred. It can be used to produce a spatial arrangement of samples and species along axes generated by the vegetation data such that their position reflects their similarity (Dudzinski & Arnold, 1973: 905; Goldsmith *et al.*, 1986: 501-2; ter Braak, 1986: 1167). Detrended Correspondence Analysis was applied to the samples-by-species matrix derived from the Khowarib vegetation data set (Table 2) using the computer program CANOCO 3.12 (ter Braak, 1991) which performs partial, detrended and canonical correspondence analyses (CCA). This program is an extension of the Cornell Ecology program DECORANA which is used for DCA and reciprocal averaging (Hill, 1979a).

Canonical Correspondence Analysis (CCA)

CCA, applied using CANOCO 3.12, is a relatively new multivariate analysis technique developed by ter Braak and designed to directly relate community composition to environmental variables. This is achieved by finding the ordination axes which reveal to the greatest possible extent the common structure of both the samples-by-species and samples-by-environmental variables matrices (presented in Tables 3 and 4) (Gauch, 1982: 163; ter Braak, 1986: 1167; ter Braak, 1987a). It is an extension of ordination techniques such as DCA which extract continuous axes of variation from species abundance data which can then be interpreted in the light of data concerning known environmental variables (ter Braak, 1986: 1167). Canonical ordination such as CCA, combines both ordination and regression to produce a **multivariate direct gradient analysis** of the relationships between a number of species and environmental variables (ter Braak, 1986: 1167; ter Braak, 1988: 159).

CCA analyses were applied to both the complete data set and a reduced data set from which the mountain samples had been removed, for reasons explained in the results section below.

In the ordination diagrams constructed from the CCAs the species and sites are represented as points (except for the second CCA analysis where distance is treated as ordinal) and the environmental variables as vectors portrayed in two ways: as arrows if the variable is ordinal or continuous, or by points if the variable is nominal or dichotomous (ter Braak, 1986: 1167). In the case of ordinal variables, environmental information is expressed by the directions and relative lengths of the representative arrows. The strength of the variable is related to length of the arrow with the

Table 4: Original matrix of samples-b
cal Correspondence Analysis (CCA).

Environmental variables	01 02
NOMINAL VARIABLES:	
Location:	
plains (1/0)	1 1
riverine (1/0)	0 0
mountain (1/0)	0 0
ORDINAL VARIABLES (See key below):	
Distance:	
plains and riverine (0-2)	0 0
mountain (0-1)	- -
Impact measurements:	
lopping (0-4)	3 3
browsing (0-4)	3 3

Ke

DISTANCE:

plains and riverine: 0 - in settlement
1 - outskirts of settlement
2 - 5km from settlement
mountain: 0 - lower slopes
1 - upper slopes

IMPACT

lopping:

browsing

position of the arrowhead determine
correlations of that variable with th
measure of how much species chang
that the more important variables (i.e
by longer arrows. Nominal environm
sented by points located at the centre
to that environmental class. The co
visually the dominant patterns in th
species and sites to the environmenta

In the Khowarib vegetation data se
follows: lopping and browsing are o
arrows whereas the location of the
topographic categories and at differ
variables and are represented as poin

Testing of specific hypotheses: Monte Carlo permutation testing and partial CCA

Using the program CANOCO, specific hypotheses were tested concerning the influence of particular environmental variables on the vegetation community. These tests rely on the forward selection of environmental variables by Monte Carlo permutation tests, in this case using the default selection of 99 permutations (Ter Braak, 1988: 159; Gaillard *et al.*, 1992: 7). The data are thus considered analogous to experimental data; each environmental variable is viewed as a 'treatment' imposed on the vegetation, and the resulting community pattern is the 'response' to this treatment (Gaillard *et al.*, 1992: 9). In doing this, the percentage of variation in species abundance that can be attributed to a particular variable is revealed as the probability of that variable contributing significantly to the assemblage after a number of permutations (Gaillard *et al.*, 1992: 7). To overcome the problem of close association between variables a partial CCA can be applied so that the effect of 'background' variables are statistically partialled out as covariables, and the significance of a particular variable in its effect on the vegetation assemblage can be tested statistically (ter Braak, 1987b: 557; ter Braak, 1988: 159; Gaillard *et al.*, 1992: 9).

This analytical method was used to test the null hypotheses that there was no significant difference in species assemblages in samples with differing:

i. intensities of lopping
ii. intensities of browsing
iii. distances from the Khowarib settlement

Results

Classification

The results of the TWINSPAN classification are represented by an ordered two-way table of the original data (Table 5).

As can be seen from Table 5 and Figure 4, TWINSPAN classified the Damara samples into three major sample groups. These did not correspond exactly to the three known topographic categories, thus indicating that species composition and abundance were reflecting other underlying external variables. The three TWINSPAN groups were as follows:

Group I

Acacia tortilis is the indicator species for this group which is represented by plains samples at all distances from Khowarib and **riverine samples near to Khowarib**. The **plains samples within Khowarib** have the highest weighted averages for *A. tortilis*.

Table 5: Ordered two-way table o
by TWINSPAN classification. TW
are as follows:

level 1 = 0-2 individu
2 = 3-5
3 = 6-10
4 = 11-20
5 = > 20

Species	16	17
Faidherbia albida	-	2
Acacia erioloba	1	2
Combretum wattii	2	3
Pechuel-loeschea leubnitziae	-	-
Salvadora persica	5	4
Acacia tortilis	1	2
Boscia albitrunca	-	-
Gossypium cf. anomalum	-	-
Lycium sp.	-	-
Tamarix usneoides	-	-
Colophospermum mopane	2	-
Maerua schinzii	1	-
Boscia foetida	-	-
Acacia senegal	-	-
Commiphora multijuga	-	-
Ceraria longipedunculata	-	-
Terminalia prunioides	-	-
Commiphora virgata	-	-
Catophractes alexandri	-	-
Combretum apiculatum	-	-
Commiphora pyracanthoides	-	-
Commiphora sp. (/aba/hub)	-	-
sample divisions	0	0
	0	0
	GRO	

Also characteristic of this group
and, to a lesser degree, *Acacia eric*

The third TWINSPAN division s
contain all the plains samples fr
from the outskirts of Khowarib a
group Ib contains most of the rem
two riverine samples from the c
dominated particularly strongly b
samples, has a generally lower sp
recorded in only 6 samples. This

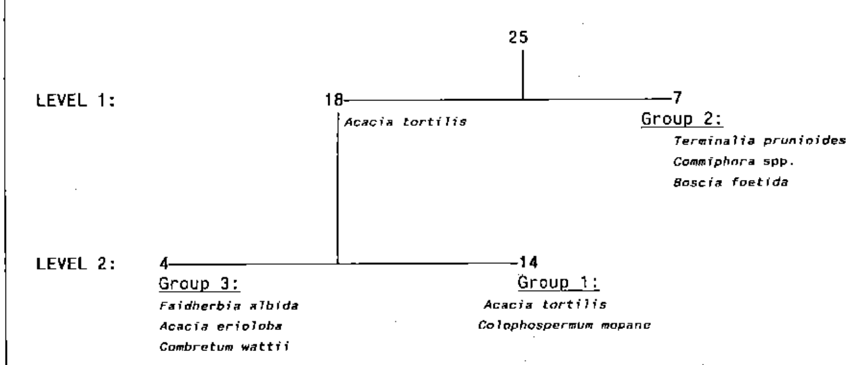

Figure 4: Dendrogram derived from TWINSPAN classification of the Khowarib data set. The 3 major divisions are indicated, together with the number of samples and dominant species in each division.

having an effect on the species composition of these **plains** and **riverine** samples which was independent of the topographic habitat divisions. A correlate of this effect was reduced species diversity with increased proximity to the settlement.

Group 2

This is a very well-defined group characterised by *Terminalia prunioides* and, to a lesser extent, *Boscia foetida* and *Acacia senegal.* These samples represent those located in the mountain topographic category and this appears to be the major underlying factor determining species composition in this group. The exception to this is sample 10 which is a **plains** sample located **5 km from Khowarib**.

Group 3

This group is characterised by high levels of *Salvadora persica*, with *Combretum wattii* and *Faidherbia albida* exclusive to this group and *Acacia erioloba* another important species. This group contains only the four **riverine** samples **located 5 km from Khowarib** and, therefore, indicates that distance from the settlement was having a strong effect on species composition in the riverine samples. Not only was species richness slightly higher in the samples **5 km away** from the settlement but the composition itself was very different with two species which are relatively dominant in this group, *C. wattii* and *F. albida*, recorded only at this site.

Detrended Correspondence Anal

When DCA was applied to the D
the overall variation was high (
considerable amount of the varia
axes constructed to fit the data.
accounted for 20.9% variance of
.313 and thus the cumulative perc
28.4%.

When the ordination scores for
position on axis 1 it was possibl
Broadly speaking, the first four
occurred in the **riverine** vegetat
similarity in the composition of t
of **plains** samples at all distanc
samples **close** to the settlement (
from Khowarib occur closely to
samples **near** Khowarib suggest
from the settlement that were af
environmental constraints. Like
six mountain samples (20-25) als
by one **plains** sample (10) fron
atypical sample in terms of these

The species ranks follow this pa
ples from **5 km** outside the settl
closely together at one end of t
found in both **plains** samples at
ples **near** the settlement (e.g. *Ac*
persica), and completed by spec
spp. associated with **mountain** sa

The combined presentation of t
ages in an arranged matrix as in
along the matrix diagonal, the u
above.

The graphical presentation of th
groups described above is shown
correspond with the TWINSPA
that group 2 is very distinct in te
groups 1 and 3 are more simi
continuum of variation in specie

Table 6: Ranked scores for samples and species in relation to the axis 1 ordination scores produced by detrended correspondence analysis. (The relationship between sample scores and the groups produced by TWINSPAN classification as described above is indicated).

Sample TWINSPAN Groups	Sample N	ranked Axis 1 scores	Species	ranked Axis 1 scores
3	18	.0000	*Pechuel-Loeschea leubnitziae*	-.9237
3	19	.0138	*Faidherbia albida*	-.9087
3	17	.2996	*Combretum wattii*	-.6696
3	16	.9004	*Acacia erioloba*	.0510
1	07	1.1395	*Lycium* sp.	.7786
1	06	1.2297	*Salvadora persica*	.8583
1	11	1.5093	*Acacia tortilis*	1.6287
1	14	1.5489	*Tamarix usneoides*	1.8495
1	02	1.6030	*Colophospermum mopane*	2.6473
1	01	1.6856	*Boscia albitrunca*	2.6991
1	04	1.7225	*Gossypium anomalum*	2.6991
1	08	1.7726	*Maerua schinzii*	3.1646
1	05	1.7938	*Boscia foetida*	3.7947
1	03	1.9343	*Terminalia prunioides*	4.5622
1	15	2.0322	*Acacia senegal*	4.6332
1	12	2.1315	*Commiphora multijuga*	4.7185
1	13	2.2717	*Ceraria longipedunculata*	4.9276
2	09	2.3240	*Commiphora pyracanthoides*	5.2316
2	22	3.4386	*Catophractes alexandri*	5.3118
2	21	4.2150	*Commiphora virgata*	5.7234
2	20	4.3202	*Combretum apiculatum*	6.3973
2	23	4.3458	*Commiphora* sp. (/aba/hub)	6.3973
2	24	4.5929		
2	10	4.9262		
2	25	5.8618		

Two samples can be considered outliers of the groups described above. First, sample 10, which is located in the plains habitat 5 km from Khowarib, is atypical of the other **plains** samples located **5 km from Khowarib** due to its extremely high value for *Catophractes alexandri*, which is only found at one other **mountain** sample. It also has a relatively high value for *Terminalia prunioides*, a species representative of the **mountain** samples. Sample 10 was located in closer proximity to the mountain slopes than the other **plains** samples (see Figure 3) and it is probably a higher incidence of rocky dolomite that is responsible for its floristic similarity with the **mountain** samples. Second, sample 25, an **upper slope mountain** sample, is the only sample contain-

Table 7. Arranged matrix of samp
scores.

Species
Pechuel-loeschea leubnitziae
Faidherbia albida
Combretum wattii
Acacia erioloba
Lycium sp.
Salvadora persica
Acacia tortilis
Tamarix usneoides
Colophospermum mopane
Boscia albitrunca
Gossypium anomalum
Maerua schinzii
Boscia foetida
Terminalia prunioides
Acacia senegal
Commiphora multijuga
Ceraria longipedunculata
Commiphora pyracanthoides
Catophractes alexandri
Commiphora virgata
Combretum apiculatum
Commiphora sp. (/aba/hub)

ing two species, *Combretum apicu*
at relatively high levels.

Canonical Correspondence Analys

The CCA of the data set, indica
mental and both sample and spec
the TWINSPAN classification and

Analysis 1:

When CCA was applied to the fu
division within the samples and sp
of variance in the species data a
species and environmental varia
mountain topographic category o
graphical separation between m
shown in Figure 6a. Axis 2, on th

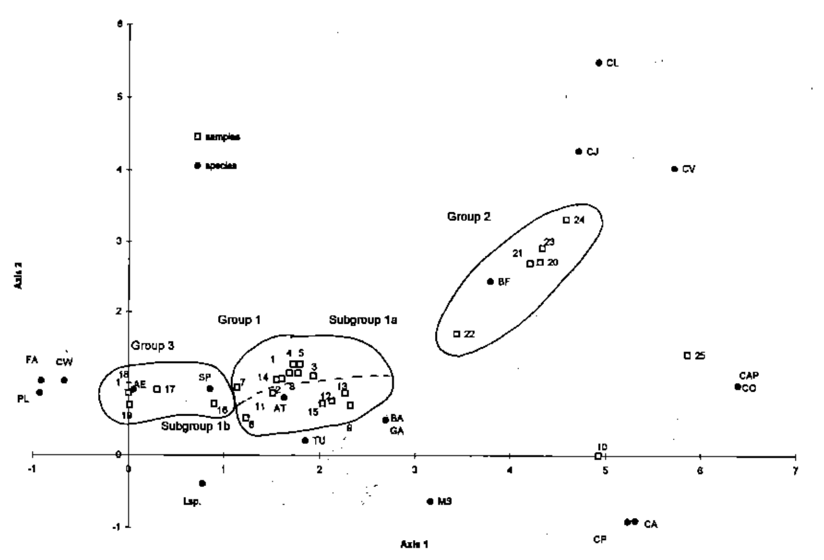

Figure 5: Ordination diagram of Detrended Correspondence Analysis (DCA) with TWINSPAN classification groups.

Key:

FA= *Faidherbia albida*; CW= *Combretum wattii*; PL= *Pechuel-Loeschea leubnitziae*; AE= *Acacia erioloba*; Lsp.= *Lycium* sp.; AT= *Acacia tortilis*; TU= *Tamarix usneoides*; CM= *Colophospermum mopane*; BA= *Boscia albitrunca*; CA= *Catophractes alexandri*; GA= *Gossypium anomalum*; MS= *Maerua schinzii*; BF= *Boscia foetida*; CJ= *Commiphora multijuga*; CL= *Ceraria longipedunculata*; CP= *Commiphora pyracanthoides*; CAP= *Combretum apiculatum*; CV= *Commiphora virgata*; CO= *Commiphora* sp. (/aba/hub).

values for the effects of lopping and browsing, and these values are reflected in the figures for the effect of distance from the settlement. This axis explains a cumulative percentage variance of 30% of the species data and 62.4% of the variation in the relationship between species and the environmental variables. Table 7 shows the axis 1 and 2 figures for the weighted correlation matrix from which the ordination diagram is constructed. Although the composition of samples 20-25 was primarily determined by their mountain location, the CCA does suggest some impact of human and animal utilisation by placing samples from the lower slopes, i.e. those nearest to the settlement, closer to the vectors representing human and animal impact.

Despite the slightly stronger effect of browsing, the direction and length of the arrows representing both browsing and lopping are similar thus indicating that they were having corresponding effects on the vegetation surrounding Khowarib. These arrows extend in the opposite direction to the location of the centroid representing the furthest distance from the settlement (Figure 6c), thereby indicating that, as would be

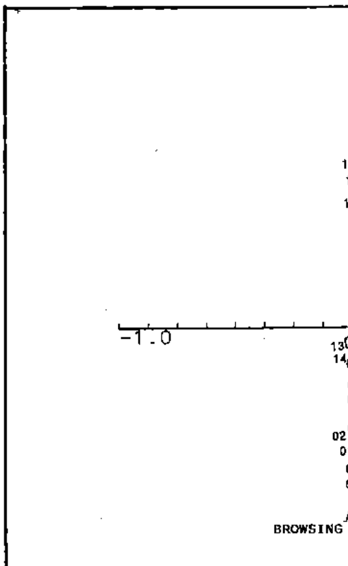

Figure 6a: Sample ordination

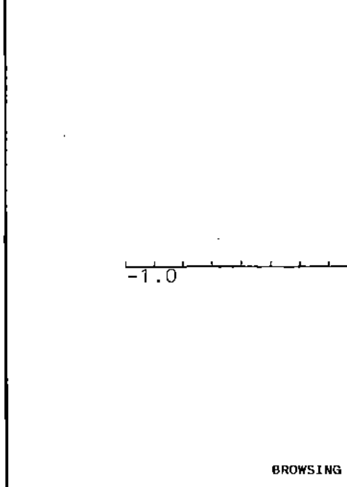

Figure 6b: Species ordination

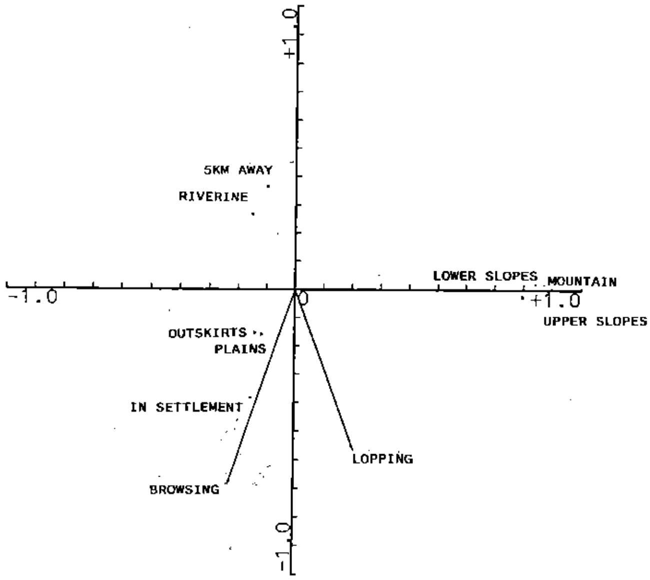

Figure 6c: Environmental variables ordination

Figure 6: CCA ordination diagram of full data set: a. samples; b. species; c. environmental variables.

Key:

Species: FA= *Faidherbia albida*; CW= *Combretum wattii*; PL= *Pechuel-Loeschea leubnitziae*; AE= *Acacia erioloba*; Lsp.= *Lycium* sp.; AT= *Acacia tortilis*; TU= *Tamarix usneoides*; CM= *Colophospermum mopane*; BA= *Boscia albitrunca*; GA= *Gossypium anomalum*; MS= *Maerua schinzii*; BF= *Boscia foetida*; CJ= *Commiphora multijuga*; CL= *Ceraria longipedunculata*; CP= *Commiphora pyracanthoides*; CA= *Catophractes alexandri*; CV= *Commiphora virgata*; CO= *Commiphora* sp. (/aba/hub); CAP= *Combretum apiculatum*; SP= *Salvadora persica*; AS= *Acacia senegal*.

Samples: 1-12= plain; 13-19= riverine; 20-25= mountain.

expected, the effects of browsing and lopping are more intense with increasing proximity to the settlement.

Table 8: Axis 1 and 2 species-envir
CCA ordination diagram is constr

Environmental variables	Specie 1
browsing	-.2201
lopping	.1970
mountain:	.9426
lower slopes	.5047
upper slopes	.7777
plains	-.3629
riverine:	-.3093
in settlement	-.2411
outskirts	-.2858
5km away	-.2252
% cumulative variance:	18.3%

In contrast to the mountain sampl
Figure 5, were more similar in sp
floristic continuum in which dist
differences in intensity of human
Figures 6a and 6b indicate that
Khowarib shared the greatest sim
vergent in species composition w
intensities of browsing and loppin
these samples, the impact of hu
importance of underlying conditio

The overlaying of the species infor
Figure 6a, displays which specie
Samples 20-25, for example, are
ioides, Acacia senegal and *Commi*
high proportions of *Combretum w*
ples were located in the mount
settlement respectively.

Analysis 2:

Due to the very distinct nature o
classification, DCA and CCA, an
tains accounted for the greatest p

was applied to a reduced data set comprised of the more comparable plains and riverine samples. In this case the species-environment correlation for axis 1 was extremely significant (0.919) and this axis explained 17.2% and 54.9 % of variance in the species data and the species-environment data respectively. Reference to the weighted correlation matrix (Table 9) indicates that this is due to the significant effects of browsing (0.7113) and distance from the settlement (-0.8817). These are both measures of settlement impact and indicate that proximity to Khowarib was the most important determinant of floristics in these samples. Lopping, the third measure of human impact, also had a positive effect on species composition (0.5804) but was not as significant as browsing and distance. Axis 2 is determined primarily by location in the plains or riverine areas indicating that these topographic categories would, under conditions of no human and animal disturbance, account for most of the variance in species composition in these samples.

The ordination diagrams in Figs. 7a and 7b provide a clear graphical representation of these relationships. The wide spread of the samples in Fig. 7a, as opposed to clusters around the plains and riverine centroids as seen in Fig. 6a, indicates the comparable nature of these topographic categories in terms of species composition, and the distortion of the data set caused by inclusion of the mountain samples in the first CCA. Fig. 7b, shows very clearly the increasing diversity of species with increasing distance from the settlement, and the tolerance of *Acacia tortilis* under conditions of high levels of human and animal utilisation.

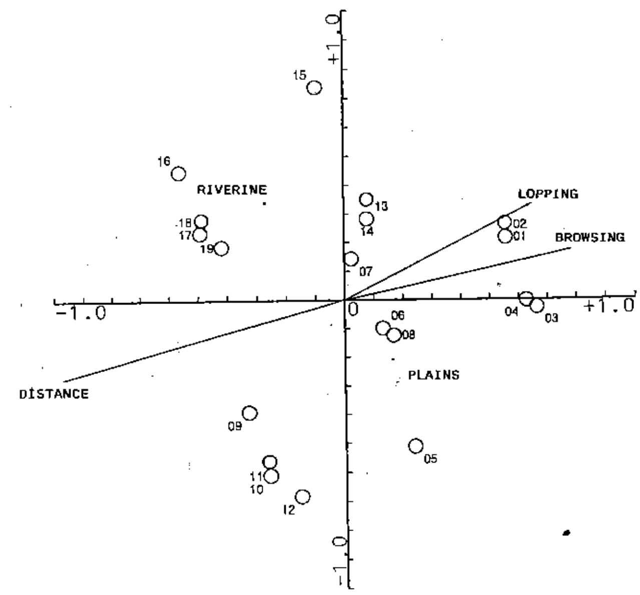

Figure 7a: Samples and environmental variables ordination

Table 9: Axis 1 and 2 species-environment correlation coefficients for the plains and riverine samples, from which the second CCA ordination diagram is constructed.

Environmental variables	Species axis 1	Species axis 2	Environmental axis 1	Environmental axis 2
browsing	.7113	.1003	.7743	.1703
lopping	.5804	.1899	.6317	.3233
distance	**-.8817**	-.1587	-.9597	-.2703
plains	.5035	**-.4071**	.5481	-.6933
riverine	-.5035	.4071	-.5481	.6933
% cumulative variance:	17.2%		54.9%	

Discussion

Settlement impacts

The above analysis indicates that the Khowarib settlement is having a negative impact on local woody vegetation communities, primarily by reducing species richness and increasing dominance by a handful of tolerant species. This relationship was significant for all three of the environmental variables used as measures of settlement impact, i.e. browsing, lopping, and distance from the settlement. Using similar methods, Shackleton (1993: 247) found a significant loss of woody species richness in a harvested site on communal land in the eastern Transvaal Lowveld, and Vetaas (1993: 170) in northeastern Sudan found a change in physiognomy of vegetation from open woodland to a very open shrubland, which could be at least partly attributed to human and livestock impacts. Within Namibia, Strohbach (1992), again using a similar multivariate approach, also recorded the 'loss of genetic diversity' in grass species, and the increasing density of woody species, with increasing intensities of livestock grazing in the commercial farming District of Grootfontein (northern Kalahari sandveld).

The Khowarib results should be interpreted with a certain degree of caution, however.

First, the data set is comprised of a vegetation survey which only covered an area up to a maximum distance of 5kms away from Khowarib settlement. This calls into question the issue of scale in vegetation analysis generally and more importantly, it highlights the danger of drawing conclusions regarding human impacts on vegetation from a survey which essentially only confirms the use of woody vegetation resources at a small, local scale. In other words, while humans and livestock may be having what can be described as a negative impact on woody vegetation at a small scale, it would

be grossly inaccurate to extrapola
on vegetation communities at a la
make this point explicitly becaus
degradation effects of humans an
or spatial scales over which their r

Second, the conventional view is
perennial woody species in drylan
tion, and pressure on these reso
recruitment and replacement. Th
which interprets ecological dynan
tions of equilibrium, and focusing
processes of change which are gr
accurate to think of woody speci
tally-driven establishment events v
structure, and possibly override t
activities recorded in this study
systems see, for example, Holling,
et al, 1987; DeAngelis and Wate
1989; Behnke *et al*, 1993; Homewo

Finally, although the incidence o
Khowarib it should be stated tha
stem, indicating conservative use a
tants. In addition, many species c
use. *Colophospermum mopane*, fo
thus extremely resilient at an in
species which is sought-after for b

Methodological considerations

Given the current focus within N
'desertification' (cf. Wolters, 199
land tenure, it is essential that co
cerning vegetation status and util
odologies which are appropriate a
continue whereby sweeping stater
ing the degraded state of vegetat
farmers (cf. van Warmelo, 1962: 3

Although based on a small data
techniques may be considered a
nificance of a number of variable
community patterns and composi
handle complex data sets with a n
fact that they do not make sweepi

data are distributed, enhances their relevance for the assessment of utilisation impacts. Furthermore, the recent use of these techniques by Cowlishaw and Davies (forthcoming) in the Pro-Namib, and their proposed use to analyze vegetation communities in the Kaokoveld (Jürgens, 1995), suggests a growing interest in applying this methodology to the Namibian context.

With regard to the Sesfontein-Khowarib area, a much larger woody vegetation dataset of some 3,000 individuals is currently being collected by Sullivan as part of a longer project defining vegetation resource use by Damara-speaking communal farmers, and assessing the impacts of this use on the vegetation resource base. As an extension of the study presented in this paper, specific issues to be addressed with this new data set include to what extent human and livestock use parameters remain significant in community composition once the spatial scale of analysis has been widened, and the degree by which selection for particular species affects their availability and population structure. This will allow the further interpretation of the Khowarib data set, and will provide additional information for assessment of the methodology described in this paper, as well as highlighting specific resource use issues in the context of assertions made regarding vegetation degradation in this area.

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Appendix 1

Names, families and author citations for plant species mentioned in this paper (following the current species list of the National Botanical Research Institute of Namibia; see also Kolberg *et al*, 1992).

Welwitschiaceae
Welwitschia mirablis Hook. F.

Moraceae
Ficus sycomorus L.

Loranthaceae
Plicosepalus kalachariensis (Schinz) Danser

Portulacaceae
Ceraria longipedunculata Merxm. & Podlech

Capparaceae
Boscia albitrunca (Burch.) Gilg & Benedict
Boscia foetida Schinz subsp. *foetida*
Maerua schinzii Pax

Moringaceae
Moringa ovalifolia Dinter & A.Berger

Fabaceae
Acacia erioloba E.Mey.
Acacia montis-usti Merxm. & A.S
Acacia robynsiana Merxm. & A.S
Acacia senegal (L.) Willd. var. *ros*
Acacia tortilis (Forsskal) Hayne s
Colophospermum mopane (Kirk e
Faidherbia albida (Delile) A.Che
Mundulea sericea (Willd.) A.Che

Balanitaceae
Balanites welwitschii (Tiegh.) Exe

Burseraceae
Commiphora giessii J.J.A.van der
Commiphora kraeuseliana Heine
Commiphora multijuga (Hiern) K
Commiphora pyracanthoides Eng
Commiphora virgata Engl.

Euphorbiaceae
Euphorbia virosa Willd.

Rhamnaceae
Ziziphus mucronata Willd. subsp.

Tiliaceae
Grewia bicolor C.Juss.

Malvaceae
Gossypium anomalum Wawra ex

Sterculiaceae
Sterculia quinqueloba (Garcke) K

Tamaricaceae

Tamarix usneoides E.Mey. ex Bunge

Combretaceae
Combretum apiculatum Sond.
Combretum imberbe Wawra
Combretum wattii Exell
Terminalia prunioides C.Lawson

Apiaceae
Phlyctidocarpa sp. Cannon & Theobald

Salvadoraceae
Salvadora persica L.

Boraginaceae
Cordia sinensis Lam.

Solanaceae
Lycium sp. L.

Bignoniaceae
Catophractes alexandri D.Don

Pedaliaceae
Sesamothamnus guerichii (Engl.) E.A.Bruce

Acanthaceae
Petalidium sp. Nees

Asteraceae
Pechuel-Loeschea leubnitziae (Kuntze) O.Hoffm.

Poaceae
Kaokochloa nigrirostris De Winter