



## The impacts of people and livestock on topographically diverse open wood- and shrub-lands in arid north-west Namibia

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### ABSTRACT

1. It is generally considered that the open woodlands of north-west Namibia are experiencing widespread degradation due to over-use of resources by local herders.

2. Data are presented regarding community floristics, diversity, density, cover and population structure for woody vegetation. These are analysed in relation to abiotic factors of topography and substrate, and to settlement impacts represented indirectly by distance from settlement and directly by measures of branch cutting and browsing.

3. None of the vegetation indices upheld predicted patterns of degradation except on a small scale, confined to within settlements. Moreover, in nearly all cases, local settlement effects were within the range of variability observed at larger scales.

4. It is concluded that continuing perceptions and

fears of degradation in this area relate more to ideology than evidence. In particular, it is argued that factors conferring resilience and persistence on both the environment and the regional herding economy are obscured by: (1) disregard for the implications of spatial and temporal scale in interpretations of ecological data; (2) a conceptual adherence to equilibrium dynamics that stresses density-dependent impacts of people and livestock over and above the role of abiotic factors in constraining and driving primary productivity; and (3) remnants of a colonial ideology, which tends to view 'traditional communal farming' practices as environmentally degrading.

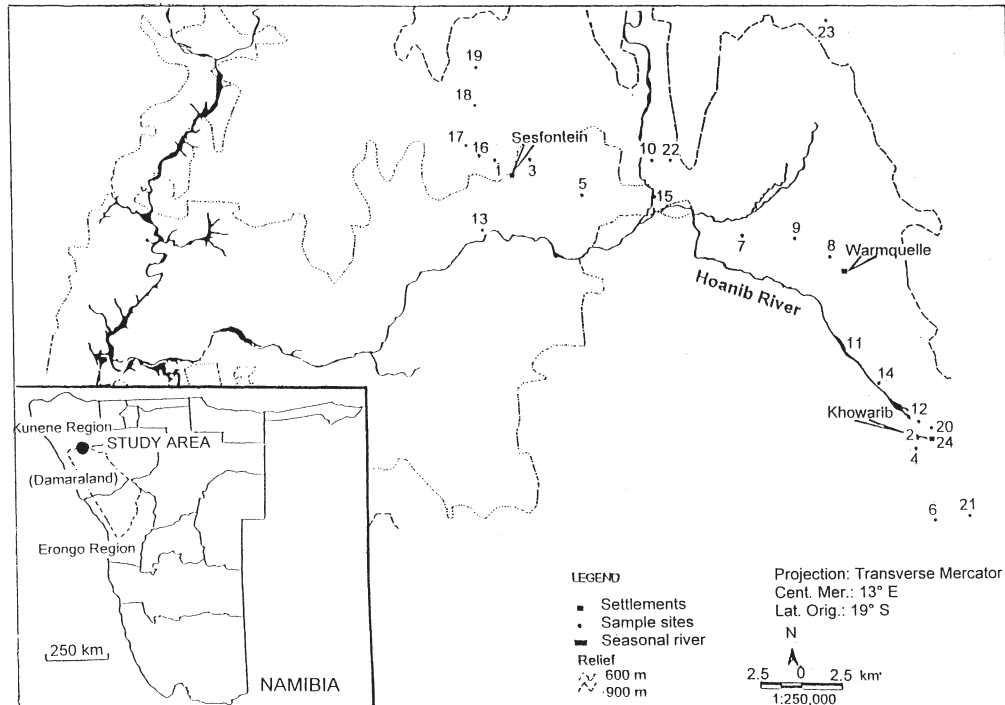
**Key words.** Open woodland degradation, desertification, pastoralism, policy, scale, biotic and abiotic factors, traditional communal farming, Namibia.

### INTRODUCTION

Over the last few decades, concern has been expressed repeatedly regarding the impacts of communal land-use practices by pastoralists on the vegetation of north-west Namibia. Statements abound implying imminent ecosystem 'collapse' due to human mismanagement of natural resources (cf. Infoscience, 1994: 22). It is considered, for example, that 'the whole . . . area has been overgrazed so thoroughly that only the large trees remain in a level plain of bare sand' (Van Warmelo, 1962: 39), that 'severe degradation has occurred' (Loxton, Hunting & Associates, 1974: 22) and that 'the ravaged landscape is testimony to mass overgrazing' (Næraa *et al.*, 1993: 82). International classifications consider the region to be among the 'susceptible drylands' of Africa (Middleton & Thomas, 1997: 57),

and a national climate of concern regarding problems of degradation in Namibia is fostered by the country's Programme to Combat Desertification (NAPCOD) which, as stated in a recent policy document, considers the existence and acceleration of land degradation to be 'undisputed fact' (Dewdney, 1996: iii).

Despite the confidence with which assertions of degradation are made in Namibia, few, if any, have been tested with, or are supported by, empirical data. Studies to date have produced ambiguous results, which nonetheless have been interpreted as due to degradation processes (cf. 1995 and 1996 Summer Desertification Projects by the Desert Research Foundation of Namibia (DRFN)). This tendency to perceive observed patterns with reference to a desertification paradigm not only leads to a self-fulfilling degradation prophecy but also overlooks alternative explanations for



**Fig. 1.** Map of Namibia showing the location of the study area in relation to the former 'homeland' of Damaraland and the new Region of Kunene (inset), and the location of sample sites for the woody vegetation data set in relation to the three study settlements of Sesfontein (19°07' S 13°36' E), Khowarib (19°16' S 13°52' E) and Warmquelle (19°11' S 13°49' E). The site numbers correspond with those in Table 2. Produced by the National Remote Sensing Centre (NRSC), Windhoek.

ecological phenomena that may be more parsimonious. At the same time, a near vacuum of information concerning the contemporary natural resource-use and management practices engaged in by Namibia's communal area farmers perpetuates misunderstanding about the assumed degrading effects of these practices.

Despite these complexities, policy and development interventions are directed at alleviating the problem of desertification, with potentially dramatic effects on the livelihoods of rural farmers in the arid north-west of the country. Not least among these is an emphasis on reducing the region's herd. Echoing Van Warmelo's exhortations in 1962 that 'overstocking . . . must be avoided like the plague . . . through careful supervision of stock and population' (p. 35), for example, is the recent view held by management of a current Ministry of Agriculture development project in the Sesfontein area (see Fig. 1) that all livestock should be removed from the so-called Sesfontein-Khowarib Basin in the Hoanib River catchment (pers. comm. with Project

Manager, 1996). A plethora of initiatives in post-independence Namibia that aim to promote alternative sources of livelihood are similarly driven, at least in part, by an agenda of demoting the area's livestock economy. The increasing focus on creating pathways whereby benefits from animal wildlife can devolve to local 'communities' (cf. Ashley, Barnes & Healey, 1994; Ashley & Garland, 1994; Jones, 1995; Turner, 1996; Ashley & LaFranchi, 1997; Ashley, 1997 in lit. '*Wildlife Integration for Livelihood Diversification*' (WILD) project plan.), for example, is perceived to be a viable means of reducing 'the risk of environmental degradation' by capitalising on 'the different feeding and watering behaviour of game' (Ashley *et al.*, 1994).

Given this general context of concern regarding land degradation in Namibia, and in relation to wider debate regarding 'desertification' issues (cf. Shackleton, 1993; Thomas & Middleton, 1994; Thomas, 1997), this paper draws on two years of fieldwork to explore the measurable effects of plant use on woody vegetation

in and around three rural settlements in north-west Namibia. This is extracted from a fuller analysis which also includes short-term monitoring of herbaceous vegetation over two growing seasons and under different grazing pressures (Sullivan, 1998).

## BACKGROUND TO STUDY AREA

A fundamental constraint on productivity in the area is its aridity; rainfall for the settlement of Sesfontein has an annual mean of 95 mm and a coefficient of variation of 70% ( $N=24$ ; data from the Climate Research Unit, University of East Anglia, UK, analysed in Sullivan, 1998: 56). Despite this aridity, the vegetation of north-west Namibia is diverse in structure, physiognomy and floristics, reflecting varied topographic factors and associated soil and microclimate characteristics. Floristically, it is considered part of the succulent-dominated Karoo-Namib biogeographical Region described by Werger (1978a: 145–170), and structurally as part of the Karoo-Namib regional centre of endemism as identified by White (1983). It is also interspersed with many open woodland taxa of the Sudano-Zambezian Region, particularly along wide ephemeral river valleys (Werger, 1978b: 234), and the resulting high individuality of the area has led Jürgens (1991: 21, 30–32) to identify a separate Damaraland-Kaokoland Domain based on floristics, phytosociology and geographical distribution of taxa. The area has numerous endemic or near-endemic taxa (Nordenstam, 1974: 58; Maggs, Kolberg & Hines, 1994: 97–98), while several species are thought to represent a relict Afro-arid flora sharing a markedly disjunct distribution with the arid regions of north-east Africa and the Middle-East (Nordenstam, 1974: 60, 63). The study area itself falls within the category 'Mopane Savanna' as defined within Namibia by Giess (1971: 9–10); it is dominated by *Colophospermum mopane* (Kirk ex Benth.) Kirk ex Léonard, has many representatives of the family Acanthaceae and a uniquely high diversity of the genus *Commiphora* Jacq. on rocky substrates (nomenclatural authorities follow Kolberg *et al.*, 1992).

Like much of Namibia, the north-west has a dynamic history of use by various indigenous groups, although permanent sources of water at the study settlements of Sesfontein, Warmquelle and Khowarib have allowed continuous habitation, at least for most of this century. By virtue of being remote and inaccessible, the area was spared some of the larger excesses of control, land

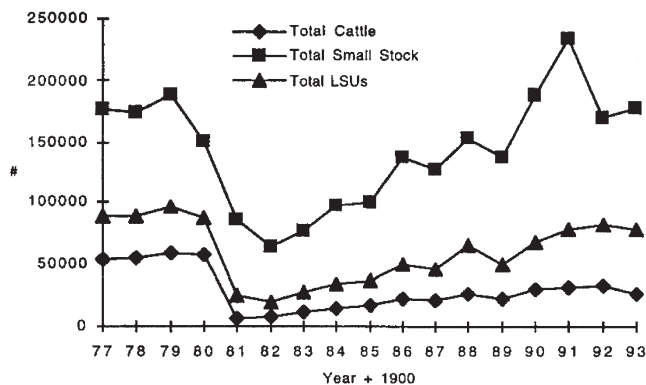
**Table 1.** Population figures and structure for the settlement of Sesfontein 1947/48 and 1991 (derived from Van Warmelo (1962: 8, 40) and National Planning Commission (1991));  $\pm$  = approximate numbers.

| Language group | 1947/48 | 1991      |
|----------------|---------|-----------|
| Damara         | 374     | $\pm 480$ |
| Herero         | 262     | $\pm 200$ |
| 'other'        | 149     | $\pm 126$ |
| Total          | 785     | $\pm 806$ |

appropriation and European settlement imposed by the German and South African administrations of this century. The area consequently remains unfenced and is managed as communal rangeland by its current inhabitants. Livestock are the mainstay of the regional economy, with localised horticulture, gathered resources and drought relief providing additional sources of subsistence. Cash income is variously received from: waged employment, primarily within the civil service; government pensions; and informal income-generating activities, including herding for wealthier families and selling the products of local industry such as beer-brewing and handicrafts.

At the heart of the belief that 'a combination of poverty and traditional farming techniques are leading to processes of land degradation and deforestation' in Namibia's communal areas (Quan, Barton & Conroy, 1994: 16) is an assumption of dramatic, unmanaged increases in both livestock and human populations. These assumptions are not supported, however by available data for the region. Demographic data for the largest of the study settlements, for example, show almost no change between 1947/48 and 1991 (see Table 1) and certainly do not support estimates of an average national population increase of 3.33% per annum (Dewdney, 1996: 70). Masked by these figures, however, is an extremely fluid and mobile population who move in order to better sustain their herds when faced by local grazing shortages, in search of employment within both rural and urban areas, and for an abundance of seemingly haphazard reasons in the context of an arid and unpredictable environment (for migration histories see: Sullivan, 1996a, 1998; Rohde, 1997b).

Livestock in the region also fluctuate widely. As Fig. 2 demonstrates, small-stock numbers in the early- to mid-1990s were roughly the same as in the mid-1970s, while cattle and total Livestock Units had fallen. The dramatic decline of the regional herd in the early 1980s reflects the devastating effects of several years of below



**Fig. 2.** Total livestock population for the former Damaraland 'homeland' in north-west Namibia from 1977 to 1993; LSU = Livestock Unit, calculated here as 1 cow or bull = 1, 1 calf = 0.5, 1 head of small stock, primarily goats, = 0.2, 1 kid or lamb = 0.1. (source: Rohde, 1997b: 436, derived from National Veterinary Services (Windhoek) Livestock Census Reports for North and South Damaraland (not including Otjohorong Reserve)). The problems of collecting livestock census data in remote areas notwithstanding, these data are considered useful in demonstrating the direction and magnitude of population fluctuations for the latter part of this century.

average rain; the steep recovery of the livestock population since then, however, indicates a high degree of herd resilience under communal management in this arid and variable area. Also disconcerting is the lack of historical context surrounding statements such as this: 'More than 100 years of heavy grazing has left much of this region appearing severely degraded' (Ward, 1997: 2). Given such views, the erosion of regional herding economies over the last few centuries due to mercantile and imperial expansion into the territory, followed by the devastating effects of rinderpest in 1897 and the systematic persecution of indigenous groups under German colonial rule and a later Apartheid administration, might never have happened. The implication of all these, however, is that the Namibian landscape supported successful herding economies prior to these events, and that any overall increases in livestock population since the early part of this century might reflect a longer-term process of recovery in the wake of these undermining circumstances (see also, Bell, 1987: 82).

## METHODS

### Approach

The aims of this study were first, to determine, using a number of standard ecological indices, the extent of

measurable damage to woody vegetation caused by utilization by people and livestock around permanent settlements, and second, to interpret the results in relation to the commonly expressed narratives of environmental degradation for the area. In arid environments, where rainfall and therefore primary productivity is extremely variable and unpredictable in time and space, woody plants can act as relatively long-term indicators of vegetation change because they are long-lived and able to withstand the effects of drought. The use of such indicators is particularly important in the absence of long time-series of data because they allow the substitution of a spatial dimension for a temporal one, if it is known, as in this case, that areas of settlement have been relatively continuous through time. The approach taken accords with Dregne's (1985) statement that desertification, as a process of ecosystem 'deterioration', should be displayed by measurable indices such as 'reduced productivity of desirable plants' and 'undesirable alterations in the biomass and the diversity of . . . flora'. As such, it purposefully treats the environment as 'analytically separable' from people (cf. Leach & Mearns, 1996: 11), despite a long history of human occupation and herding in the area (Rudner, 1979; Viereck, 1967; Sandelowsky, 1977: 222; Sandelowsky, van Rooyen & Vogel, 1979; Wadley, 1979; Kinahan, 1983, 1991, 1993), because this reflects the way in which the discourse regarding desertification in the area is framed.

## Predictions

On the basis of the degradation arguments outlined above, a number of predictions were made concerning the likely form that woody vegetation degradation might take around settlements in the north-west of Namibia. These were as follows.

1. Vegetation community patterns will be most strongly associated with, and explained by, measures of resource use.
2. Proximity to settlement, associated with relatively high intensities of use of woody species for fuel and construction purposes, will be positively related to reductions in: woody species diversity; plant density; and plant cover.
3. The cutting of mature individuals for timber, and/or the prevention of recruitment to adult size-classes due to intensive browsing of young individuals by livestock, will cause skewing in woody plant species population structure with varying distances from settlement.

## Field methods

### Sampling strategy

Following Leithead (1979), the woody vegetation of the so-called Sesfontein-Khowarib basin was surveyed using a 'zig-zag' transect method in which each consecutive individual is 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. The strength of this technique lies in the fact that it makes no assumptions regarding the density or distribution of plants, and thus the vegetation itself dictates the length of the transect up to the set number of individuals decided for a sample (see below). This feature of the technique is well-suited to the surveying of dryland vegetation where species distributions are far from random; instead they are characteristically patchy and dispersed, and clumping of individual plants or associated species may be common (cf. Prentice & Werger, 1985; Ben-Shahar, 1991).

In order to take into account the substantial differences in topography and substrate in this area, as well as to sample vegetation under different degrees of settlement pressure, sampling was stratified into a number of levels. At the broadest level, the area was divided into three topographic categories, i.e. plains, riverine and mountain terrains, based on geomorphological and plant physiognomic

characteristics. These were further stratified on the basis of soil characteristics or substrate (following preliminary soil surveys reported in Infoscience (1994: 11–12) and corroborated by fieldwork in southern Kunene (Mouton, 1995: 17)), such that the plains samples were classified as occurring on either alluvial silts or sandy loams, riverine samples always occurred on alluvial silts, and the more varied mountain samples had substrates of calcrete, dolomite or schist. Stratification of the survey on the basis of broad geomorphological categories is consistent with results from previous descriptions of plant communities in the pro-Namib of north-west Namibia (Cowlshaw & Davies, 1997; Sullivan & Konstant, 1997), and follows Walter's (1986) suggestion that geomorphological features may comprise effective units for classification of desert ecosystems. Olsvig-Whittaker, Shachak & Yair (1983: 161–163) also demonstrate the significance of substrate factors in causing spatial heterogeneity in vegetation assemblages in a watershed of the Negev Desert, largely through effects on soil moisture availability.

The final level of stratification involved sampling at different distances from the primary permanent settlements in the area, i.e. Sesfontein, Warmquelle and Khowarib, in each of these topographic and substrate categories. Distance from a settlement was thus used as an indirect measure of resource-use pressure with transects located within settlement, on the outskirts of settlement, and at distances ranging from 3 km to 20 km from settlement. The study design can be described as a 'comparative mensurative experiment', the location of samples in space comprising a range of 'treatments' of these samples (cf. Hurlbert, 1984: 189).

A total of fifty-three transects were sampled in 1995 and 1996. The objective for each transect was to measure forty plant individuals; in a small number of cases, such as when a watercourse or obvious change in substrate or topographic stratum (as defined above) was encountered, transects were shortened accordingly. The 1995–1996 dataset is comprised of measurements for 2115 plant individuals. This dataset was augmented by a further twenty-two transects comprised of some 635 individuals, which were measured in a preliminary survey in 1992, conducted using the methodology described above with the exception of measuring slightly fewer (normally thirty) individuals in each transect (Sullivan & Konstant, 1997). The full data set analysed here consists of seventy-five transects with measurements for 2760 individuals. Pseudoreplication was avoided for all analyses based on site by surveying

**Table 2.** Characteristics of the twenty-four sample sites sampled in 1992, 1995 and 1996 (see Fig. 1 for site location). Ses/Warm and Warm/Khow=in between the settlements of Sesfontein and Warmquelle, and Warmquelle and Khowarib respectively.

| Site no. | Topographic category | Substrate      | Distance from settlement (km) | Settlement | No. of transects | No. of plants sampled | Mean use-scores for each site: |              |
|----------|----------------------|----------------|-------------------------------|------------|------------------|-----------------------|--------------------------------|--------------|
|          |                      |                |                               |            |                  |                       | Lopping 0-6                    | Browsing 0-4 |
| 1        | Plains               | Alluvial silts | 0                             | Sesfontein | 4                | 160                   | 1.8                            | 1.2          |
| 2        |                      |                | 0                             | Khowarib   | 4                | 115                   | 0.8                            | 2.1          |
| 3        |                      |                | 0.5                           | Sesfontein | 3                | 120                   | 0.6                            | 0.4          |
| 4        |                      |                | 0.5                           | Khowarib   | 5                | 160                   | 0.6                            | 1.4          |
| 5        |                      |                | 5                             | Sesfontein | 4                | 160                   | 0.3                            | 0.2          |
| 6        |                      |                | 5                             | Khowarib   | 3                | 110                   | 0.0                            | 0.0          |
| 7        |                      |                | 10                            | Ses/Warm   | 3                | 115                   | 0.0                            | 0.8          |
| 8        | Sandy loams          |                | 0                             | Warmquelle | 3                | 120                   | 3.4                            | 1.3          |
| 9        |                      |                | 0.5                           | Warmquelle | 3                | 120                   | 2.6                            | 0.0          |
| 10       |                      |                | 8                             | Ses/Warm   | 3                | 115                   | 0.0                            | 0.0          |
| 11       |                      |                | 8                             | Warm/Khow  | 2                | 60                    | 0.2                            | 0.0          |
| 12       |                      |                | 0.5                           | Khowarib   | 3                | 120                   | 0.3                            | 0.6          |
| 13       | Riverine             | Alluvial silts | 3                             | Sesfontein | 3                | 90                    | 0.8                            | 1.7          |
| 14       |                      |                | 5                             | Khowarib   | 4                | 120                   | 0.2                            | 0.0          |
| 15       |                      |                | 8                             | Sesfontein | 3                | 120                   | 0.3                            | 0.8          |
| 16       | Mountain             | Calcrete       | 0                             | Sesfontein | 3                | 120                   | 1.2                            | 2.0          |
| 17       |                      |                | 0.5                           | Sesfontein | 3                | 120                   | 0.3                            | 1.5          |
| 18       |                      |                | 3                             | Sesfontein | 3                | 120                   | 0.0                            | 0.3          |
| 19       |                      |                | 5                             | Sesfontein | 3                | 120                   | 0.1                            | 0.7          |
| 20       |                      |                | 0.5                           | Dolomite   | 4                | 150                   | 0.3                            | 0.8          |
| 21       |                      |                | 5                             | Khowarib   | 1                | 25                    | 0.0                            | 0.0          |
| 22       |                      |                | 8                             | Sesfontein | 3                | 120                   | 0.0                            | 0.1          |
| 23       |                      |                | 20                            | Ses/Warm   | 3                | 120                   | 0.0                            | 0.0          |
| 24       | Schist               | 0.5            | Khowarib                      | 2          | 60               | 0.8                   | 0.7                            |              |
| Total:   |                      |                |                               |            | 75               | 2760                  |                                |              |

at least three to four transects in the majority of sample locations (cf. Hurlbert, 1984: 190); this excludes multivariate analyses of community data, for which  $N=75$  samples (see below). Site and transect location were recorded using a Global Positioning System (GPS). Table 2 summarizes the structure of this dataset and Fig. 1 provides a map of the location of transects.

#### *Individual attributes recorded*

For each individual >2 cm basal diameter, the following attributes were recorded. 1. The species was identified. 2. Basal diameter was recorded, using a diameter reading forestry tape. This measure was recorded in preference to the more commonly used diameter at breast height to ensure that cut, broken and coppicing stems were included and in recognition of the shrubby and often stunted growth-forms that characterise many arid-adapted woody species. For taller trees, basal

diameter was measured above the basal swellings characteristic of this growth-form. 3. Height was recorded, using a Suunto direct-reading hypsometer. Heights were not recorded for the 1992 Khowarib dataset due to the lack of the necessary measuring equipment. 4. The distance between each consecutive individual in the transect was measured.

#### *Measures of human and livestock impact*

Woody plants are cut by people for a variety of reasons: primarily, to obtain poles for construction purposes; less frequently, for firewood (for which dead wood is preferred); and, as observed among pastoralist groups elsewhere, to enable livestock to reach otherwise inaccessible green browse, particularly in the dry season, through partial lopping or pollarding (cf. Morgan (1981: 104), Homewood & Hurst (1986: 6) and Barrow (1988: 7) for references to this practice



**Table 3.** Monte Carlo permutation tests of significance ( $P=0.01$ ) for environmental variables for the reduced data set of plains and riverine samples following forward selection and partialling out of remaining variables as covariables using CCA (CANOCO 3.12, ter Braak, 1991).

| Environmental variable   | Other variables partialled out |             |             |             |
|--------------------------|--------------------------------|-------------|-------------|-------------|
|                          | <i>F</i>                       | <i>P</i>    | <i>F</i>    | <i>P</i>    |
| Topography               | <b>9.83</b>                    | <b>0.01</b> | <b>9.79</b> | <b>0.01</b> |
| Substrate                | <b>13.59</b>                   | <b>0.01</b> | <b>9.79</b> | <b>0.01</b> |
| Lopping                  | <b>3.81</b>                    | <b>0.01</b> | 1.05        | n.s.        |
| Browsing                 | 2.32                           | n.s.        | 2.00        | n.s.        |
| Distance from settlement | 1.43                           | n.s.        | 2.14        | n.s.        |
| Combined use measures    |                                |             | <b>1.99</b> | <b>0.01</b> |
| Topography and substrate |                                |             | <b>6.23</b> | <b>0.01</b> |

among Kenyan pastoralists). The degree of **branch removal** or **lopping** for human use, identified by the occurrence of clean cut marks through the branches or main stem and clearly distinguishable from utilisation by desert-dwelling elephants (as assessed by Viljoen & Bothma, 1990), was classified according to the following scale: 0, no branch removal; 1, slight branch removal, one to two large branches or only small branches removed; 2, moderate, 25–50% of branches removed; 3, severe, 50–75% of branches removed; 4, very severe, >75% of branches removed, often with a loss of plant height; 5, cut through the main stem/s so that the height of the plant is substantially reduced, but regrowth by coppicing is observed; 6, cut through the main stem and dead, i.e. no sign of coppicing.

The evidence of **browsing** by livestock was recorded on a four-point scale as follows: 0, no sign of browsing; 1, slight, only a few leaves affected; 2, moderate, often with a noticeable browse line; 3, heavy, affecting the shape of the plant.

### Analysis

Community patterns in the floristic data, and their relationships with the environmental characteristics of each sample (as in Table 3) were explored with Detrended Correspondence Analysis and Canonical Correspondence Analysis (DCA and CCA) using the programme CANOCO 3.12 (ter Braak, 1991). These relationships were tested statistically with Monte Carlo permutation tests applied to the full set of environmental variables using forward selection of these variables, and the statistical effects of specific

variables were tested following partialling out of remaining variables as covariables (see ter Braak, 1986, 1987a, b, 1988, 1990; James & McCulloch, 1990; Gaillard *et al.*, 1992). For the CCA, lopping, browsing, distance from settlement, and altitude were treated as ordinal variables and represented as arrows in the graphical output of this analysis (Fig. 4), such that the length and direction of the arrow represents a variable's explanatory strength and direction of impact on community patterns, respectively. Topographic and substrate categories, and settlement, were treated as nominal variables and their graphical locations with respect to community patterns are represented as points.

For both the indirect and direct ordination analyses, all the species and samples were treated as active and thus jointly determine the ordination. Rare species can have a disproportionate effect on multivariate analyses and were therefore downweighted. This follows Cowlshaw & Davies (1997: 286), who demonstrate the significance of rarity and patchiness in the dispersion of species in a similar pro-Namib environment by indicating the disparity between observed species-area curves for this area and a theoretical curve representing a random distribution of species. In Monte Carlo permutation testing, the default selection of ninety-nine permutations was used, providing a measure of significance of  $P=0.01$ .

With regard to the second set of predictions listed above, analysis of variance (ANOVA) and generalised linear modelling (GLM) procedures were applied, using SPSS 7.0 for Windows, to explore statistically the relationships between distance from settlement (i.e.

representing differing intensities of resource-use) and the following indices calculated for each sample.

1. Species diversity, using Hill's  $N_2$  diversity index (Hill, 1973) and calculated by CANOCO 3.12. This is based on Simpson's index  $\lambda$  (Simpson, 1949) and represents the number of effective or dominant species in each sample, such that a high  $N_2$  value indicates low dominance and high diversity and *vice versa*.
2. Mean distance between sampled plant individuals, as a proxy measure of plant density.
3. Mean basal area, as a measure of plant cover.

Finally, height and basal diameter measures for *Acacia tortilis* (Forsskal) Hayne subsp. *heteracantha* (Burchell) Brenan ( $n=663$ ) were each used as indices of the population structure of this species in relation to distance from settlement. This species is common in the study area on plains on alluvial silts and is used locally for a variety of purposes. It is one of the main sources of building poles and firewood, its nutritious leaves and pods provide important forage for livestock, its pods and gum are eaten by people, and various plant parts are used medicinally (Van den Eynden, Vernemmen & Van Damme, 1992: 72–76; Sullivan, 1998). Size in woody plants is generally related to reproductive capacity (Mueller-Dombois & Ellenberg, 1974: 94) and reflects both past opportunities for individual plant recruitment and future potential for recruitment from juvenile individuals. The relationship between these measures and settlement pressure, tested statistically using one-way ANOVA, was used to illuminate the effect that these pressures have on both past and potential recruitment (cf. Sullivan, Konstant & Cunningham, 1995).

## RESULTS

### Floristic patterns

Figure 3 illustrates the graphical distribution of samples following DCA of a samples-by-species matrix constructed from the data set. The clustering of samples according to their topographic and substrate categories, with samples occurring on mountain slopes completely separated from those located in the plains and riverine topographic categories, is suggestive of a strong relationship between the species composition of samples and these abiotic factors. Given the extremely 'noisy' nature of multivariate community data, the eigenvalues of 0.79 and 0.46 for axes 1 and 2 of this

analysis, and the cumulative percentage variance of 25.8% accounted for by these axes, further indicate that these abiotic factors have a high explanatory strength in relation to floristic patterns in the data set.

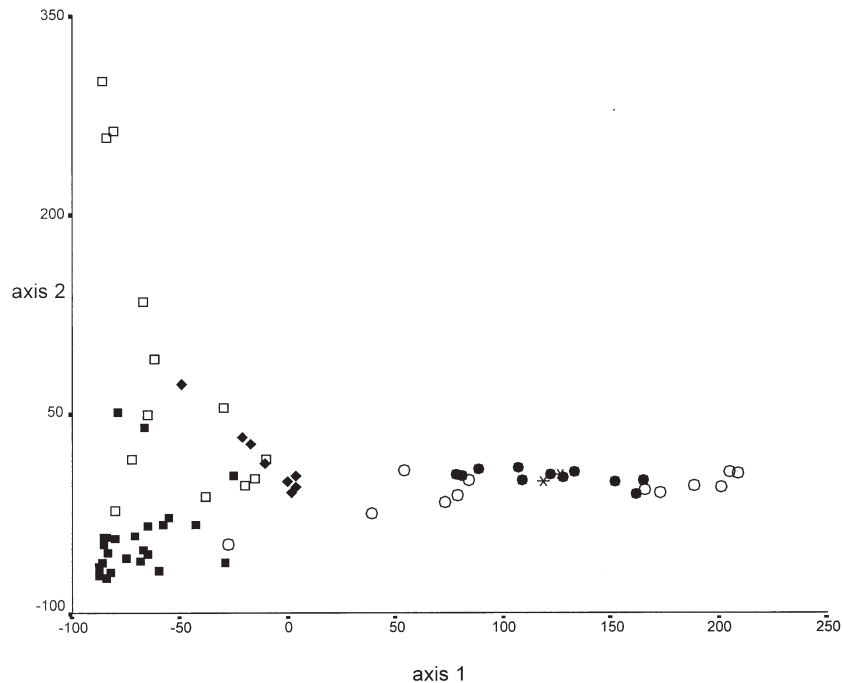
Given the strong division in the data set between mountain samples *versus* plains and riverine samples, and the apparent floristic similarity within these categories, separate direct ordination analyses were carried out for reduced data sets comprised of samples on each side of this division. This was intended to increase the chances of teasing out patterns in the floristic data which may be due to settlement pressure. Due to space constraints, only the output of the CCA for plains and riverine samples will be presented here.

Figure 4 presents axes 1 and 2 of the direct ordination of the plains and riverine samples and Table 3 indicates the results of significance testing for the effects of the environmental variables on floristic patterns in the data. These first two axes have a high explanatory strength; eigenvalues for the species axes 1 and 2 are 0.58 and 0.31 respectively, and have a cumulative percentage variance of 42.6% and these same figures for the environmental axes 1 and 2 are 0.94, 0.83 and 80.5%. (These axes are calculated from the samples-by-species and the samples-by-environment variables respectively (see ter Braak, 1987b: 41, 47–48)). Again, however, the samples are largely clustered according to their topographic and substrate category. Table 3 goes further than this by suggesting that the measures of resource-use incorporated in this analysis made a statistically low and largely insignificant contribution to the patterns in the data.

### Diversity

In analysis of the relationship between vegetation resource-use and species diversity (by sample), and with plant density, plant cover and population structure in the analyses which follow, distance from settlement was used as an indirect measure of varying pressures on these resources. This use of distance from settlement as a surrogate measure for intensity of resource use was supported by significant negative relationships between this variable and lopping and browsing ( $r = -0.46$  and  $-0.5$  respectively,  $P = 0.01$ ). These significant relationships also suggest that a gradient of use around settlements overrides potentially complicating factors such as tracks and the location of temporary and permanent farm outposts away from primary settlements. Average figures for lopping and browsing by transect are indicated on Table 2.



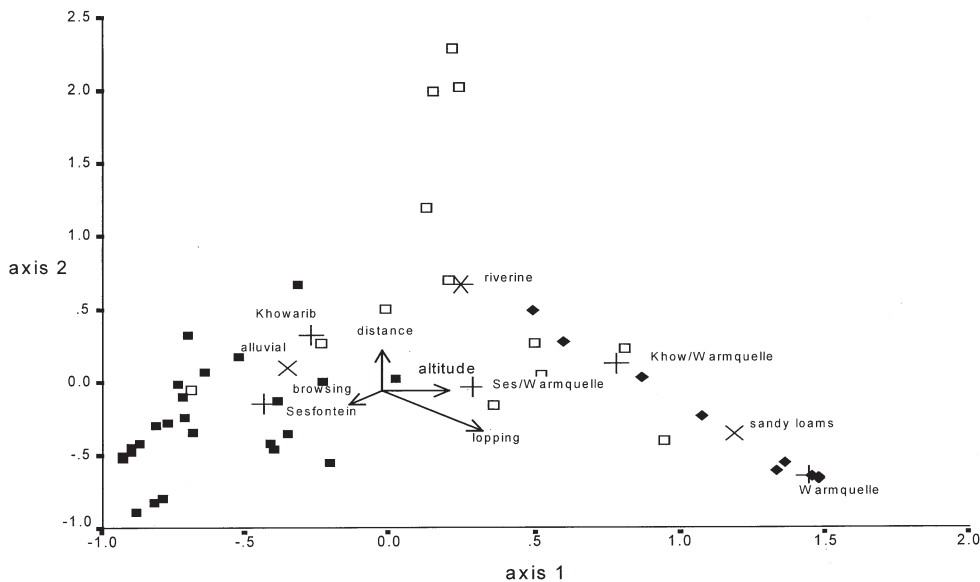


**Fig. 3.** DCA (Detrended Correspondence Analysis) ordination diagram showing the location of samples on ordination axes 1 and 2; ■ = plains on alluvial silts, □ = riverine, ◆ = plains on sandy loams, ○ = mountain on calcrete, ● = mountain on dolomite and, \* = mountain on schist.

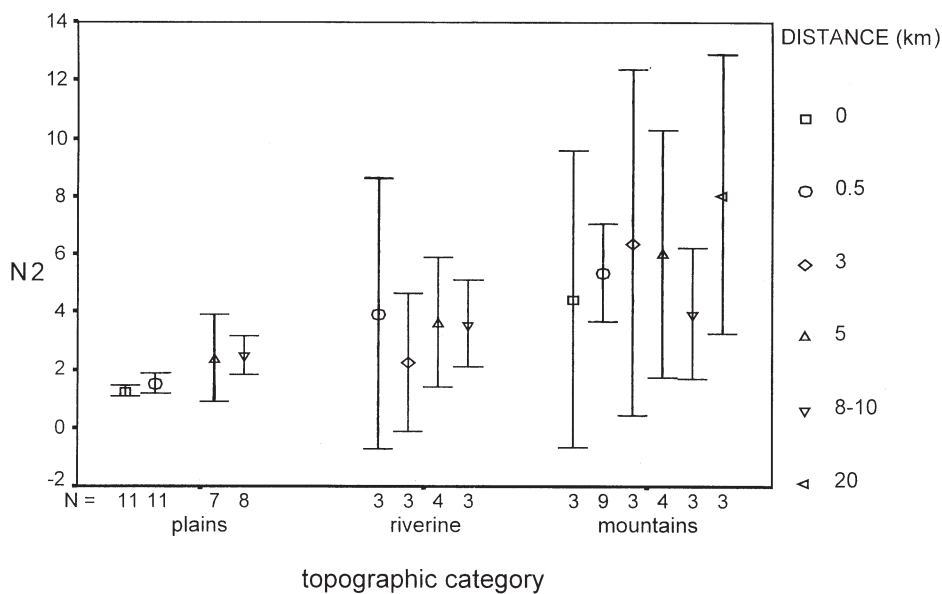
N2 diversity values were significantly different when analysed by both topographic and substrate category (one-way ANOVA,  $F$ -ratio = 44 and 25.6 respectively,  $P = 0.0001$ ); in the former analysis all categories were significantly different from each other at  $P = 0.05$ , while in the latter the greatest differences lay between plains and riverine *versus* mountain substrates, thus further supporting the division of the data set along these lines for the CCA (above). The relationship of distance from settlement to N2 values was analysed by topographic category. This yielded a significant result for plains samples only (one-way ANOVA,  $F$ -ratio = 4.82,  $P = 0.01$ ), and this was considerably weaker than the relationships described above between diversity, topography and substrate. Fig. 5 in fact demonstrates that the relationship between distance from settlement and diversity is somewhat ambiguous. Importantly, with regard to assumptions of reduced biodiversity due to settlement impacts in the area, samples within settlements, i.e. which are under the greatest amount of pressure on resources, are within the range of variability displayed for the N2 values recorded for each topographic category.

### Distance between plants

Again, topography and substrate were significantly related to the mean distance between plant individuals (in a one-way ANOVA of distance between plants by topography the  $F$ -ratio was 55.8,  $P = 0.0001$ ; in a general factorial GLM with topography entered as a fixed factor and substrate as a covariable, the overall model had an  $F$ -ratio of 74.9 while this value for substrate alone was 108.5, both at  $P = 0.0001$ ). As Fig. 6 indicates, transects in the plains topographic category on alluvial silts had the longest distances between trees (and therefore the lowest plant density). The relationship between settlement pressure and distance between plant individuals was assessed using a general factorial GLM with topographic and substrate category entered as fixed factors and distance from settlement as a covariable. This indicated that distance from settlement was significantly related to mean distance between trees although, as Table 4 demonstrates, the strength of this relationship was lower than that for both topography and substrate. Fig. 6 in fact shows that mean distance between trees does not decrease in



**Fig. 4.** CCA (Canonical Correspondence Analysis) ordination diagram showing the location of plains and riverine samples on ordination axes 1 and 2: ■ = plains on alluvial silts, □ = riverine and, ◆ = plains on sandy loams; \*, ×, and +, the centroids of topographic and substrate categories, and settlement, respectively, as labelled on the figure; and the arrows represent the ordinal variables of lopping, browsing, distance from settlement and altitude, again as labelled on the figure.



**Fig. 5.** Error bars showing 95% confidence intervals about the mean for N2 diversity values for topographic category by distance from settlement.

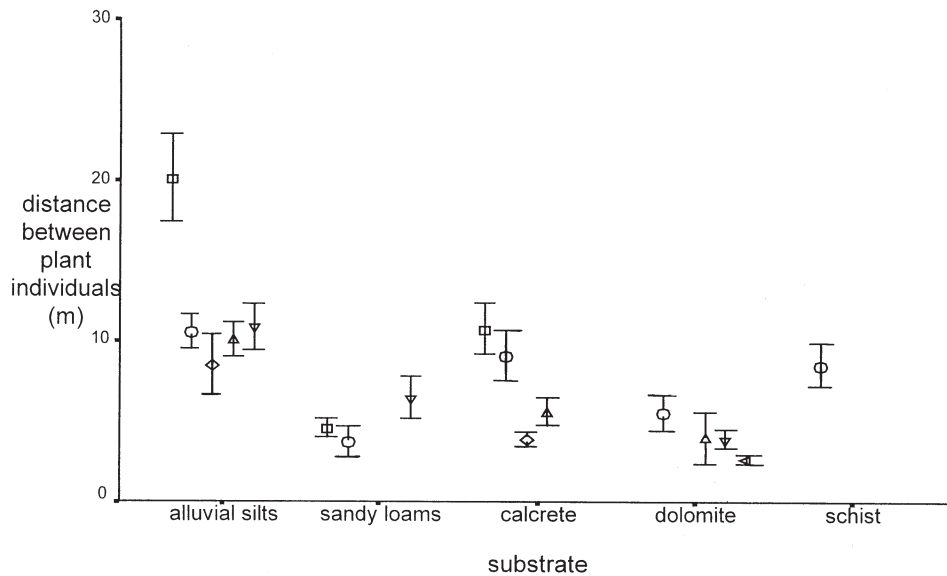


Fig. 6. Error bars showing 95% confidence intervals about the mean for the mean distance between plant individuals (m) for substrate by distance from settlement. For key see Fig. 5.

Table 4. *F*-test statistics and significance levels for general factorial GLM analysis of the relationship between distance from settlement and mean distance (m) between plant individuals with samples grouped by topographic category and substrate.

|                      | <i>F</i> | <i>P</i> |
|----------------------|----------|----------|
| Model                | 59.83    | 0.0001   |
| Intercept            | 374.30   | 0.0001   |
| Covariables          |          |          |
| Topographic category | 41.981   | 0.0001   |
| Substrate            | 56.867   | 0.0001   |
| Factor               |          |          |
| Distance             | 37.232   | 0.0001   |

Table 5. *F*-test statistics and significance levels for general factorial GLM analysis of the relationship between distance from settlement and mean basal area (cm<sup>2</sup>), with samples grouped by topographic category and substrate.

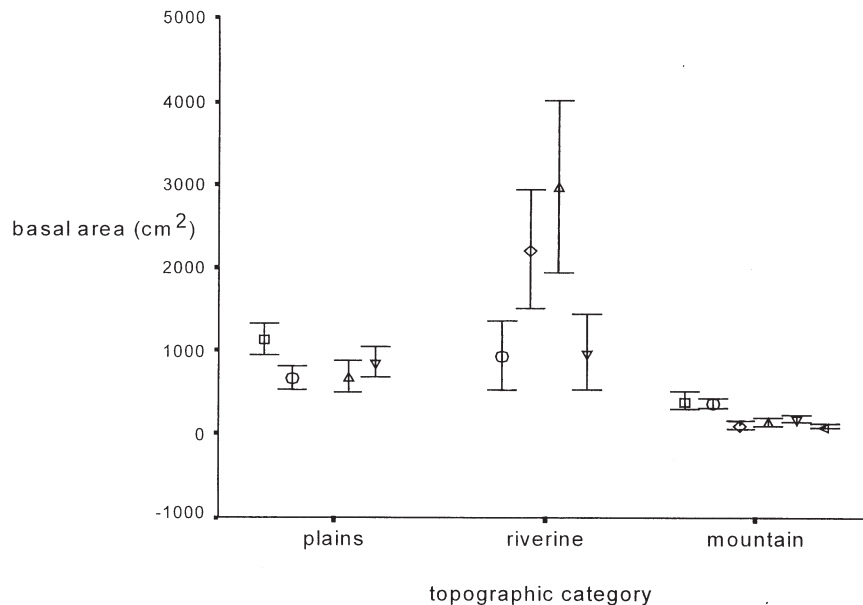
|                      | <i>F</i> | <i>P</i> |
|----------------------|----------|----------|
| Model                | 31.88    | 0.0001   |
| Intercept            | 99.62    | 0.0001   |
| Covariables          |          |          |
| Topographic category | 61.38    | 0.0001   |
| Substrate            | 1.28     | n.s.     |
| Factor               |          |          |
| Distance             | 2.66     | n.s.     |

a simple gradient away from settlements as might be predicted by the degradation model, other than for samples on a substrate of dolomite; and even here, samples nearest settlements, which have the longest distances between individuals (i.e. the lowest density), are within the range of variation shown at distances further from settlement. Notwithstanding this general lack of a gradient in distances between plant individuals with varying intensities of resource-use pressure, and as Fig. 6 demonstrates, the mean distance between trees is in fact greatest for transects located nearest to settlements for all substrate categories except plains on

sandy loams. This pattern is indicative of areas of localised settlement impacts in the form of reduced plant density within settlements.

**Basal area**

A similar analysis of basal area, measured in cm<sup>2</sup>, again demonstrated a significant relationship with topographic category (one-way ANOVA, *F*=91.9, *P*=0.0001), but in this case general factorial GLM analyses indicated that neither substrate nor distance from settlement contributed significantly to the model (see Table 5). As Fig. 7 shows, plants in the mountain



**Fig. 7.** Error bars showing 95% confidence intervals about the mean for basal area ( $\text{cm}^2$ ) for topographic category by distance from settlement. For key see Fig. 5.

topographic category had the smallest basal areas which, given their relatively rocky and shallow soils and the predominance of shrubby life-forms found in these habitats, is to be expected. Fig. 7 again demonstrates a lack of the anticipated trend in the data set in relation to settlement pressure on resources; for the plains and mountain topographic categories, mean basal area is in fact slightly higher for samples within settlements, i.e. the opposite of what might be predicted by the degradation model. The pattern should, however, be seen in the context of the relatively low densities recorded above for samples within settlements and it could be also suggested that it might reflect a tendency for settlements to be established at locations favoured by high plant biomass, particularly with large trees for shade. Nevertheless, given the assertions of devastating vegetation loss related at the beginning of this paper, these data have value even if only to demonstrate that settlement within the study area does not lead necessarily to reduced plant cover in comparison to sites under less direct pressure.

#### Population structure of *Acacia tortilis*

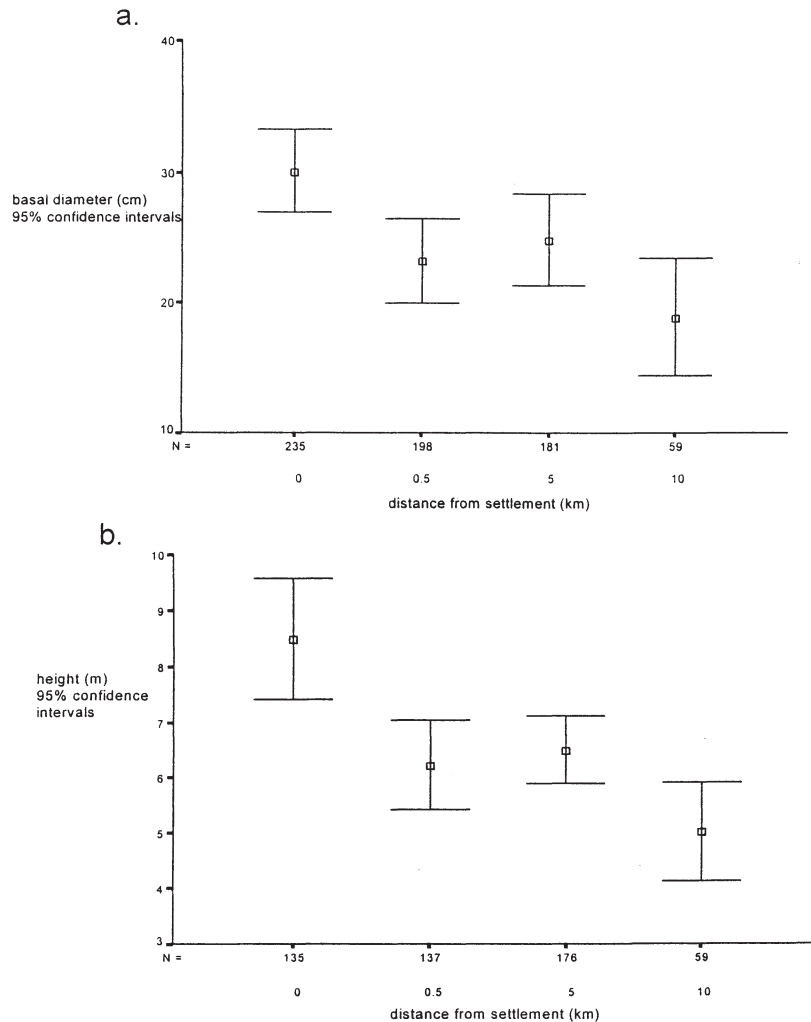
Measures of branch cutting and browsing for individuals of *A. tortilis* were significantly negatively

**Table 6.** Results of one-way ANOVA of height and basal diameter measures by distance from settlement for *Acacia tortilis* (Forsskal) Hayne subsp. *heteracantha* (Burchell) Brenan.

|           | Basal diameter | Height |
|-----------|----------------|--------|
| <i>N</i>  | 663            | 507    |
| <i>F</i>  | 5.19           | 8.77   |
| <i>P</i>  | 0.002          | 0.0001 |
| <i>df</i> | 3              | 3      |

correlated with distance from settlement ( $r = -0.49$  and  $-0.48$  for cutting and browsing respectively,  $P = 0.0001$ ,  $n = 663$ ), which indicates that distance from settlement is a good indirect measure of resource-use pressure for this particular species. As shown in Table 6, distance from settlement was significantly related to the size measures of basal diameter and height for this species. Fig. 8a and b indicate that both these measures were largest within settlements; the remaining distance classes overlapped considerably, although measures for the distance class furthest from settlement were lowest in both cases.

Interpretation of these results in accordance with the degradation paradigm would suggest that recruitment

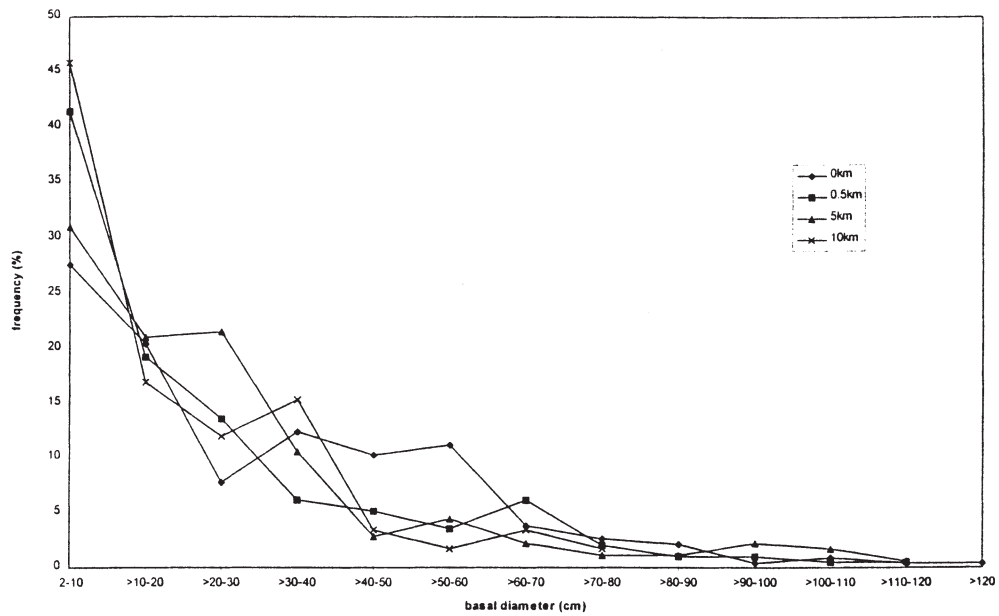


**Fig. 8.** Error bars showing 95% confidence intervals about the mean for *Acacia tortilis* (Forsskal) Hayne subsp. *heteracantha* (Burchell) Brenan by distance from settlement for (a) basal diameter (cm) and (b) height (m).

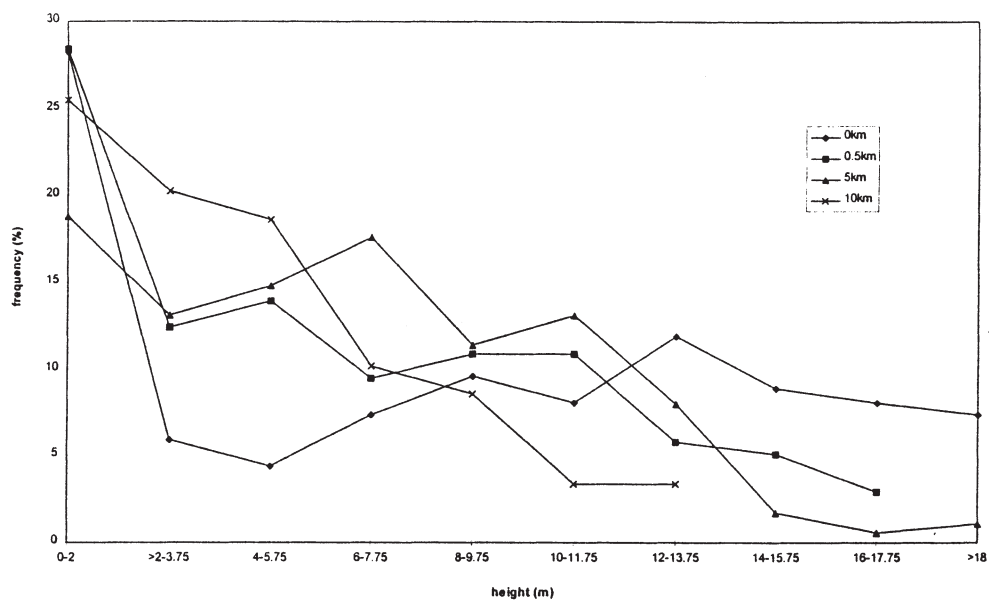
of juveniles, i.e. of smaller individuals, is adversely affected by settlement pressure, with possibly long-term consequences for the viability of the population. Analysis of the size class distributions of these measures, however, suggests a rather different picture. Fig. 9a and b demonstrate that both size measures, and particularly basal diameter, conform well to the reverse J-shaped distribution associated with healthy tree populations that display high recruitment potential. This is true for all distances from settlement, for which the frequencies of individuals in the smaller regeneration size classes were comparable. Fig. 9b

further shows that the reason for the relatively high mean heights measured for *A. tortilis* within settlements was the greater frequency of extremely tall individuals recorded for these samples; this had the effect of pulling the mean disproportionately upwards and contributing to the significant results produced in the ANOVA. Again, the degradation paradigm might suggest that this is due to the effects of branch cutting in reducing the size of otherwise large individuals. As would be expected from a 'healthy' population, however, height and basal diameter had a strong positive association ( $r=0.8$ ,  $P=0.0001$ ,  $n=507$ ), indicating that levels of

a.



b.



**Fig. 9.** Size class distribution of *Acacia tortilis* (Forsskal) Hayne subsp. *heteracantha* (Burchell) Brenan by distance from settlement for (a) basal diameter (cm) and (b) height (m).



cutting are not high enough to reduce the expected relationship between these size measures. This relationship remained significant and positive even when only individuals from within settlements were tested, i.e. those subject to the greatest intensities of utilisation ( $r=0.82$ ,  $P=0.0001$ ,  $n=135$ ).

## DISCUSSION

The present findings provide little support for the assertions of degradation outlined at the beginning of this paper except, perhaps, for localised situations within settlements. It is contended that there are three reasons for this apparent discontinuity between 'evidence' and assumed 'reality' for this area, which have relevance for development practitioners, policy-makers and academic researchers alike. These are: first, a tendency not to make explicit the implications of spatial and temporal scale in the interpretation of ecological data; second, a lack of emphasis on the role of abiotic factors in constraining and driving primary productivity in arid environments over and above the impacts of people and livestock; and finally, remnants of a colonial ideology that tends to view 'traditional communal farming' practices as environmentally degrading. These will be discussed in turn below.

### Scale

None of the measured woody vegetation variables demonstrated that land-use pressure was having a negative impact on anything but a local scale. Furthermore, widening the scale of analysis from that surveyed in a preliminary study of resource-use impacts in the area (Sullivan & Konstant, 1997) demonstrated that settlement pressure is within the range of variability expressed by a variety of measures over larger scales, including areas currently experiencing little or no utilization by people or livestock. In addition, patterns in the data set at both community and individual-species levels failed to provide consistent evidence for the degrading effects of resource utilization, even though woody species, through the stability conferred by their longer lifespans, can act as longer-term and more robust indicators of vegetation change.

Recent analyses of matched archival with current photographs, and of time-series of aerial photographs, for sites in the former Damaraland, increase the time-depth of this discussion back to the late 19th century. These analyses indicate that an overall increase in

woody vegetation has occurred since the first half of this century, largely irrespective of the degree or type of site utilisation, and is attributed at least partly to long-term climatic factors, primarily a period of relatively high rainfall averages during the first few decades of this century (Rohde, 1997a; 1997b: 307–331, 341–375). This evidence similarly contradicts 'the stereotypical belief that communal farming and . . . densely populated communal settlements, cause irreversible environmental degradation', and suggests that 'the case for climate change as the dominant factor affecting trees and shrubs within an inherently resilient environment . . . challenges the wide-spread perception that the landscape of western Namibia is a product of prolonged processes of desertification' (Rohde, 1997a: 135; 1997b: 314, 376).

The lack of evidence for a gradient of degradation effects on vegetation around focal settlements indicated by the analyses presented here, together with the above suggestion of climate-induced woody vegetation increase over the longer-term, emphasize the importance of recognizing that spatial and temporal scale affect conclusions regarding ecosystem behaviour (Auerbach, 1984: 414–415). In particular, this paper highlights the danger of confirming the degradation effects of resource-use by people and livestock by extrapolating results from a small, 'sacrificial area' (cf. Sandford, 1983; Perkins & Thomas, 1993), to vegetation communities over larger spatial scales (see also Warren & Agnew, 1988: 7, 12; Dahlberg, 1994: 27–29, 37). As Perkins & Thomas (1993: 191) point out with regard to the spatial component of small-scale degradation effects around boreholes in the Kalahari, 'Relating these changes to the issue of environmental degradation requires careful consideration of the spatial nature of changes and their relationship with natural environmental perturbations and variability'.

More generally, the results of this study accord with the idea that so-called perturbations may affect smaller scales, both spatial and temporal, more than larger ones, and increasing the spatial or temporal scale of observation may in fact reveal a large degree of ecosystem persistence (Connell & Sousa, 1983: 792; DeAngelis & Waterhouse, 1987: 2–3). In addition, short-lived or transient 'patch dynamics' observed at smaller scales may be crucial elements in the persistence of systems at larger scales or 'higher' hierarchical levels (DeAngelis & Waterhouse, 1987: 2) which, in accordance with theories of complex systems, can be seen as an emergent property of small-scale instability

and variability (Wiens, 1984: 454; Solbrig, 1991; Costanza *et al.*, 1993).

According to this view, local variability arising as a result of varying intensities of resource utilization may be considered as 'positive', in terms of conferring long-term persistence and complexity to quantifiable measures of the wider 'ecosystem' through maintaining and creating small-scale patchiness and diversity. These issues have important implications for how the results of ecological studies in this arid environment are interpreted. Clearly, information derived at the small-scale and in the short-term needs to be situated within an understanding of the range of dynamics that a system may display under different spatial and temporal conditions before degradation labels, and the attribution of blame associated with these, can be made with any degree of certainty.

### Abiotic factors

Related to the above, it has recently been argued that interpretation of patterns in dryland environments with reference to the apparently degrading effects of people and livestock obscures the fundamental relationship between variable abiotic factors and primary productivity (Coughenour *et al.*, 1985, 1990; Homewood & Rodgers, 1987; Abel & Blaikie, 1990; Behnke, 1993; Dahlberg, 1994; Milton & Ho man, 1994). This is important because patterns that are currently explained as caused by human mismanagement of resources, with all the intervention that this justifies, may in fact be due to normal variation in an inherently variable system. Underlying this debate are questions surrounding the appropriateness for drylands of conceptual models derived from a temperate-zone ecology that emphasizes density-dependent interactions between the biotic components of ecosystems and successional processes in relation to disturbance from a desirable and definable equilibrium state. Recent thinking suggests that variable environments such as drylands instead should be embraced by an acceptance of non-equilibrium, i.e. of the integral role of abiotic sources of variability and non-linear interactions between biotic and abiotic ecosystem components (Caughley, 1987; Ellis & Swift, 1988; Westoby, Walker & Noy-Meir, 1989; Behnke, Scoones & Kerven, 1993; Ellis, Coughenour & Swift, 1993; Norbury, Norbury & Oliver, 1994; Scoones, 1995; Sullivan, 1996b; Stott, 1997, 1998).

The data discussed in this paper demonstrate that

variations in topography and substrate accounted for observed patterns in the data in nearly all instances. Similarly, in an environment where annual rainfall has a coefficient of variation of >60%, extreme rainfall and flooding events can be expected to play a defining role in constraining opportunities for recruitment. A conceptual approach that firmly accepts that variable abiotic parameters are central to ecosystem behaviour, implies a shift in interest to encompass the ways in which a condition of non-equilibrium, characterised by continual and unpredictable fluctuation at different scales, is essential for ecosystem health and resilience (Holling, 1986). Instead of being concerned with avoiding deflections away from a perceived 'climax' community, the appropriate focus would be on the ways in which both ecological and social 'systems' with inherently low quantitative stability, particularly at smaller scales, maintain the same qualitative relationships, i.e. persist, in the face of continual change. Such insights regarding the ecology of arid land pastoral systems have significant implications for the development of appropriate land-use policy in drylands. In particular, they suggest that a dynamic livestock economy based on herd mobility and the mediation of conflict over focal resources (cf. Behnke, 1993), should be promoted as opposed to attempts to introduce stability of production through delineating individual land-holdings (cf. Republic of Namibia, 1995) and reducing herds to defined stocking levels.

### An ideology of 'traditional communal farming'

Finally, and as pointed out for the southern African context by Boonzaier *et al.* (1990: 77), there is a tendency by natural scientists, bureaucrats and development officials alike to lump together all African rural production systems under the label 'traditional communal farming' and to proceed to intervene in these systems on the assumption that they are characterised by a number of common flaws (see also Little & Brokensha (1987: 203) and references in Leach & Mearns (1996: 1–2)). For example, as the quotes at the beginning of this paper suggest, and despite evidence to the contrary, 'traditional' farming practices are considered to culminate inevitably in environmental degradation. This perception has been widespread in southern Africa, where it has been additionally tainted by overtones of politically-justified racial prejudice. Describing the

Griquas who inhabited the area between the Orange and Modder Rivers in South Africa, de Klerk (1947: 351), for example, states that 'The Bantu Tribes had scant respect for the soil and kept large herds' . . . and 'played an important part in the eradication of our indigenous forests'. Similarly, the so-called 'denuded grazing areas' of the former 'Rhodesian lowveld' is considered by West (1968: 95) to be in an 'advanced stage of deterioration' due to a livestock economy 'based on unrestricted and uncontrollable utilization of . . . natural sweetveld'. From a wider perspective, the labelling of local farming practices as inefficient and environmentally damaging acted to justify centralised land-use planning and control by colonial, and later, post-independence administrations throughout Africa (cf. Scoones (1996: 38–46) for Zimbabwe; Fairhead & Leach (1996: 112–115) and Swift (1996: 86–88) for French West Africa).

These assumptions of degradation resulting from 'traditional' land-use practices in communally-managed areas are related to a perceived lack of local institutions responsible for the management of resources, either because these institutions are thought never to have existed effectively (the colonial view) or because they are considered to have disintegrated under the pressure of disruptive historical and political processes (the current liberal view) (Sullivan, 1999). These views have been popularised by the controversial 'Tragedy of the Commons' thesis of Hardin (1968) which uses the 'Free Rider Theorem' to suggest that the holding of resources in common necessarily leads to a lack of regulation over their use, which in turn leads to a situation of land and resource degradation (cf. Barrett, 1989: 18).

The ecological data presented here indicating extremely localised use of, and impacts on, vegetation resources in a communal area, coupled with evidence for a sustained, if dynamic, livestock population, instead concords with a picture of land use as based on pragmatic practices that minimise impacts while maximising secondary productivity when environmental (and socio-political) circumstances make this possible. In addition, anthropological fieldwork in the region emphasises the unformalised but ongoing and opportunistic adjustments made by farmers and resource-users in relation to maintaining livelihoods in an unpredictable ecological and political environment (cf. Rohde, 1997b; Sullivan, 1996a, 1998). Crucially, this suggests that exploration of the links between perceived open woodland degradation and local resource-use practices will remain incomplete

and discriminatory unless time, resources and expertise are invested in talking and listening to a diversity of resource-users.

## CONCLUSION

An attempt has been made here to respond to currently unsupported statements of degradation in north-west Namibia through the collection and analysis of standard ecological data, in order to add some focus to national and regional debates regarding land-use and environmental issues. Given consistent perceptions of degradation over several decades for this area, it is perhaps surprising that the data presented in this paper for woody vegetation indicate only very localized impacts of settlement, rather low levels of use by branch-cutting and browsing, and resilient, if variable, secondary productivity as represented by figures for the regional livestock population. Some of the results directly refute accepted wisdom regarding the area: data for the population structure of *Acacia tortilis* conform with the pattern that would be expected for a 'healthy' tree population with a high potential for regeneration, and certainly bear no relation to the assertion reported at the start of the paper that ' . . . only the large trees remain in a level plain of bare sand'. In other words, the 'evidence' appears to represent a departure from the 'reality' of degradation in the study area as it is normally portrayed. Some suggestions as to why this discontinuity may exist include adherence to conceptual ecological models that are inappropriate for drylands, and continuing misunderstanding and misinformation regarding land-use practices by communal area livestock farmers. The paper's findings have relevance for the wider debate regarding desertification and degradation processes in drylands. In particular, they imply that understanding the relationships between the use of vegetation resources and the impacts of this use, and developing and implementing appropriate land-use policy based on this information, will require a fundamentally cross-disciplinary or hybrid approach: one which accepts the challenge to integrate anthropology, ecology and political analysis in order better to represent dynamic interactions between people, environment and policy.

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