forthcoming Jan 1999 in Global Ecol + Biogeography Letters
Special Issue on degradatn in open woodlands.
nb. subject to revision.
Gl

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

Sian Sullivan

Dept. Anthropology, University College London, Gower St, London, WC1E 6BT.

s.sullivan@ucl.ac.uk

Running title: Dry woodlands and human impacts, north-west Namibia.

Abstract:

It is generally considered that the open woodlands of north-west Namibia are experiencing widespread degradation due to the misuse of resources by local herders. 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. None of the vegetation indices upheld predicted patterns of degradation except at local scales confined to within settlements. Moreover, in nearly all cases local settlement effects were within the range of variability observed at larger scales. 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 to 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 which stress the 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, policy, scale, abiotic factors, 'traditional communal farming'

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 and Associates, 1974: 22) and that 'the ravaged landscape is testimony to mass overgrazing' (Næerua, 1993: 82). A national climate of concern regarding problems of degradation in Namibia is further fostered by the country's Programme to Combat Desertification 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, few, if any, have been tested with, or are supported by, empirical data. Studies which do exist have produced ambiguous results, which have been interpreted as due to degradation processes (cf. 1995 and 1996 Summer Desertification Projects by the Desert Research Foundation of Namibia). This tendency to perceive observed patterns with reference to a desertification paradigm not only leads to a self-fulfilling degradation prophecy but overlooks alternative explanations which may in fact be more parsimonious. At the same time, a near vacuum of information concerning the contemporary natural resource-use and management practices in which Namibia's communal farmers engage perpetuates misunderstanding about the imagined 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 consideration by management of the current Ministry of Agriculture development project in the Sesfontein area that all livestock should be removed from the so-called Sesfontein-Khowarib Basin (pers. comm. with Project Manager, 1996). A plethora of initiatives in post-independent Namibia which aim to promote alternative sources of livelihood are similarly driven, in part at least, 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 *et al*, 1994; Ashley and Garland, 1994; Jones, 1995; Turner, 1996; Ashley and LaFranchi, 1997; Ashley, 1997) is, for example, perceived as 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).

This paper draws on two years of fieldwork by the author which explored the measurable effects of the rural settlements of Sesfontein, Warmquelle and Khowarib on open woodlands in arid north-west Namibia (see Fig. 1). This is extracted from a fuller analysis including short-term monitoring of herbaceous vegetation over two growing seasons and under different grazing pressures (Sullivan, forthcoming for 1998). In arid environments, where rainfall and therefore primary productivity is extremely variable and unpredictable, woody species can act as relatively long-term indicators of vegetation change because they are long-lived and able to withstand the effects of drought. 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 and Mearns, 1996: 11) despite a long history of human occupation and herding in the area (Rudner, 1957; Viereck, 1967; Sandelowsky, 1977: 222; Sandelowsky, van Rooyen and Vogel, 1979; Wadley, 1979; Kinahan, 1983, 1991, 1993), because this reflects the way in which discourse regarding desertification in the area is framed.

Background to study area

The vegetation of north-west Namibia is diverse in structure, physiognomy and floristics, reflecting varied topographic factors and associated soil and micro-climate characteristics. Floristically it is considered part of the succulent-dominated Karoo-Namib biogeographical Region (Werger, 1978a: 145-170; White, 1983), but is interspersed with many open woodland taxa of the Sudano-Zambezian Region, particularly along wide ephemeral river valleys (Werger, 1978b: 234; Jürgens, 1991: 21, 30-32). It has numerous endemic or near-endemic taxa (Nordenstam, 1974: 58; Maggs, Kolberg and Hines, 1994: 97-98), while several species are thought to represent a relic 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 by Giess (1972: 9-10); it is dominated by *Colophospermum mopane* (Kirk ex Benth.) Kirk ex Léonard[1], has many representatives of the family Acanthaceae and a uniquely high diversity of the genus *Commiphora* Jacq. on rocky substrates.

Like much of Namibia, the study area has a dynamic history of use by various indigenous groups. By virtue of being remote and inaccessible, it was spared some of the larger excesses of control, land appropriation and European settlement imposed by the German and South African administrations of this century. The area consequently remains unfenced and 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 wage 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.

---

[1] Nomenclatural authorities follow Kolberg *et al* (1992).

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 *et al*, 1994: 16) is an assumption of dramatic 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 (see migration histories in Sullivan, 1996a and Rohde, 1997b). As Fig. 2 indicates, livestock in the region also fluctuate widely.

Methods

Predictions

On the basis of the degradation arguments outlined in the introduction 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;
    - 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 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 (see Fig. 3). 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 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 species, and thus the vegetation itself dictates the length of the transect. 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 or associated species may be common (cf. Prentice and 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 and use 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 by this author (Sullivan, 1993; Sullivan and Konstant, 1997) and by

Cowlishaw and Davies (1997), and follows Walter's (1986) suggestion that geomorphological features may comprise effective units for classification of desert ecosystems[2].

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 3kms to 20kms 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 53 transects were sampled in 1995 and 1996. The objective for each transect was to measure 40 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 22 transects comprised of some 635 individuals, which were measured in a preliminary survey of this area by the author in 1992, conducted using the methodology described above with the exception of measuring slightly fewer (normally 30) individuals in each transect (Sullivan, 1993; Sullivan and Konstant, 1997). The full dataset analysed here consists of 75 transects with measurements for 2750 individuals. Pseudoreplication was avoided by surveying at least 3-4 transects in the majority of sample locations (cf. Hurlbert, 1984: 190). Site and transect location were recorded using a Global Positioning System (GPS). Table 2 summarises the structure of this dataset and Fig. 4 provides a map of the location of transects.

---

[2] Olsvig-Whittaker *et al* (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.

Individual attributes

For each individual >2 cm diameter, the following attributes were recorded:

- The species was identified. Assistance with species identification was provided by Pat Craven and Gillian Maggs of the National Botanical Research Institute, Windhoek.

- Basal diameter, 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.

- Height, using a Suunto direct-reading hypsometer. Heights were not recorded for the 1992 Khowarib dataset due to the lack of necessary measuring equipment.

Measures of human and livestock impact

Woody species 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 and Hurst (1986: 6) and Barrow (1988: 7) for references to this practice 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 and Bothma, 1990), was classified according to the following scale:

- 0 = no branch removal;
- 1 = slight branch removal; 1-2 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 4-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

The data were analysed statistically as follows:

- Community patterns in the floristic data, and their relationships with the environmental characteristics of each sample including indirect and direct measures of resource-use (i.e. distance from settlement, and lopping and browsing respectively) were explored with detrended and canonical ordination (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 (full explanations of these methods can be found in Gauch, 1982; Ter Braak, 1986, 1987a, 1987b, 1988, 1990; James and McCulloch, 1990; Gaillard *et al*, 1992).

  For both the indirect DCA and direct CCA 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 Cowlishaw and 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 99 permutations was used, providing a measure of significance of $p = 0.01$.

- Using SPSS 7.0 for Windows, Analysis of variance (ANOVA) and generalised linear modelling (GLM) procedures were used 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 N2 diversity index (Hill, 1973) and calculated by CANOCO 3.12. This is based on Simpson's well-known index λ (Simpson, 1949) and represents the number of effective or dominant species in each sample such that a high N2 value indicates low dominance and high diversity and *vice versa*;
    2. mean distance between 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 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. Size in woody plants is generally related to reproductive capacity (Mueller-Dombois and 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 and Cunningham, 1995).

Results

Floristic patterns

Fig. 5 illustrates the graphical distribution of samples following DCA of a samples-by-species matrix constructed from the dataset. 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. 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 factors have a high explanatory strength in relation to floristic patterns in the dataset.

Given the strong division in the dataset 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 datasets 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, the output of the CCA for plains and riverine samples only will be presented here.

Fig. 6 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%. 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 dataset.

Diversity

In analysis of the effects of vegetation resource-use on species diversity (by sample), and on 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 postulated positive relationship between resource-use and proximity to settlement is supported by Fig. 7a and b which demonstrate that recorded levels of both branch removal and browsing declined incrementally with distance from settlement.

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 dataset along these lines for the CCA above. The effect of distance from settlement on N2 values was analysed by topographic category. This yielded a significant effect 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. 8 in fact demonstrates that the relationship between distance from settlement and diversity is somewhat nonlinear. Importantly, 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 had significant effects on 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. 9 indicates, transects in the plains topographic category on alluvial silts had the longest distances between trees (and therefore the lowest plant density).

The effects of settlement pressure were 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 had a significant effect on mean distance between trees although, as Table 4 demonstrates, the effect of distance from settlement was lower than that of both topography and substrate. Fig. 9 in fact shows that mean distance between trees does not decrease in a simple gradient away from settlements as might be predicted by the degradation model, other than for samples on a substrate of dolomite; even here, samples nearest settlement 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. 9 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^2, again demonstrated that topographic category had an extremely significant effect (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. 10 shows, plants in the mountain 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. 10 again demonstrates a lack of anticipated trend in the dataset in relation to settlement pressure on resources; for the plains and mountain topographic categories, mean basal area (and therefore plant cover) is in fact slightly higher for samples within settlements, i.e. the opposite to what might be predicted by the degradation model.

Population structure of *Acacia tortilis*

Measures of branch cutting and browsing for individuals of *A. tortilis* were significantly correlated with distance from settlement (Spearman's rank was -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 species. As shown in Table 6, distance from settlement had a significant effect on the size measures of basal diameter and height. Fig. 11a and b indicate that both these measures were smallest 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 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. 12a and b demonstrate that both size measures, and particularly basal diameter, conform well with the reverse J-shaped distribution associated with healthy tree populations displaying high recruitment potential. This is true for all distances from settlement. Fig. 12b 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 by ANOVA above. The frequencies of individuals in these samples in the <2m regeneration size classes were comparable to those from distances further away from settlement. 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 an extremely high positive association (Pearson's correlation = 0.8, p = 0.0001, n = 507) indicating that levels of cutting are not high enough to reduce the anticipated 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 (Pearson's correlation = 0.82, p = 0.0001, n = 135).

Discussion

The brief analyses above 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 3 reasons for this, which have relevance for development practitioners, policy-makers and academic researchers alike. These are: first, a tendency to not 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 use-impacts of people and livestock; and finally, remnants of a colonial ideology which tends to view ‘traditional communal farming’ practices as environmentally degrading. These will be discussed in turn below.

1. 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 and 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 utilisation by people or livestock. In addition, patterns in the dataset at both community and individual-species levels failed to provide consistent evidence for the degrading effects of resource utilisation, 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 to up to the late 19th century. These 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).

These findings emphasise the importance of recognising that spatial and temporal scale affect conclusions regarding ecosystem behaviour (Auerbach, 1984: 414-415). In particular, they highlight 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 and Thomas, 1993) to vegetation communities over larger spatial and temporal scales (see also Warren and Agnew, 1988: 7, 12; Dahlberg, 1994: 27-29, 37). This is confirmed by Wiens (1994: 38) who states that 'Extrapolation to a landscape level from measurements obtained at a local scale, is sensitive to the form of variation from local populations'. As Perkins and 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 and Sousa, 1983: 792; DeAngelis and Waterhouse, 1987: 2-3). In addition, shortlived 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 and 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). This hierarchical relationship between different spatial and temporal scales is summarised in Fig. 13.

According to this view, local variability arising as a result of varying intensities of resource utilisation may be more correctly viewed as 'positive' in terms of conferring long-term persistence to quantifiable measures of the wider 'ecosystem'. These findings have important implications for how the results of ecological studies in this arid environment are interpreted; clearly, data derived at the small-scale and in the short-term need to be situated within an understanding of the range of dynamics that the system under study may display under different spatial and temporal conditions before they can be attributed to the degradation effects of land-use by local farmers.

2. Abiotic factors

Related to the above, it has been recently 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[3]. This is important because patterns which 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 conceptual issues of whether a temperate-zone ecology based on equilibrium dynamics, emphasising density-dependent interactions between the biotic components of ecosystems and successional processes in vegetation communities in relation to disturbance from equilibrium, should be replaced by a theory of non-equilibrium, focusing on abiotic sources of variability and nonlinear interactions between biotic and abiotic ecosystem components.

---

[3] See, for example, Sandford, 1983; Wiens, 1984; Coughenour *et al*, 1985, 1990; Caughley, Shephard and Short, 1987; Homewood and Rogers, 1987; Ellis and Swift, 1988; Warren and Agnew, 1988; Westoby, Walker and Noy-Meir, 1989; Abel and Blaikie. 1990; Boonzaier *et al*, 1990; Galvin, 1990; Behnke, 1993; Behnke, Scoones and Kerven, 1993; Ellis, Coughenour and Swift, 1993; Dahlberg, 1994; Milton and Hoffman, 1994; Norbury, Norbury and Oliver, 1994; Dean *et al*, 1995; Scoones, 1995; Leach and Mearns, 1996; Sullivan, 1996b.

The data presented above 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 which 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. For arid land pastoral systems this implies a policy environment which promotes a dynamic livestock economy based on herd mobility and the mediation of conflict over focal resources (cf. Behnke, 1993) rather than on imposing stability through delineating land-holdings and reducing herds to defined stocking levels.

3. 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[4]. For example, as the quotes at the beginning of this paper suggest, and despite evidence to the contrary, 'traditional' farming practices are considered to necessarily culminate in environmental degradation. This perception has been widespread in southern Africa and 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:

---

[4] See also Little and Brokensha (1987: 203) and references in Leach and Mearns (1996: 1-2).

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 and Leach (1996: 112-115) and Swift (1996: 86-88) for French West Africa).

This situation is related to a perceived lack of local institutions responsible for the management of resources, either because these institutions are thought to have never 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). 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 instead supports a view of local resource-use practices as characterised by unformalised constraints. In addition, anthropological fieldwork in the region emphasises the 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, forthcoming for 1998). Crucially, this suggests that exploration of the links between perceived open woodland degradation and local farming practices will remain incomplete and discriminatory unless time, resources and expertise are invested in talking and listening to a diversity of resource-users.

Acknowledgements

My thanks go to Kathy Homewood and Phil Stott for advice and supervision; members of the Human Ecology Research Group, Anthropolgy Dept, UCL, particularly Dan Brockington, Guy Cowlishaw, Alan Dangour, Hilda Kiwasila and Emmanuel de Merode, for discussion and encouragement; Rick Rohde, Pat Craven, Linda Baker and John Paterson for friendship and support in Namibia; Ruwenzori office services for a supportive environment in which to write this paper; and to Suro Ganuses and Phil Hutchinson, without whom fieldwork for this paper would not have been possible. Financial support was received from the Economic and Social Research Council, The Equipment Fund at UCL, the Emslie Horniman and Ruggles-Gate Funds of the Royal Anthropological Institute, and the Parkes Foundation and Boise Fund of the Depts. of Biological Anthropology at Cambridge and Oxford Universities respectively.

References

Abel, N.O.J. & Blaikie, P.M. (1990) Land degradation, stocking rates and conservation policies in the communal rangelands of Botswana and Zimbabwe. *ODI Pastoral Development Network Paper.* **29a**.

Ashley, C. (1997) *Wildlife Integration for Livelihood Diversification (WILD) project plan*. Draft document.

Ashley, C. and Garland, E. (1994) Promoting community-based tourism development: why, what and how? *Research Discussion Paper.* **4,** Directorate of Environmental Affairs, Ministry of Environment, Windhoek, Namibia.

Ashley, C. & LaFranchi, C. (1997) Livelihood strategies of rural households in Caprivi: implications for conservancies and natural resource management. *Research Discussion Paper.* **20,** Directorate of Environmental Affairs, Ministry of Environment, Windhoek, Namibia.

Ashley, C., Barnes, J. and Healy, T. (1994) Profits, equity, growth and sustainability: the potential role of wildlife enterprises in Caprivi and other communal areas of Namibia DEA *Research Discussion Paper.* **2,** Directorate of Environmental Affairs, Ministry of Environment, Windhoek, Namibia.

Auerbach, M.J. (1984) Stability, probability and the topology of food webs. *Ecological communities: conceptual issues and the evidence*. (ed. by D.R Strong, D Simberloff, L.G Abele, and A.B Thistle), pp. 413-436. Princeton University Press, Princeton.

Barrett, S. (1989) On the over-grazing problem. *LEEC Paper* **89-07**.

Barrow, E. (1988) Trees and pastoralists: the case of the Pokot and Turkana. *ODI Social Forestry Network Paper* **6b**.

Behnke, R. (1993) *Natural resource management in pastoral Africa*. Paper presented to the UNEP workshop on listening to the people: social aspects of dryland management, December 1993, Nairobi.

Behnke, R.H., Scoones, I. and Kerven, C. (eds.) (1993) *Range ecology at disequilibrium: new models of natural variability and pastoral adaptation in African savannas*. ODI, IIED, Commonwealth Secretariat ,London

Ben-Shahar, R. (1991) Successional patterns of woody plants in catchment areas in a semi-arid region. *Vegetatio.* **93,** 19-27.

Boonzaier, E.A., Hoffman, M.T., Archer, F.M. and Smith, A.B. (1990) Communal land use and the 'tragedy of the commons': some problems and development perspectives with specific reference to the semi-arid regions of Southern Africa. *J. Grassld. Soc. sth. Afr.* **7(2),** 77-80.

Caughley, G. (1987) Ecological relationships. Kangaroos: their ecology and management in the sheep rangelands of Australia (ed. by G Caughley, N Shepherd, and J Short), pp. 159-187. Cambridge University Press, Cambridge.

Connell, J.H. & Sousa, W.P. (1983) On the evidence needed to judge ecological stability or persistence. *Amer. Nat.* **121,** 789-824.

Coughenour, M.B., Coppock, D.L. and Ellis, J.E. (1990) Herbaceous forage variability in an arid pastoral region of Kenya: importance of topographic and rainfall gradients. *J. Arid Environm.* **19,** 147-159.

Coughenour, M.B., Ellis, J.E., Swift, D.M., Coppock, D.L., Galvin, K., McCabe, J.T. and Hart, T.C. (1985) Energy extraction and use in a nomadic pastoral ecosystem. *Science.* **230,** 619-624.

Cowlishaw, G. & Davies, J.G. (1997) Flora of the Pro-Namib Swakop River catchment, Namibia: community classification and implications for desert vegetation sampling. *J. Arid Environm.* **36,** 271-290.

Dahlberg, A. (1994) Contesting views and changing paradigms: the land degradation debate in Southern Africa *Discussion Paper.* **6,** Nordiska Afrikainstitutet, Uppsala, Sweden.

De Klerk, J.C. (1947) Pastures of the southern Orange Free State, a century ago and today. *Fmg. S. Afr.* **April,** 347-354.

Dean, W.R.J., Hoffman, M.T., Meadows, M.E. and Milton, S.J. (1995) Desertification in the semi-arid Karoo, South Africa: review and reassessment. *J. Arid Environm.* **30,** 247-264.

DeAngelis, D.L. & Waterhouse, J.C. (1987) Equilibrium and nonequilibrium concepts in ecological models. *Ecol. Monogr.* **57,** 1-21.

Dewdney, R. (1996) *Policy factors and desertification: analysis and proposals.* Report for NAPCOD, Windhoek.

Dregne, H.E. (1985) Aridity and land degradation. *Environment.* **27(8),** 16, 18-20, 28-33.

DRFN 1995 Summer desertification project. *Occasional Paper.* **2,** DRFN, Windhoek, Namibia.

DRFN 1996 *Report of the Summer desertification project.* Funded by USAID and SIDA.

Ellis, J.E. & Swift, D.M. (1988) Stability of African pastoral ecosystems: alternative paradigms and implications for development. *J. Range Mgmt.* **41,** 450-459.

Ellis, J.E., Coughenour, M.B. and Swift, D.M. (1993) Climate variability, ecosystem stability, and the implications for range and livestock development. *Range ecology at disequilibrium: new models of natural variability and pastoral adaptation in African savannas* (ed. by R.H Behnke, I Scoones, and C Kerven), pp. 31-41. ODI, IIED, Commonwealth Secretariat, London.

Fairhead, J. & Leach, M. (1996) Rethinking the forest-savanna mosaic: colonial science and its relics in West Africa. *The lie of the land: challenging received wisdom on the African environment* (ed. by M Leach, and R Mearns), pp.105-121. The International African Institute, James Currey and Heinemann, London, Oxford and Portsmouth.

Gaillard, M.J., Birks, H.J.B., Emanuelsson, U. and Bergland, B.E. (1992) Modern pollen/land-use relationships as an aid in the reconstruction of past land-uses and cultural landscapes: an example from south Sweden. *Vegn Hist. Archaeobot.* **1,** 3-17.

Galvin, K.A. (1990) Nutritional ecology of pastoralists in dry tropical Africa. *Amer. J. Hum. Biol.* **4,** 209-221.

Giess, W. (1971) A preliminary vegetation map of South West Namibia. *Dinteria.* **4,** 1-114.

Hardin, G. (1968) The tragedy of the commons. *Science.* **162,** 1234-1248.

Hill. M.O. (1973) Diversity and evenness: a unifying notation and its consequences. *Ecol.* **54,** 427-432.

Holling, C.S. (1986) The resilience of terrestrial ecosystems: local surprise or global change. *Sustainable development of the biosphere* (ed. by W.C Clark, and R.E Munn), pp. 292-317. Cambridge University Press, Cambridge.

Homewood, K.M. & Hurst, A.V. (1986) Comparative ecology of pastoralist livestock in Baringo, Kenya. *ODI Pastoral Development Network Paper.* **21b.**

Homewood, K. & Rodgers, W.A. (1987) Pastoralism, conservation and the overgrazing controversy. *Conservation in Africa: people, policies and practice* (ed. by D Anderson and R. Grove), pp. 111-128. Cambridge University Press, Cambridge.

Hurlbert, S.H. (1984) Pseudoreplication and the design of ecological field experiments. *Ecol. Monogr.* **54(2),** 187-211.

Infoscience (1994) *Report on sustainable development in the Sesfontein/Khowarib Basin.* Infoscience, Windhoek.

James, F.C. & McCulloch, C.E. (1990) Multivariate analysis in ecology and systematics: panacea or Pandora's box? *Annu. Rev. Ecol. Syst.* **21,** 129-166.

Jones, B.T.B. (1995) Wildlife management, utilization and tourism in communal areas: benefits to communities and improved resource management. *Research Discussion Paper.* **5,** Directorate of Environmental Affairs, Ministry of Environment, Windhoek, Namibia

Jürgens, N. (1991) A new approach to the Namib Region 1: phytogeographical subdivision. *Vegetation.* **97,** 21-38.

Kinahan, J. (1983) Walking to the rain: prehistoric nomads of the Brandberg. *SWA Annual.* 93-96.

Kinahan, J. (1991) *Pastoral nomads of the central Namib Desert: the people history forgot.* Namibian Archaeological Trust and New Namibian Books Windhoek, Namibia.

Kinahan, J. (1993) The rise and fall of nomadic pastoralism in the central Namib Desert. *The archaeology of Africa* (ed. by T Shaw, P Sinclair, B Andali and A Okpoko), pp. 372-385. Routledge, London.

Kolberg, H., Giess, W., Müller, M.A.N. and Strohbach, B. (1992) List of Namibian plant species. *Dinteria.* **22,** 1-21.

Leach, L. & Mearns, R. (1996) Environmental change and policy: challenging received wisdom in Africa. *The lie of the land: challenging received wisdom on the African environment* (ed. by M. Leach and R. Mearns) pp. 1-33. The International African Institute, James Currey and Heinemann, London, Oxford and Portsmouth.

Leithead, H.L. (1979) Measuring the growth of trees. *Rangelands.* **1(1),** 29-30.

Little, P.D. & Brokensha, D.W. (1987) Local institutions, tenure and resource management in East Africa. *Conservation in Africa: people, polices and practice* (ed. by D Anderson and R Grove), pp. 193-209. Cambridge University Press, Cambridge.

Loxton, R.F., Hunting and Associates (1974) *The natural resources of Damaraland.* Unpublished report undertaken for the Department of Bantu Administration and Development, Pretoria.

Maggs, G.L., Kolberg, H.H. and Hines, C.J.H. (1994) Botanical diversity in Namibia: an overview. *Strelitzia.* **1,** 93-104.

Milton, S.J. & Hoffman, M.T. (1994) The application of state and transition models to rangeland research and management in arid succulent and semi-arid grassy Karoo, South Africa. *Afr. J. Range and Forage Sci.* **11(1),** 18-26.

Morgan, W.T.W. (1981) Ethnobotany of the Turkana: use of plants by a pastoral people and their livestock in Kenya. *Econ. Bot.* **35,** 96-130.

Mouton, D.P. (1995) Soil characteristics under different grazing regimes in northwestern Namibia *DRFN Occasional Paper.* **2,** Windhoek, Namibia.

Mueller-Dombois, D. & Ellenburg, H. (1974) *Aims and methods of vegetation ecology.* John Wiley and Sons, London.

Næraa, T., Devereux, S., Frayne, B. and Harnett, P. (1993) Coping with drought in Namibia: informal social security systems in Caprivi and Erongo, 1992. *NISER Research Report.* **12,** Multidisciplinary Research Centre, University of Namibia, Windhoek.

National Planning Commission (NPC) (1992) *Population and housing census, preliminary report.* NPC, Central Statistics Office, Windhoek, Namibia.

Norbury, G.L., Norbury, D.C. and Oliver, A.J. (1994) Facultative behaviour in unpredictable environments: mobility of red kangaroos in arid Western Australia. *J. Animal Ecol.* **63,** 410-418.

Nordenstam, B. (1974) The flora of the Brandberg. *Dinteria.* **2,** 3-67.

Olsvig-Whittaker, L., Shachak, M. and Yair, A. (1983) Vegetation patterns related to environmental factors in a Negev Desert watershed. *Vegetatio.* **54,** 153-165.

Perkins, J.J. & Thomas, D.S.G. (1993) Spreading deserts or spatially confined environmental impacts? Land degradation and cattle ranching in the Kalahari desert of Botswana. *Land Degrad. Rehab.* **4,** 179-194.

Prentice, I.C. & Werger, M.J.A. (1985) Clump spacing in a desert dwarf shrub community. *Vegetatio.* **63,** 133-139.

Quan, J., Barton, D. and Conroy, C. (1994) A preliminary assessment of the economic impact of desertification in Namibia. *Research Discussion Paper.* **3,** Directorate of Environmental Affairs, Ministry of Environment, Windhoek, Namibia.

Rohde, R.F. (1997a) Looking into the past: interpretations of vegetation change in Western Namibia based on matched photography. *Dinteria.* **25,** 121-149.

Rohde, R. (1997b) *Nature, cattle thieves and various other midnight robbers: images of people, place and landscape in Damaraland, Namibia.* Unpublished PhD thesis, University of Edinburgh.

Rudner, J. (1979) The use of stone artefacts and pottery among the Khoisan peoples in historic and protohistoric times. *S. Afr. Archaeol. Bull.* **34,** 3-17.

Sandelowsky, B. (1977) Mirabib: anarchaeological study in the Namib. *Madoqua.* **10(4),** 221-283.

Sandelowsky, B., van Rooyen, J.H. and Vogel, J.C. 1979 Early evidence for herders in the Namib. S. *Afr. Archaeol. Bull.* **34,** 50-51.

Sandford, S. (1983) *Management of pastoral development in the third world.* John Wiley and Sons, Chichester.

Scoones, I. (1995) *Living with uncertainty: new directions in pastoral development in Africa.* IIED, London.

Scoones, I. (1996) Range management science and policy: politics, polemics and pasture in southern Africa. *The lie of the land: challenging received wisdom on the African environment* (ed. by M. Leach and R. Mearns), pp. 34-53. The International African Institute, James Currey and Heinemann, London, Oxford and Portsmouth.

Simpson, E.H. (1949) Measurement of diversity. *Nature.* **63,** 688.

Solbrig, O. (1991) Savanna modelling for global change. *Biol. Intern. (Special Issue).* **24,** 1-47.

Sullivan, S. (1993) *The importance of indigenous woody species to rural subsistence in Namibia, Africa.* Unpublished BSc dissertation, Dept. Anthropology, University College London.

Sullivan, S., Konstant, T.L. and Cunningham, A.B. (1995) The impact of utilization of palm products on the population structure of the Vegetable Ivory Palm (Hyphaene petersiana, Arecaceae) in north-central Namibia. *Econ. Bot.* **49(4),** 357-370.

Sullivan, S. (1996a) The 'communalization' of former commercial farmland: perspectives from Damaraland and implications for land reform. *SSD Research Report.* **25,** Social Sciences Division, Multi-discipliniary Research Centre, University of Namibia, Windhoek.

Sullivan, S. (1996b) Towards a non-equilibrium ecology: perspectives from an arid land. *J. Biogeog.* **23,** 1-5.

Sullivan, S. & Konstant, T.L. (1997) Human impacts on woody vegetation, and multivariate analysis: a case study based on data from Khowarib settlement, Kunene Region. *Dinteria.* **25,** 87-120.

Sullivan, S. (forthcoming for 1998) *People, plants and practice in drylands: socio-political and ecological dimensions of resource-use by Damara farmers in north-west Namibia.* Unpublished PhD thesis, Dept. Anthropology, University College London.

Swift, J. (1996) Desertification: narratives, winners and losers. *The lie of the land: challenging received wisdom on the African environment* (ed. by M Leach and R Mearns), pp. 73-90 The International African Institute, James Currey and Heinemann, London, Oxford and Portsmouth.

Ter Braak, C.J.F. (1986) Canonical correspondence analysis: a new eigenvector technique for multivariate direct gradient analysis. *Ecol.* **67(5),** 1167-1179.

Ter Braak, C.J.F. (1987a) Partial correspondence analysis. *Classification and related methods of data analysis* (ed. by H.H Beck), pp. 557-564, Proceedings of IFCS Conference, June 1987, Amsterdam.

Ter Braak, C.J.F. (1987b) *CANOCO: a FORTRAN progam for canonical community ordination by partial, detrended, canonical correspondence analysis, principal components analysis and redundancy analysis (version 2.1).* Institute of Applied Computer Science, Statistics Department, Wageningen.

Ter Braak, C.J.F. (1988) CANOCO: an extension of DECORANA to analyze species-environment relationships. *Vegetatio.* **75,** 159-160.

Ter Braak, C.J.F. (1990) *Update notes: CANOCO version 3.1.* Agricultural Mathematics Group, Wageningen.

Ter Braak, C.J.F. (1991) *CANOCO 3.12.*

Turner, S. (1996) Conservancies in Namibia: a model for successful common property resource management? *SSD Discussion Paper.* **13,** Social Sciences Division, Multi-disciplinary Research Centre, University of Namibia, Windhoek.

Van Warmelo, N.J. (1962) Notes on the Kaokoveld (South West Africa and its people). *Ethnological Publications.* **26,** Dept. of Bantu Administration, Pretoria.

Viereck, A. (1967) The Damaraland culture: a 'Later Sone Age' horizon in SWA. *J. of the SWA Sci. Soc.* **21,** 13-31.

Viljoen, P.J. and Bothma, J. du P. (1990) The influence of desert-dwelling elephants on vegetation in the northern Namib Desert, SWA/Namibia. *J. Arid Environm.* **18,** 85-96.

Wadley, L. (1979) Big elephant shelter and its role in the Holocene prehistory of central SWA. *Cimbebasia* B. **3(1),** 1-76.

Walter, H. (1986) The Namib Desert. *Ecosystems of the world: 12b hot deserts and arid shrublands* (ed. by M Evenari, I Noy-Meir and Goodall, D.W). Elsevier, Amsterdam.

Warren, A. and Agnew, C. (1988) An assessment of desertification and land degradation in arid and semi-arid areas. *Drylands Paper.* **2,** Drylands Programme, IIED, London.

Werger, M.J.A. (1978a) Biogeographical division of southern Africa. *Biogeography and ecology of southern Africa. Monogr. Biol. 31* (ed. by M.J.A Werger), pp. 145-170, Junk, the Hague.

Werger, M.J.A. (1978b) The Karoo-Namib domain *Biogeography and ecology of southern Africa. Monogr. Biol. 31* (ed. by M.J.A Werger), pp. 231-299, Junk, the Hague.

West, O. (1968) The possibility of using irrigated pastures for the rehabilitation of denuded grazing areas in the Rhodesian lowveld. *Proc. Grassld Soc. sth. Afr.* **3,** 95-99.

Westoby, M., Walker, B. and Noy-Meir, I. (1989) Opportunistic management for rangelands not at equilibrium. *J. Range Mgmt.* **42,** 266-274.

White, F. (1983) *The vegetation of Africa. A descriptive memoir to accompany the UNESCO/AETFAT/UNSO vegetation map of Africa.* UNESCO, Paris.

Wiens, J. (1984) On understanding a nonequilibrium world: myth and reality in community patterns and processes. *Ecological communities: conceptual issues and the evidence* (ed. by D.R Strong, D Simberloff, L.G Abele and A.B Thistle), pp. 439-457, Princeton University Press, Princeton.

Caption titles: Tables

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)).

Table 2. Woody vegetation samples and plant individuals by site characteristic.

Table 3. Monte Carlo permutation tests of significance ($p = 0.01$) for environmental variables for the reduced dataset of plains and riverine samples following forward selection and partialling out of remaining variables as covariables.

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

Table 5. F-test statistics and significance levels for general factorial GLM analysis of the effect of distance from settlement on mean basal area (cm^2) with samples grouped by topographic category and substrate.

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.

Caption titles: Figures

Fig. 1. Map of Namibia showing the location of the three study settlements of Sesfontein, Khowarib and Warmquelle.

Fig. 2. Total livestock population for the former Damaraland homeland 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 Otjohorongo Reserve).

Fig. 3. Selection of tree individuals for measurement using a 'zig-zag' transect (following Leithead, 1979: 29).

Fig. 4. Location of transect sites for the woody vegetation dataset. Transect numbers correspond with those in Table 2 which summarises site characteristics.

Fig. 5. 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, O = mountain on calcrete, ● = mountain on dolomite and ∗ = mountain on schist.

Fig. 6. 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.

Fig. 7. The relationship between a. branch removal and b. browsing and distance from settlement for plains, riverine and mountain topographic categories. The scales of use run

from 1 to 6 for lopping and from 1 to 4 for browsing and are calculated here as averages for each topographic-by-distance category.

Fig. 8. Error bars showing 95% confidence intervals for N2 diversity values for topographic category by distance from settlement.

Fig. 9. Error bars showing 95% confidence intervals for the mean distance between plant individuals (m) for substrate by distance from settlement. The legend is as for Fig. 8.

Fig. 10. Error bars showing 95% confidence intervals for basal area (cm^2) for topographic category by distance from settlement.

Fig. 11. Error bars showing 95% confidence intervals for *Acacia tortilis* (Forsskal) Hayne subsp. *Heteracantha* (Burchell) Brenan by distance from settlement for a. basal diameter (cm) and b. height (m).

Fig. 12. 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).

Fig. 13. A diagrammatic conceptual framework for evaluating ecological hierarchy determinants at various spatial and temporal response scales. The appropriate level of biological analysis is indicated on the diagonal (after Solbrig, 1991, Fig. 1).

Table 1.

language group	1947/48	1991
Damara	374	±480
Herero	262	±200
‘other’	149	±126
total	785	806

Table 2.

topographic category	***substrate***	***distance from settlement (km)***	***settlement***	***no. of transects***	***no. of plant Individuals***
plains	alluvial silts	0	Sesfontein	4	160
			Khowarib	4	115
		0.5	Sesfontein	3	120
			Khowarib	5	160
		5	Sesfontein	4	160
			Khowarib	3	110
		10	Sesfontein/Warmquelle	3	115
	sandy loams	0	Warmquelle	3)	120
		0.5	Warmquelle	3	120
		8	Sesfontein/Warmquelle	3	115
			Warmquelle/Khowarib	2	60
riverine	alluvial silts	0.5	Khowarib	3	120
		3	Sesfontein	3	90
		5	Khowarib	4	120
		8	Sesfontein	3	120
mountain	calcrete	0	Sesfontein	3	120
		0.5	Sesfontein	3	120
		3	Sesfontein	3	120
		5	Sesfontein	3	120
	dolomite	0.5	Khowarib	4	150
		5	Khowarib	1	25
		8	Sesfontein	3	120
		20	Sesfontein/Warmquelle	3	120
	schist	0.5	Khowarib	2	60
			TOTAL:	**75**	**2760**

Table 3.

environmental variable	F	p	other variables partialled out F	p
topography	**9.83**	**0.01**	**9.79**	**0.01**
substrate	**13.59**	**0.01**	**9.79**	**0.01**
lopping	**3.81**	**0.01**	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			**1.99**	**0.01**
topography and substrate			**6.23**	**0.01**

Table 4.

	F	p
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	p
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.

Table 6.

	basal diameter	**height**
N	663	507
F	5.19	8.77
p	0.002	0.0001
df	3	3

Figure 1.

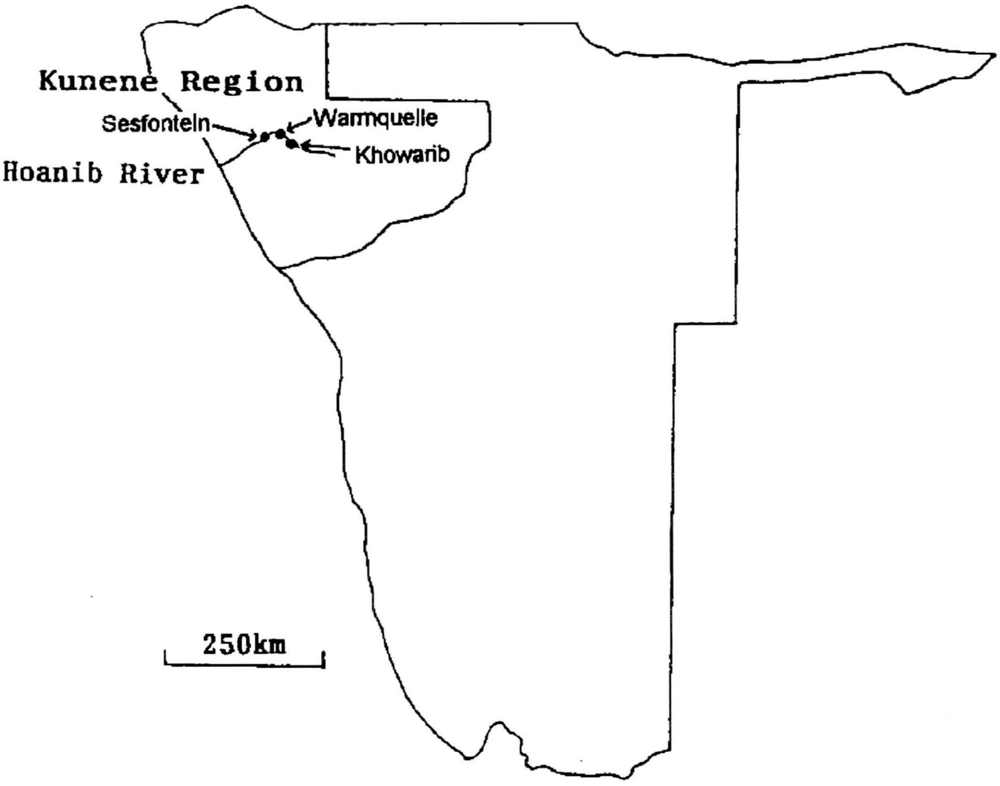
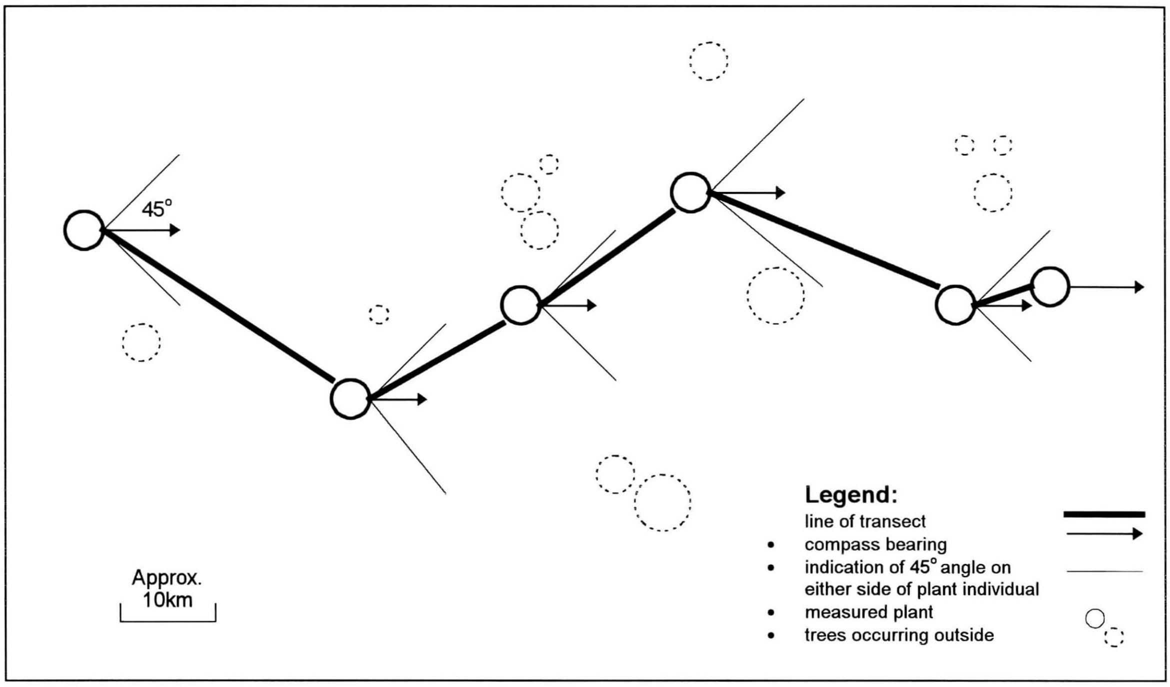
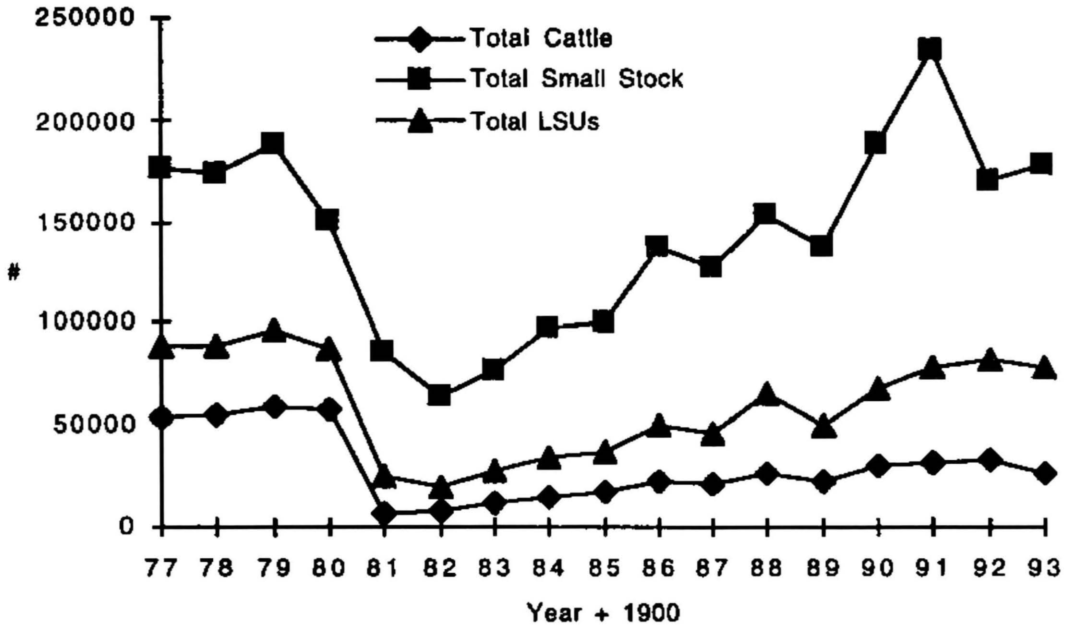
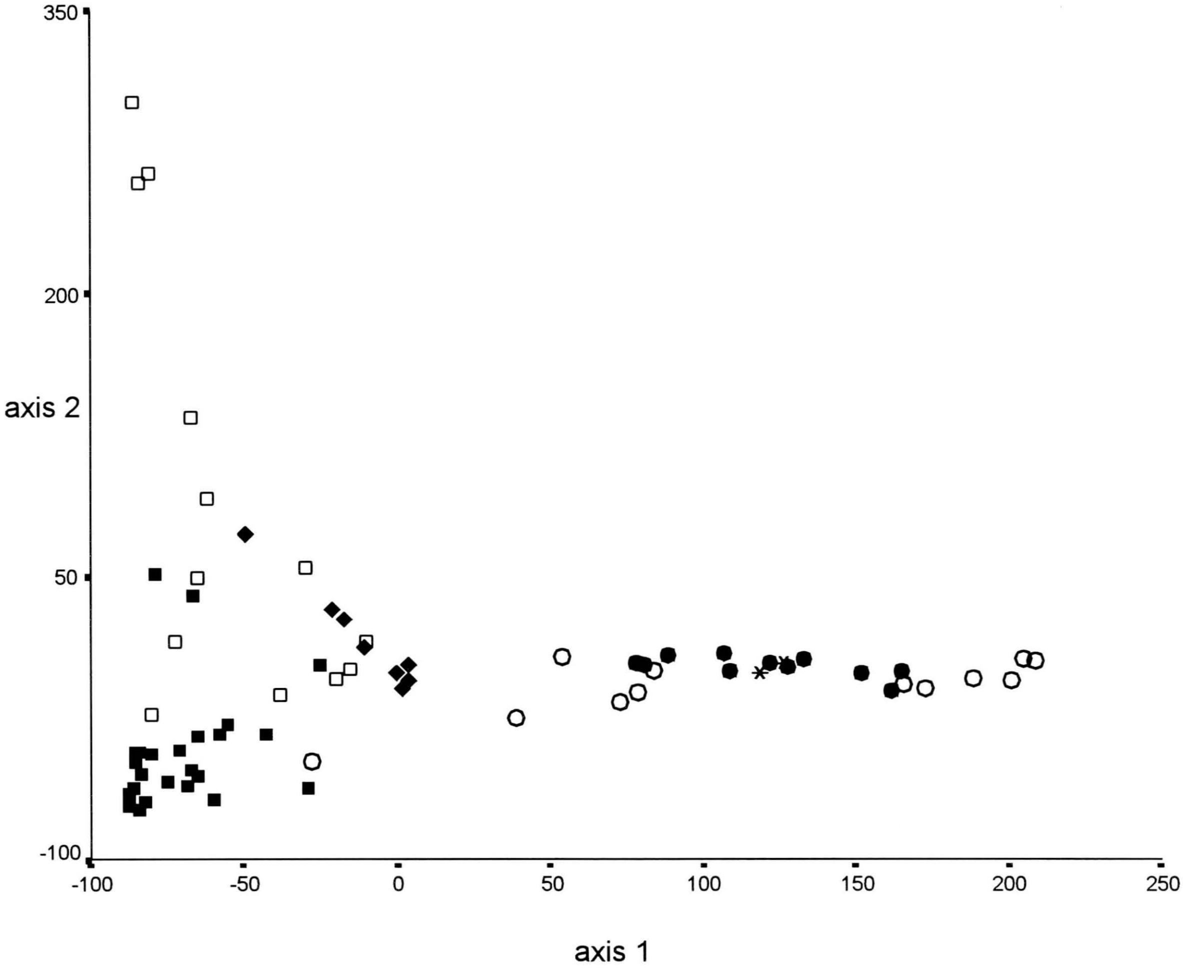
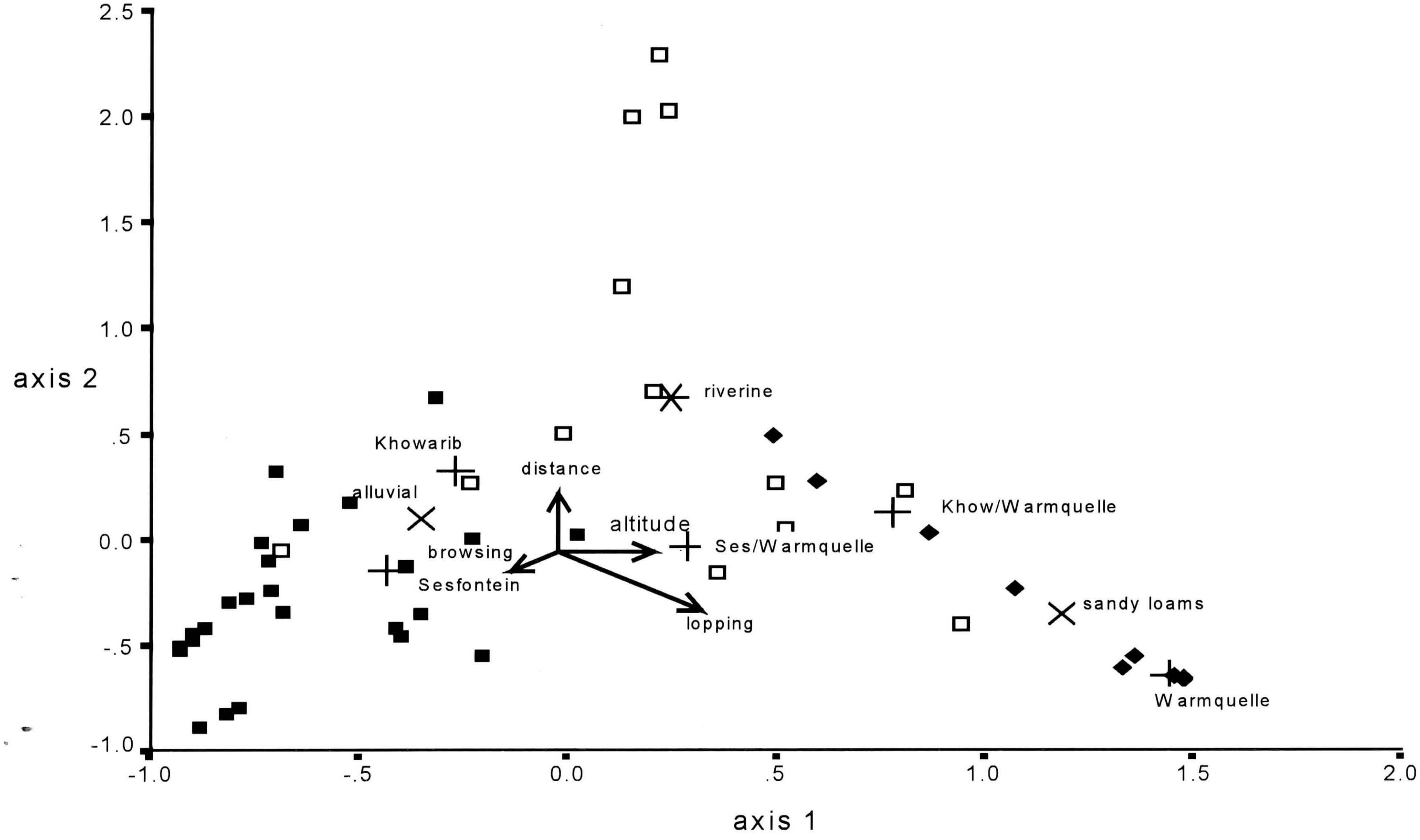

Kunene Region
Sesfonteln
Warmquelle
Khowarib
Hoanib River
250km

Figure 2.

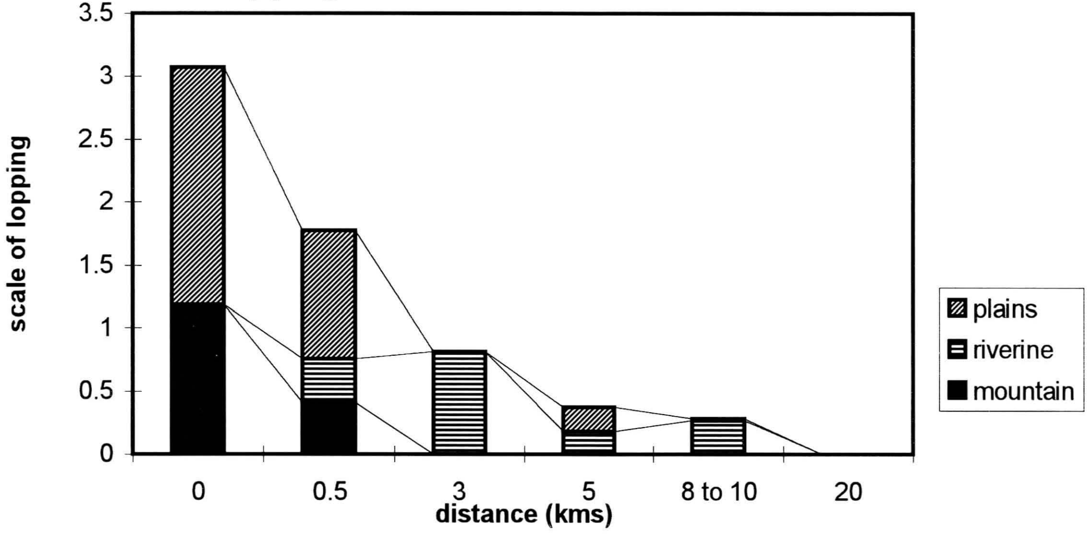

45°
Approx.
10km
Legend:
line of transect
compass bearing
indication of 45° angle on either side of plant individual
measured plant
trees occurring outside


250000
200000
150000
100000
50000
0
#
Total Cattle
Total Small Stock
Total LSUs
77
78
79
80
81
82
83
84
85
86
87
88
89
90
91
92
93
Year + 1900

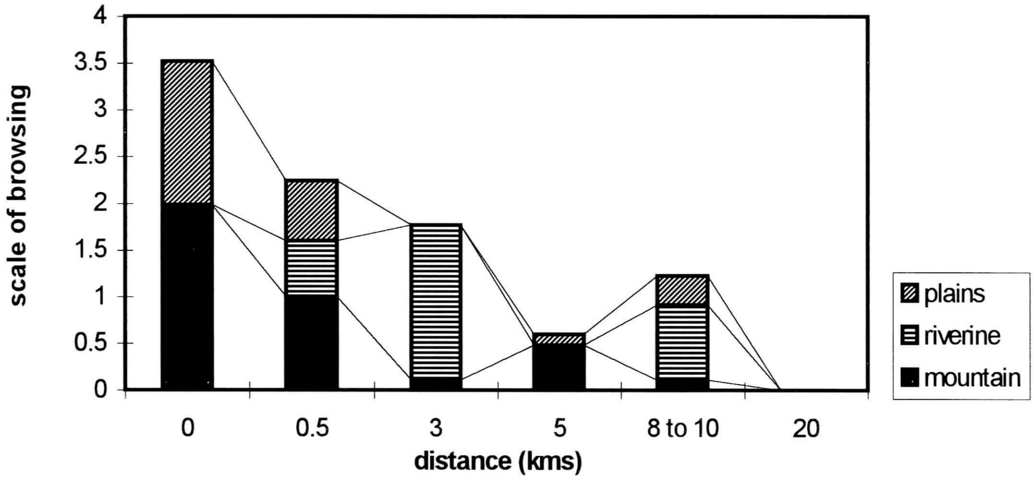

350
200
50
-100
axis 2
-100
-50
0
50
100
150
200
250
axis 1



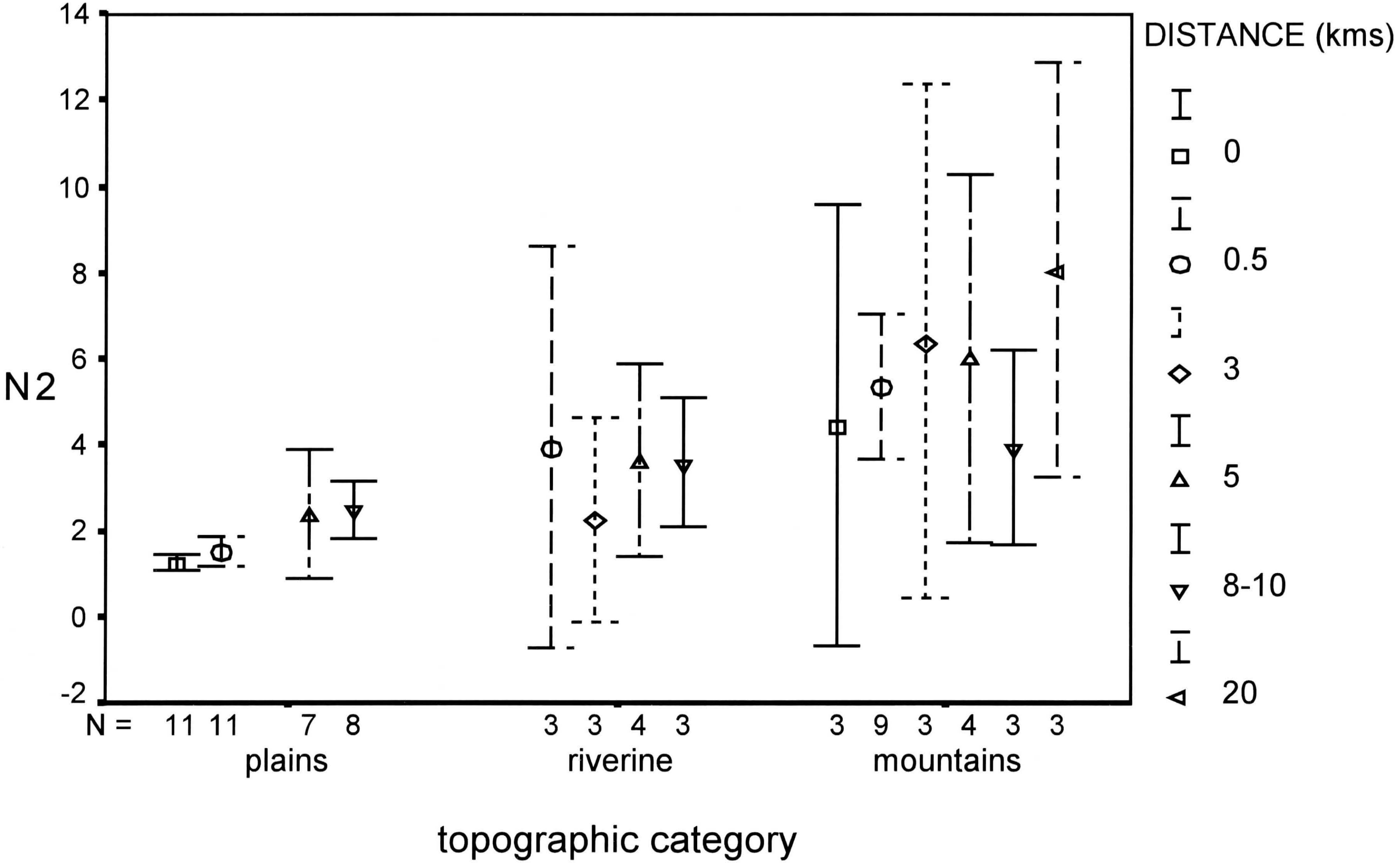
2.5
2.0
1.5
1.0
.5
0.0
-.5
-1.0
axis 2
-1.0
-.5
0.0
.5
1.0
1.5
2.0
axis 1
riverine
Khowarib
distance
alluvial
altitude
browsing
Sesfontein
Ses/Warmquelle
Khow/Warmquelle
lopping
sandy loams
Warmquelle

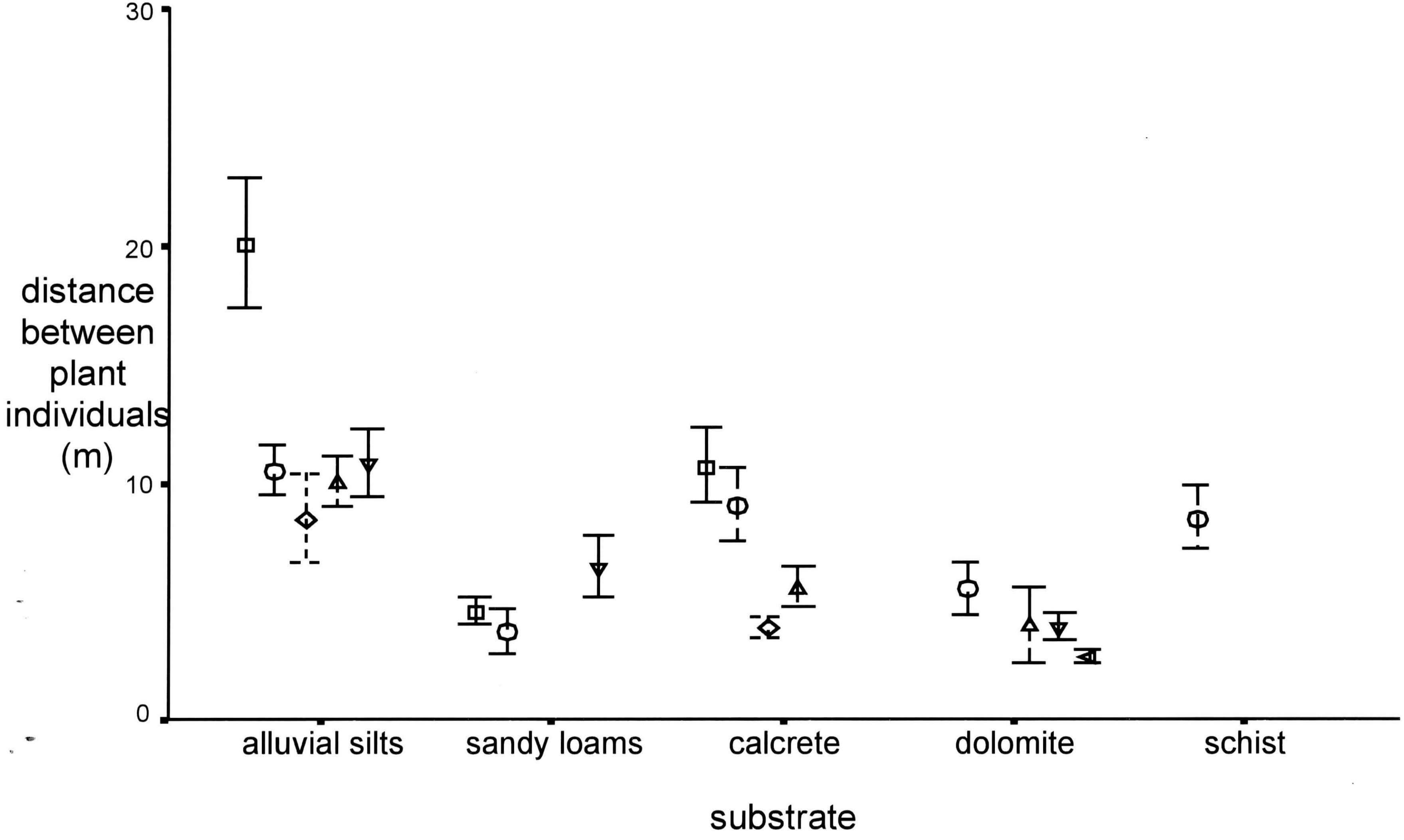


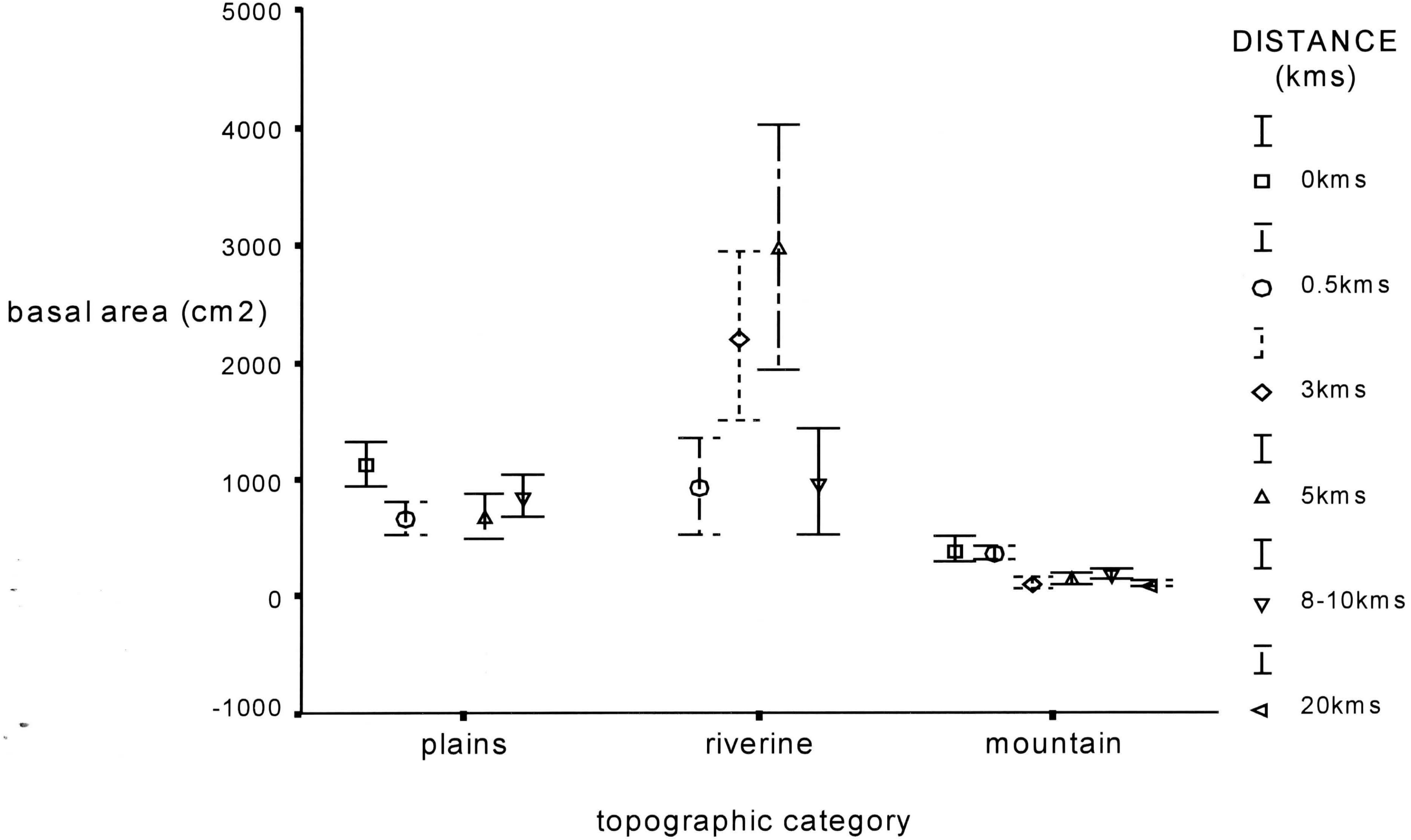
a. branch lopping and distance from settlement

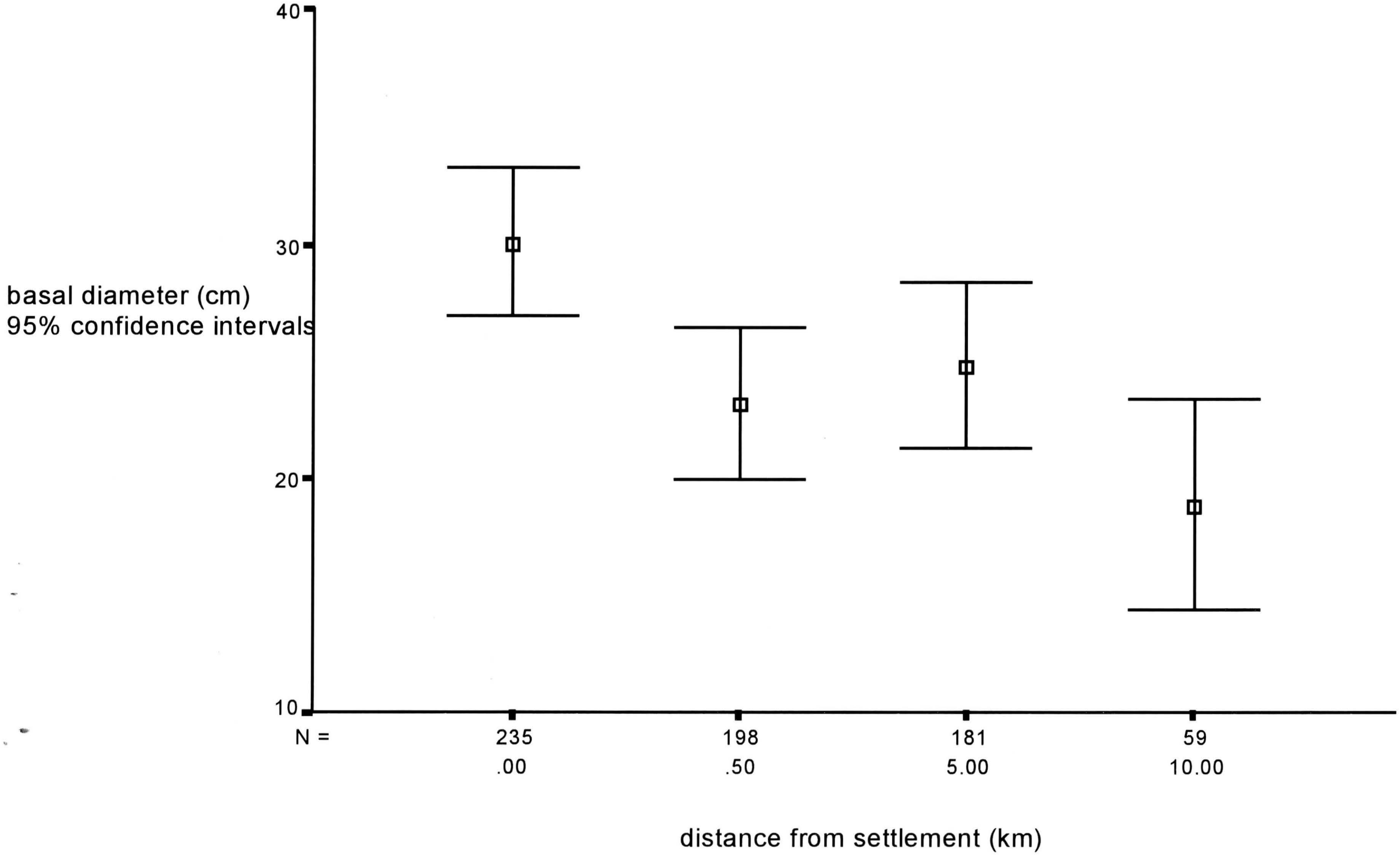


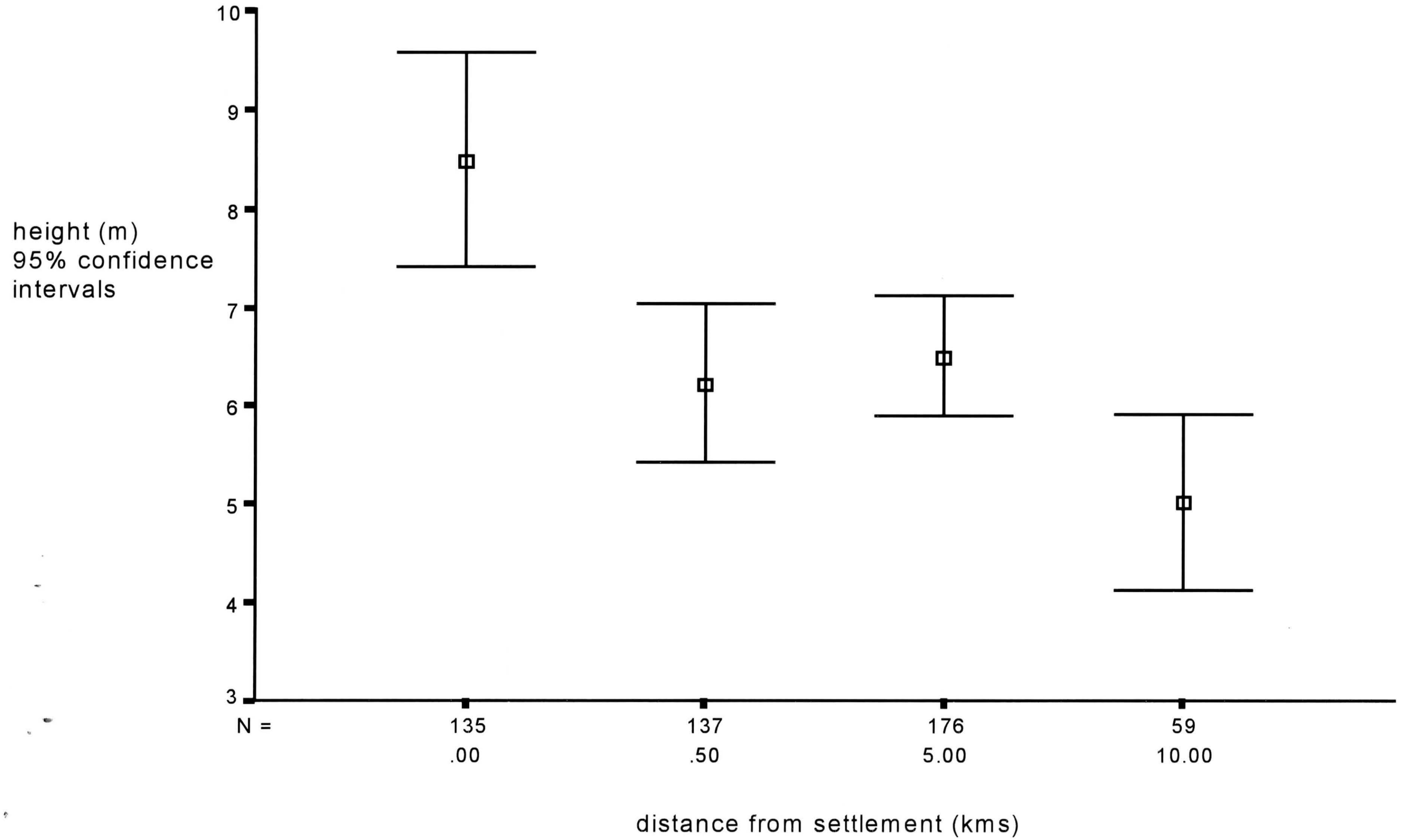
b. browsing and distance from settlement

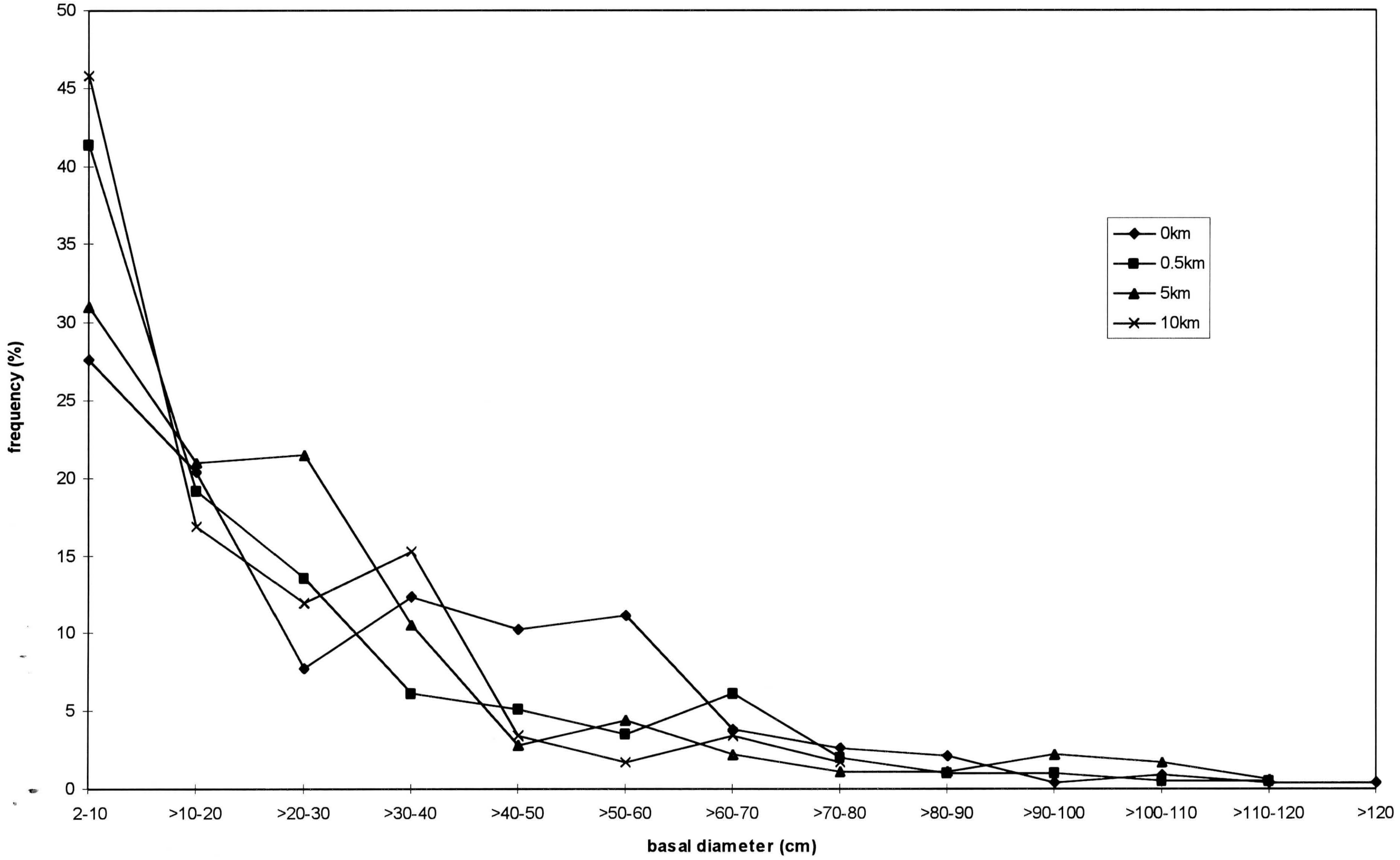

14
12
10
8
6
4
2
0
-2
N2
DISTANCE (kms)
0
0.5
3
5
8-10
20
N = 11 11 7 8 3 3 4 3 3 9 3 4 3 3
plains
riverine
mountains
topographic category


30
20
10
0
distance between plant individuals (m)
alluvial silts
sandy loams
calcrete
dolomite
schist
substrate

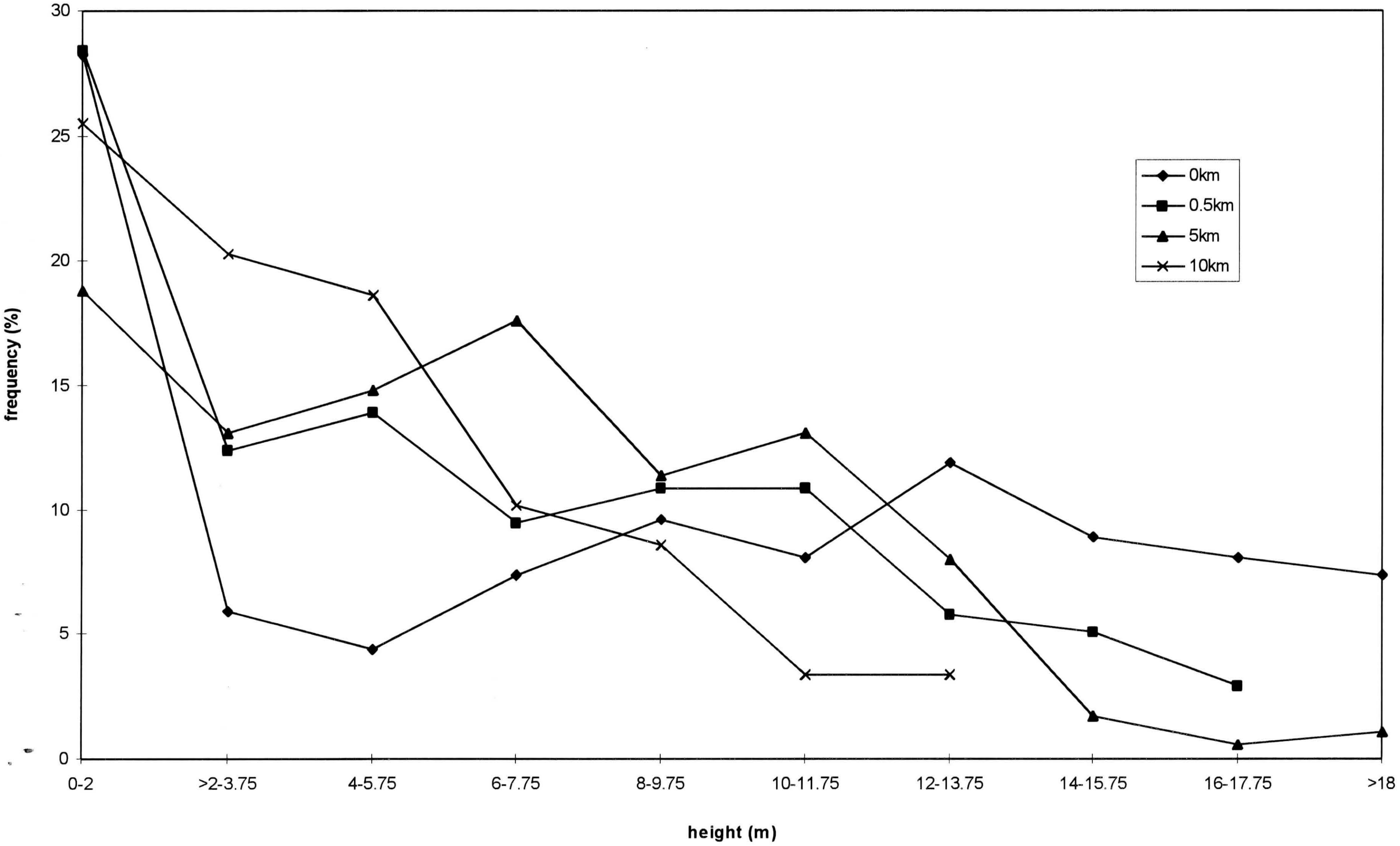

5000
4000
3000
2000
1000
0
-1000
basal area (cm2)
plains
riverine
mountain
topographic category
DISTANCE (kms)
0kms
0.5kms
3kms
5kms
8-10kms
20kms

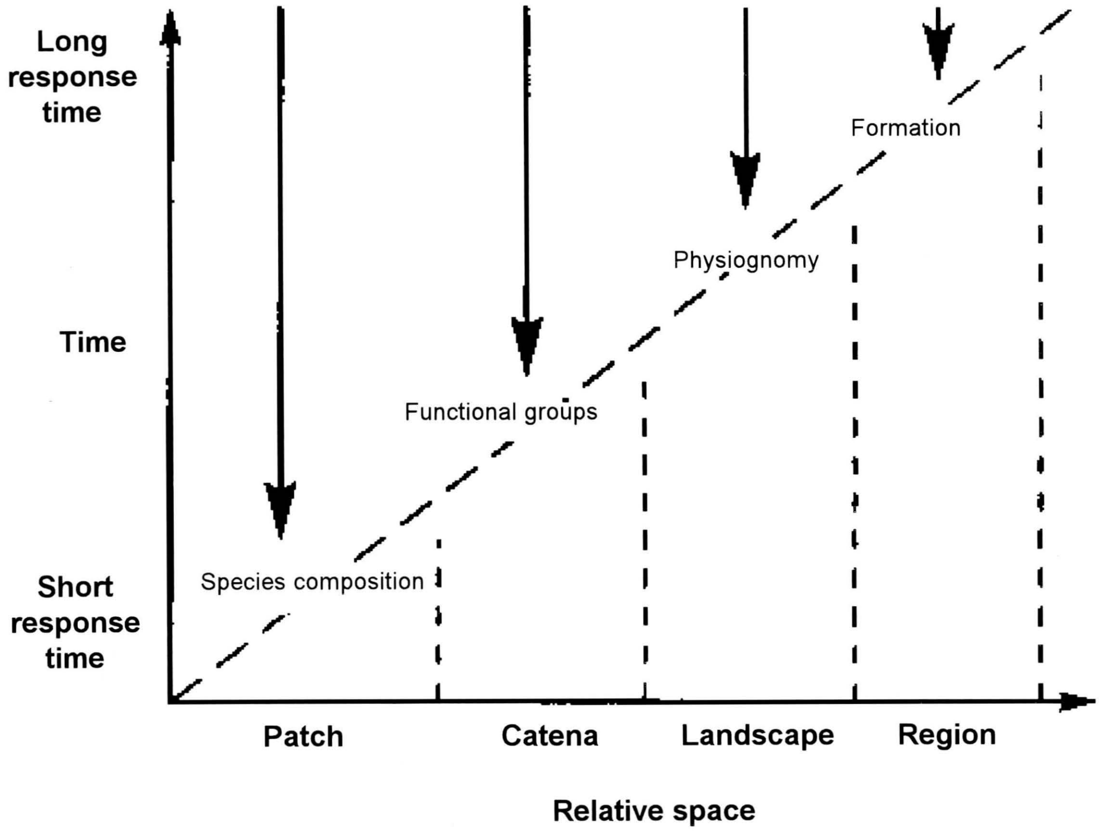

40
30
20
10
basal diameter (cm)
95% confidence intervals
N =
235
198
181
59
.00
.50
5.00
10.00
distance from settlement (km)


10
9
8
7
6
5
4
3
height (m)
95% confidence
intervals
N =
135
137
176
59
.00
.50
5.00
10.00
distance from settlement (kms)



frequency (%)
50
45
40
35
30
25
20
15
10
5
0
2-10
>10-20
>20-30
>30-40
>40-50
>50-60
>60-70
>70-80
>80-90
>90-100
>100-110
>110-120
>120
basal diameter (cm)
0km
0.5km
5km
10km


30
25
20
15
10
5
0
frequency (%)
0-2
>2-3.75
4-5.75
6-7.75
8-9.75
10-11.75
12-13.75
14-15.75
16-17.75
>18
height (m)
0km
0.5km
5km
10km


Long response time
Time
Short response time
Species composition
Functional groups
Physiognomy
Formation
Patch
Catena
Landscape
Region
Relative space