OCCASIONAL PAPER NO. 2

SUMMER DESERTIFICATION PROJECT 1994/1995 AN INVESTIGATION INTO THE BIOPHYSICAL ASPECTS AND SOCIO-ECONOMICS OF DESERTIFICATION IN NORTH-WESTERN NAMIBIA

January 1995

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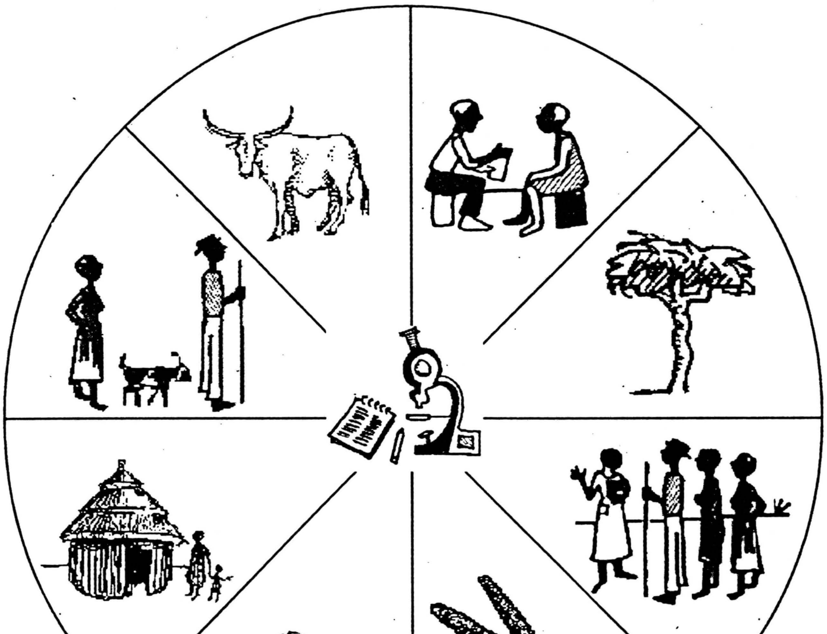
P. Jobst; E. Kakukuru; J.R. Kambatuku; D. Mouton; L. Netha; T.M. Nghitila; S.E. Shanyengana



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THE STUDY IN PERSPECTIVE
- GENERAL INTRODUCTION -

J.R. Kambatuku, K. Uariua-Kakujaha, and M.M. Abrams

THE HISTORY

The northwestern part of Namibia is widely considered to have been a focal point of human movements in the pre-historic era. The fascinating rock engravings found in both the Brandberg and the Twyfelfontein mountains are the basis for such an assessment. The artworks depict game and wild birds, suggesting that the craftsmen who produced them were not acquainted with livestock. They were either exclusively hunters or hunter-gatherers. It has been suggested that humans were attracted to Twyfelfontein by abundant game that would drink at a small spring at the base of the mountain. The general belief is that people, most certainly nomads, spent a lot of time in this area because the spring provided water year round and because the terrace above the spring provided an excellent hunting spot.

Although there are gaps in historical records concerning the transition from nomadic hunting and gathering to pastoralism, the written history of the area is rich (Kohler, 1959). The area has a long-standing history of agricultural development since the German colonial era. The Khoi-Khoi people from !Am-cib, known as Zwartboois, had to move constantly to find water and they eventually settled at Okombahe in 1870 after a short stay at !Gao-gob. It is reported that at the time, the Omaruru River near Okombahe was overgrown with thick bush harbouring an abundance of wild animals. The settling of Khoi-Khoi at Okombahe attracted the Damara people living in the Erongo mountains, who moved to seek refuge there from ill treatment by Hereros. They were joined by others from Brandberg and other mountains. The Omaruru River formed the boundary between Zwartboois and Damaras, both of whom grew gardens in the Omaruru River. At this time only three homesteads -- all Damaras -- kept a few goats.

A serious drought followed and all but a few Damaras returned to the mountains. After 1880, conflicts ensued between the Zwartboois and the Hereros in the Okombahe area. These Hereros refused to allow the return and resettling of Damaras at Okombahe until Chief Manasse Tjiseta relinquished the place for DM 800, after negotiations with the colonial administrator Major Leutwein.

Nevertheless, raids continued and when a sub-chief of Tjiseta, Daniel Kariko, was accused of a raid on Damaras, he fled with his followers to settle at Omihana, Otujapi and !Gorixas. When the proposal was made in 1918 for the establishment of the Otjihorongo Reserve, Kariko was already living there with about 230 followers. The reserve was officially proclaimed in 1925.

The Okombahe area is reported to have suffered famine in 1898, with people eating the meat of cattle that died from drought, and the reserve had to be extended to accommodate all Damara people. This reserve was finally given to the Damara people as a sign of appreciation for their refusal to join the 1904 Herero rebellion against the Germans, though it was administered from the Otjihorongo Reserve during the Union era until 1946. Numerous extensions were added to this reserve to avert famine and to accommodate people evicted from elsewhere. Portions of the farm Sore-Soris, for example, were added to accommodate people evicted from Aukeigas (now the Daan Viljoen Resort).

The Damara people, who were hunter-gatherers, followed the example of Hereros and became cattle and goat farmers when they settled at Okombahe. By 1913 their stock in the reserve already numbered 2,800 head of cattle and 2,000 head of small stock.

Dairy schemes were introduced in the Otjihorongo Reserve in 1942 and in 1947 in Okombahe. These schemes delivered weekly supplies of milk to the Omaruru Creamery, though this schedule was affected by seasonal variations. Under communal tenure the reserve was a thriving milk-producing area, boasting 78 dairies and 130 milk-separating centres in 1950 (Lau and Reiner 1993).

But the pioneering agricultural activity of the Okombahe immigrants, both Damara and Zwartboois, was cultivation in the Omaruru River. Yields fluctuated with drought and good (wet) years. The 1951-52 season produced nothing, while the following year yielded the highest-ever recorded production. All cultivation activities at Okombahe came to a standstill in 1956 due to a water shortage.

The Nationalist Party government of South Africa continued to discharge its indigent whites into Namibia until 1954 (Lau and Reiner 1993) and many of these people took land and fenced it off for private use. The farms in this study area, like Onverwag, Twyfelfontein and Losberg, were established to provide land for this group, with the government often providing subsidies for erecting fences.

Commonly referred to as *Okaoko kozongombo* ("the Kaoko of goats"), Otjihorongo always had high numbers of goats, though livestock numbers fluctuated with rainfall. Poor grazing in 1955-56 caused a major drop in small-stock numbers, from 61,000 to 50,700 in one year. This led to the imposition of stock limits of 300 small units and 100 large stock units per stock owner in subsequent years.

In 1957, there were 2,240 people (990 adult males and 1,250 women) living in the Otjihorongo Reserve. Only 990 of them were stock owners. However, these numbers may be misleading unless one notes that 830 of these stock owners were adult males. It is interesting to note that the original number of inhabitants increased ninefold within 39 years of the establishment of the reserve.

During the early 1960s, the farms that were given to whites were bought by the government and leased out for emergency grazing on a monthly basis. These farms were transformed into the communal land that comprised Damaraland following the recommendations of the Odendaal Commission of 1962-63 (Namibian National Archives, 1995). The overwhelming willingness of the then-Directorate of Land and Farmers Assistance to relinquish these farms to the Chief Bantu Commissioner following the commission's report, attests to the unfitness of this area for sedentary farming practices.

Returning to the present, farmers of this area are experiencing difficulties with an ever-deteriorating rangeland that makes livestock farming only marginally productive. In addition to the natural variations in rangeland quality, diverse management systems are applied in the area. This is one of the few, if not the only, areas in Namibia where nomadic pastoralism is still practised. The OvaHimba people of Kaokoland still follow the seasons, moving their herds in response to water and fodder availability (Paskin, 1990). Nonetheless, this custom is slowly being halted by provision of uninterrupted water supplies from boreholes; thus nomadic pastoralism is giving way to sedentary farming (Paskin, 1990).

Efforts are now geared towards helping people find alternative means of deriving a living from this harsh environment. A more recent addition to land-use practices in the area is tourism. Rest camps and other facilities aimed at the tourist market are mushrooming.

In spite of these climatic, ecological, social and economic constraints, the area is, like the entire country, burdened by a rapidly increasing population. The growing population demands and extracts more from the land and natural resources, as people's expectations grow along with their swelling numbers. This has reached serious proportions and vast tracks of land have either been deforested, bush-encroached, eroded or polluted by salinisation (Seely et al., 1994). These are processes that ultimately manifest themselves in land degradation and loss of productivity, a situation commonly referred to as desertification (Darkoh, 1993). With the memory of the catastrophic famine of Sahelian Africa still fresh , such a shift in natural resource use has sparked serious concern in Namibia which culminated in the National Workshop on Desertification in Windoek in July 1994.

Though participants at the workshop agreed on major definitions and identified problems, causes and key players, no definite accounting could be given of whether or not such degradation exists in Namibia. Contrasting opinions on this question are not unique to this country (de Queiroz, 1993), but are, perhaps, more pressing due to the normal extreme dryness of the country.

THE LINK

Recognising this handicap -- the lack of basic baseline information in addressing such a complex issue as desertification -- the workshop produced a number of goals and objectives for the Namibia Programme to Combat Desertification (NAPCOD). Prominent amongst the eight main objectives were Numbers 4 and 5, which call for the "elaboration and implementation of an appropriate interdisciplinary research programme" and "provision of appropriate education and training according to needs at all levels" (Wolters, 1994), respectively. These objectives are central to the accomplishment of NAPCOD's overall goal, since it is only through research that problems, needs and capacities can be identified; while training will enable resource users, planners and policy makers to put resources to better use.

The present study fits neatly into this framework because its objective was to gather vital information on desertification while providing research training, albeit on a small scale, to Namibian university students. An interdisciplinary approach has been fully incorporated into this project as reflected by the individual research topics that constitute it.

THE STUDY

The Summer Desertification Project (SDP) was conducted during December 1994 and January 1995 with a group of Namibian university students working with the Desert Research Foundation of Namibia (DRFN) staff at Gobabeb. The objective was to investigate the occurrence and severity of desertification in northwestern Namibia. The SDP was funded by the Swedish International Development Authority (SIDA).

Desertification is a degradation of the biophysical resources of an area; however, its causes are not all directly related to the biophysical components of a system. The socio-economic framework in which resources are used often has as much or more of an influence on sustainable resource use than the basic quantity and quality of those resources. The SDP was, therefore, designed to sample two types of data: biophysical and socio-economic. Limitations on time, resources and access to people, dictated that the project choose a small set of topics within these two general areas..

The biophysical topics were chosen to provide a suite of data on several ecosystem components and trophic levels. They included studies on soils, plant communities, and soil fauna, some of the last two of which were used as biological indicators. In addition, data from all these topics were used to test a rangeland degradation model that has been developed in South Africa. Three socio-economic subjects were chosen to investigate current and alternative land uses, as well as the history and policies that influence land-use choices.

The use of a suite of studies, interrelated to one degree or another, allowed the SDP to build an impressive data set on a series of sites. This type of data collection takes an ecosystem approach to the problem, rather than depending on one particular component. This proved to be a good approach for two reasons. First, there were essentially no other data on this area from which the students could build testable hypotheses. Second, desertification is a complex problem, not easily addressed by focusing on single parameters. Finally, this was a useful learning tool for introducing the students to a holistic view of desertification.

Unfortunately, the SDP results were limited by the short time available for the studies and the time of year in which they were conducted. Because of these constraints, the data have their limitations and are more useful as a model for future studies than a complete set of baseline data for the area. Nevertheless, the students sampled the biophysical and socio-economic components of the area and examined a volume of desertification literature provided by the DRFN staff from the library at Gobabeb. One student set up and conducted a laboratory experiment and several were involved with laboratory analyses of soils at the laboratory of the Ministry of Agriculture, Water, and Rural Development. Further analyses of plants and soil biota were conducted in the laboratories at Gobabeb. Most of the group also worked with archival information provided by the Namibian National Archives in Windhoek. The final product is a synthesis of all this data and information in a coherent and readily understandable overview of desertification in northwestern Namibia.

The report of the SDP is presented in this volume as a series of chapters, one for each student's study. Each chapter is designed to stand alone as a research paper, with an introduction to the specific topic, the methodology used, the results and a discussion of those results. Because the topics are interrelated, some of this material reappears in almost all the papers. This redundancy was unavoidable if each student was to be given the opportunity to complete a research project from hypothesis development to report preparation.

This report has deficiencies and should not be expected to provide definitive answers to the many pressing questions about desertification in Namibia. However, it does highlight the complex and multi-disciplinary nature of desertification. We hope that it will prove useful in setting forth guidelines for future desertification research. Finally, this type of research should.form the basis from which awareness of the complex nature of desertification may be generated amongst resource users and planners in Namibia as whole.

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SAMPLING METHODS

At each site a 2,500 m^2 area was measured within which four 1 m^2 quadrats were randomly sampled to a depth of 5 cm. A shallow soil pit was dug at each site (except Sites 4 and 8) to sample the surface and subsurface horizons. At the garden sites, only surface samples were collected.

ANALYSIS

Field analysis:

At each quadrat, the soil temperatures at 5 cm, using a field mercury thermometer, and infiltration rates, using a single ring infiltrometer, were measured. The soils were field textured and soil colour determined, using a Munsell soil colour chart. Visual observations were used to assess the type and extent of erosion at each site.

Laboratory Analysis:

Soil samples were sieved through a 2 mm sieve and the percent coarse fragments were calculated gravimetrically. The sieved soils were then analyzed for $NaHCO_3$-extractable phosphorus (P) (Olsen and Sommers, 1982), NH_4OAc-exchangeable cations by atomic absorption spectrometry, pH in a 1:2:5 soil:water solution and electrical conductivity (EC) in a 1:1.5 soil:water solution. In addition, particle size distribution was measured for the surface soils from sites 1-8, using the sedimentation and hydrometer method.

The effective cation exchange capacity (ECEC) was calculated as the sum of the exchangeable cations. The exchangeable sodium percentage (ESP) was calculated as the ratio of exchangeable Na to exchangeable Na, Ca and Mg (Singer and Munns, 1987). All methods used were from the Handbook of Standard Soil Testing Methods (Non-Affiliated Soil Analysis Working Committee, 1990).

Statistical Analysis:

The mean of the parameters for the surface samples at sites 1-8 were determined and compared using an ANOVA and Fisher's LSD test. Regression analyses were done for all parameters to assess the relationship between the parameters and the distance from the borehole.

RESULTS

PIOSPHERE

Most of the measured parameters (ECEC, P, EC and pH) showed higher values in the immediate vicinity of the borehole (Figs. 1-3). However, the pattern across the piosphere varied by parameter and only ECEC was linearly correlated with distance from the borehole ($r=0.95$; $P>0.05$) (Fig. 2). In contrast, ESP was lowest at the borehole (Fig. 2). The pH at the water point was neutral, in contrast to the slightly acidic sites further away (Fig.1). No significant differences in infiltration rates could be observed. This was at least partially due to the high variability of infiltration within each site.

GRAZING SITES

Site 8 showed significantly higher values ($P>0.05$) for EC and P (Figs. 4 and 5), than those at the other 3 sites. However, P values were higher at the less heavily grazed sites (Sites 5 and 8) for both the more sandy and silty soils (Fig. 4). In contrast to the ECEC (Fig. 6), ESP values (Fig. 7) were much higher at the sandy sites, but no significant differences existed between grazing pressures within the same textural class. The pH at all sites were basic and no significant differences existed between grazing intensities. Significant differences ($P>0.05$) in pH existed between sandy and silty loam sites (Table 1).

SOIL CHARACTERISTICS UNDER DIFFERENT GRAZING REGIMES IN NORTHWESTERN NAMIBIA

D.P. Mouton

ABSTRACT

Whether or not rangeland degradation has occurred is still a very controversial issue in arid and semi-arid environments. This is mainly because (1) there is no standard definition of degradation, and (2) no clearly defined biological and physical indicators exist by which degradation can be measured and defined across all systems.

This research reports on soil characteristics from several sites in northwestern Namibia, covering a range of grazing intensities. These samples were analyzed for their available nutrient levels which, together with water constraints, are the most important limitations for plant growth in arid environments.

This study on soils suggests that it is feasible to use soil characteristics as a parameter for determining the extent of environmental degradation in semi-arid and arid rangeland ecosystems. In particular, there is some evidence that a correlation exists between grazing intensity and soil quality.

INTRODUCTION

Apart from climate, the soil is the most important factor in any type of natural resource based land use. Productive soils should be able to produce specific plants under a specified system of management (Foth and Turk, 1972). This suggests that productive soils should be fertile and thus capable of providing all essential elements for plant growth in the proper amounts. These essential elements are water, air and nutrients.

In addition to climatic influences, soil quality and productivity can be directly affected by humans (Day and Ludecke, 1993). This can either be positive, through a regulated supply of plant nutrients, or negative. Negative impacts occur when there is a struggle to use land with climatic limitations; then the pressure on the land, and particularly soils, is continuously increased (Day and Ludecke, 1993; Lundgren and Taylor, 1993). The resulting drop in soil productivity can often lead to further mismanagement and overuse.

In livestock farming areas, overstocking is often the worst resource management problem, resulting in overgrazing, trampling and other related problems (Perkins and Thomas, 1993; Lundgren and Taylor, 1993). Not only is the vegetative cover removed, but a loss of topsoil and its many essential nutrients may also occur through erosion (Henning and Kellner, 1994). Although the role of humans in rangeland degradation cannot be stressed enough, Whitlow and Campbell (1990) and Schlesinger et al. (1990) believe that this deterioration of the soil's physical and chemical properties is often exacerbated by other physical factors like episodic rain and windstorms as well as extreme climatic variations. This soil deterioration ultimately results in a biologically degraded and less productive environment (Schlesinger et al. 1990; Lundgren and Taylor, 1993; Michuna and Lauenroth, 1993).

The study area for this project is the dry, arid communal area of former Damaraland in northwestern Namibia. This area is not only faced with climatic and natural resource limitations, but also extreme climatic variation and episodic rain and windstorms (Jacobson et al. in press). Annual rainfall in the area varies between 100 mm and 150 mm and is not only variable, but also unreliable (Fiona and Wolfgang, 1990). The vegetation of the studied area consists mainly of perennial and annual grasses, Acacia spp, and *Colophospermum mopane* (mopane) (see Jobst, this volume). People rely primarily on livestock farming to make a living. People and livestock numbers have increased since the establishment of this communal land in the 1960's (Rhode, 1994). This has increased demands on the land. It has also become increasingly difficult to control the movement of people and animals into and within the area (see Kakukuru, this vol.). This increased pressure on natural resources, particularly soils and vegetation, can lead to the depletion of the limited resources and ultimately can result in land degradation and desertification (Schlesinger et al. 1990; Lundgren and Taylor, 1993).

This study focused on soil characteristics within the Kunene and Erongo regions. Evidence exists that there is a correlation between soil characteristics and land degradation (Henning and Kellner, 1994). In addition, soil quality has also been shown to change with distance from a borehole (Perkins and Thomas, 1993). Therefore, this study focused on soil characteristics under different grazing intensities and varying distances from a borehole.

MATERIALS AND METHODS

SITE DESCRIPTIONS

Sampling was done in the southern Kunene and northern Erongo regions, which are covered by mainly sandy and silty loam soils.

Piosphere:

Sites 1-4: Okaumbaaha

These sites formed a grazing gradient from a borehole used by approximately 21 families and 3,200 livestock. Sample sites were chosen at intervals of 1 km, starting from the borehole (Site 1) to 3 km distance (Site 4). Information gathered from inhabitants indicated that the number of palatable grass species decreased with proximity to the borehole. This was confirmed by field observations (see Jobst, this vol.).

A topographical gradient existed which caused some surface run-off at the three sites away from the waterpoint, while the borehole was located on a depositional surface in an alluvial plain.

Grazing Sites:

These sites were chosen to provide a comparative analysis of soil properties in areas exposed to different grazing pressures. A paired set of heavily and less heavily grazed sites were sampled on both sandy and silty loam soils to provide information on the effect on soil texture.

Site 5: Otjivero

This is an area where approximately 3,000 livestock grazed and the range condition appeared relatively good. Although much of the rangeland had been trampled and grazed, there was still grass left from the last rainy season (150 mm). Many mopane seedlings were found within the vicinity of the sampled area. Intact grasses were found mainly under bushes. This site received 12 mm of rain the night before sampling (Tsimuni, pers. comm.).

Site 6: Omihana

The eight families and 2 200 livestock that live at this site are supported by two boreholes. Visual observation indicated that this site had been heavily grazed and the range condition was relatively poor.

Sites 7 and 8: "Moonlandscape"

Site 7 was south of the road west from Twyfelfontein to Torra Bay. The site was an old deserted cattle post with only a few mopane trees and no other vegetation. The soil surface was crusted by silts as a result of both overgrazing in earlier years and ongoing sheet erosion.

Site 8 was on the north side of the gravel road and included a water accumulation point. There was some surface crusting between the limited vegetation. Signs of sheet erosion were observed, but not as extensively as seen at Site 7. This site must have been severely grazed in the past, but in contrast to Site 7, the water retention was sufficient to maintain some vegetative cover.

Garden Sites:

Two gardens, both located on the banks of ephemeral rivers, were sampled to provide information on potential soil-related limitations to gardening, e.g. low nutrient levels or high salinity. Site 9 was the Okombahe market gardens, a 3-year-old garden on the banks of the Omaruru river, near the village of Okombahe. Site 10 was at the village of Onverwag Garden. This was a community garden still in the early stages of development. The villagers cited water availability and elephant damage as the two major constraints to successful establishment of gardens.

Table 1: Means for sandy sites include the piosphere, Otjivero and Omihana sites; means for silty sites include only for "Moonlandscape".

Texture Type	Silty	Sandy
EC (µS/cm)	308.5a	147b
P (mg/kg)	15.6a	9.97
pH	8.4a	6.58
ECEC (cmol+/kg)	96.7a	7.28
ESP (%)	0.4a	2.95

GARDEN SITES

Results for these 2 sites are presented in Table 2. Soils were generally alkaline at both sites with high ECEC, P, and EC. However, these values were much higher at Site 10 than at Site 9. The higher ESP and EC at Site 10 indicated that this soil was more saline than that at Site 11 and could also be considered sodic (Richards, 1964). Soils were silty at both garden sites.

Table 2: Data for Garden Sites

Sites	Okombahe Gardens	Onverwag Garden
EC (µS/cm)	416.5	3350
P (mg/kg)	27.5	46.7
pH	9.0	8.5
ECEC (cmol+/kg)	57.73	118.1
ESP (%)	2.81	28.4

DISCUSSION

PIOSPHERE

Soils with pH between 6 and 8 are optimal for sustaining growth of most plants (Day and Ludecke, 1993; Singer and Munns, 1987). Thus the slightly acidic soils of the sites away from the borehole should not limit nutrient availability.

The occurrence of higher nutrient levels at the borehole may be due to manure and urine from animals that come to drink or stay. At the other sites, the lower nutrient availability reflects less organic matter inputs by animals. However, plant growth at the borehole may be limited by trampling. A lack of water could have a limiting effect at all sites across the piosphere.

The trend in EC (Fig. 3), showed that the soils became progressively saltier with proximity to the waterpoint. This also supports the idea of manure and urine inputs as the source of higher nutrient levels at the borehole. The decrease in ESP (Fig.2) near the borehole suggests that the increase in salts is due to Ca and Mg, not Na. These results indicate that the general chemical and physical condition of the soil improves at the borehole which is in agreement with work by Perkins and Thomas (1993).

GRAZING SITES

There were no significant differences between the soils under grazing intensities at the two sandy soil sites (Figs. 4-7). Therefore, the differences in rangeland conditions may either be due to differences in recent rainfall, grazing pressure, or a combination of both.

Significant differences (P>0.05) occurred between the two silty loam sites for EC and P (Figs. 4-5), where values for the less heavily grazed site were much higher. This could be explained by the fact that this site is a water accumulation point. Salts, including anions like phosphates are deposited when water is transported from the surroundings to the accumulation point (Singer and Munns, 1987). The higher ECEC (Fig. 6) and lower ESP (Fig. 7) at both sites, compared to the sandy soils, is due to the larger increase in Ca relative to that of Na.

In general, there were significant differences between the sandy and the silty loam sites. Apart from ESP, all parameters were higher at the silty loam sites. Therefore, the lack of vegetation (see Jobst, this vol.) and the low soil productivity (see Kambatuku, this vol.) suggest the presence of other limiting factors at this site, e.g. water infiltration and availability.

It also appears that, under proper management, it would be easier to restore the condition of the sandy soils, mainly because of the poor structure of the silty soils. Infiltration rates at these silty sites are lower, while the evaporation rate is more or less the same as found at the sandy sites. Therefore, salt would tend to accumulate and not be leached through the profile. The resulting excess salt may inhibit plant growth, reducing the possibility of plant re-establishment. This is supported by the higher EC values found at Sites 7 and 8.

GARDEN SITES

The high EC and ESP (Table 3) indicated that these two sites have the potential for salinization. However, Site 10 has the additional problem of being sodic. This sodicity could limit the potential for gardening in this area, because reclamation of sodic and saline soils through leaching could be limited by the shortage and the salinity of water (Richards, 1964; Day and Ludecke, 1993; Singer and Munns, 1987). It would not be possible to rehabilitate these soils without sufficient water and such rehabilitation would only be temporary. However, it might be possible to extend the productivity of these gardens by growing salt tolerant crops, although this also would be temporary. Either solution would require thorough investigation and planning of the costs and benefits, because they are both only temporary solutions.

CONCLUSIONS

The interesting results from the borehole study (Figs. 1-3) indicate that the immediate vicinity of boreholes could be used more efficiently under proper management. Such management could include the control of movement and grazing of animals near the boreholes. However, this still needs to be investigated. The increase in P with lower grazing pressures suggests that grazing pressure can influence nutrient availability. Thus, indicating that the creation and monitoring of grazing capacities could possibly help stabilize nutrient levels.

Although silty soils showed higher nutrient levels, it appears that factors other than nutrient availability are limiting plant growth, e.g. water infiltration and availability or salt accumulations. The apparent stronger resilience of sandy soils to grazing pressures, suggests that management of these soils may be considered easier than that required for silty soils.

Taking into account the recent lack of rain in the studied area and the marginal differences between sites with different grazing pressures, it is difficult, based on soils data alone, to determine whether degradation and desertification has occurred in this area. This topic needs further study, particularly on the availability of nitrogen, the most frequently limiting nutrient for plant growth. Further studies should also broaden their field to include more regions of the country.

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Fig. 1. Phosphorous and pH variability across a piosphere.

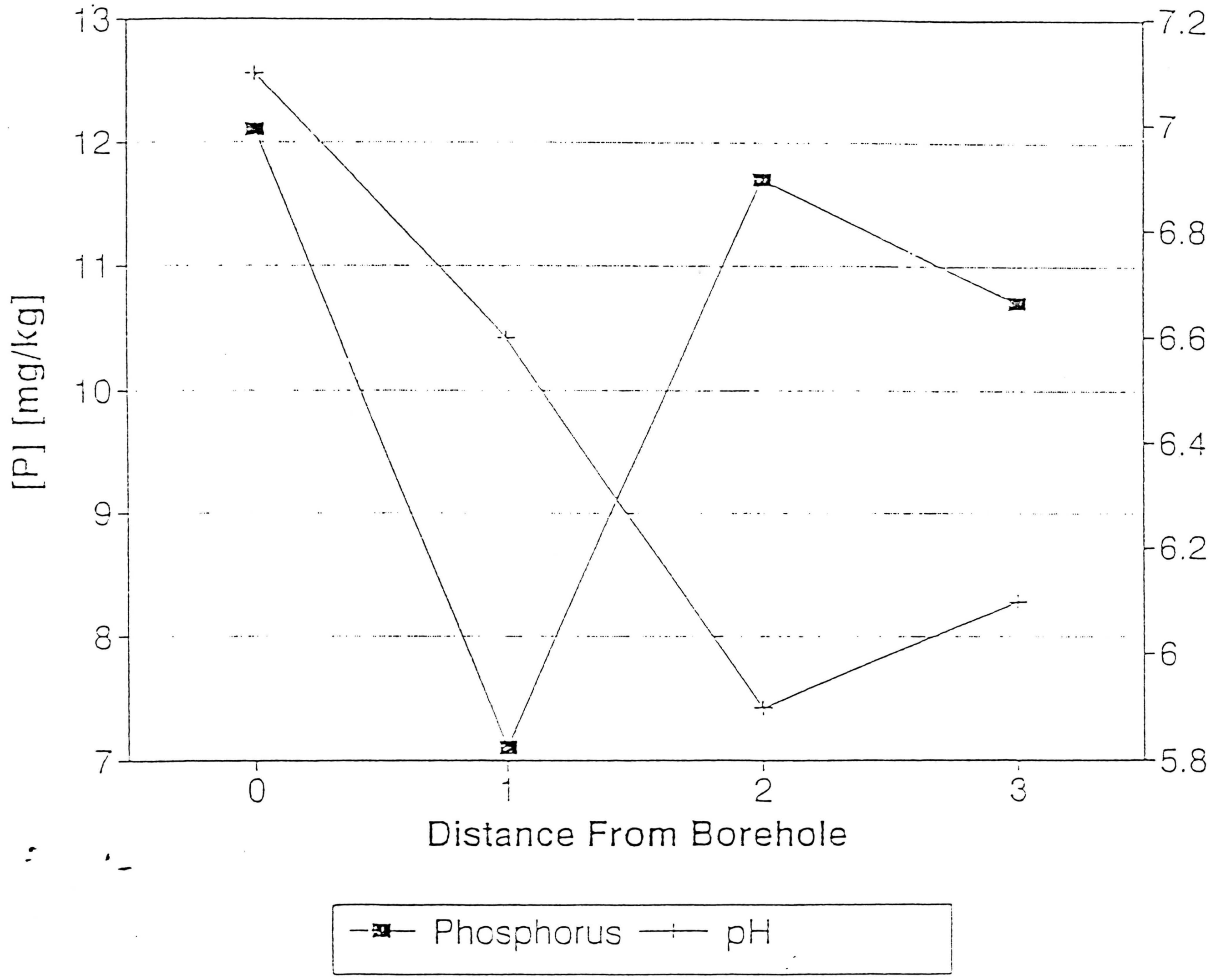


Fig. 2. ECEC and ESP across a piosphere.

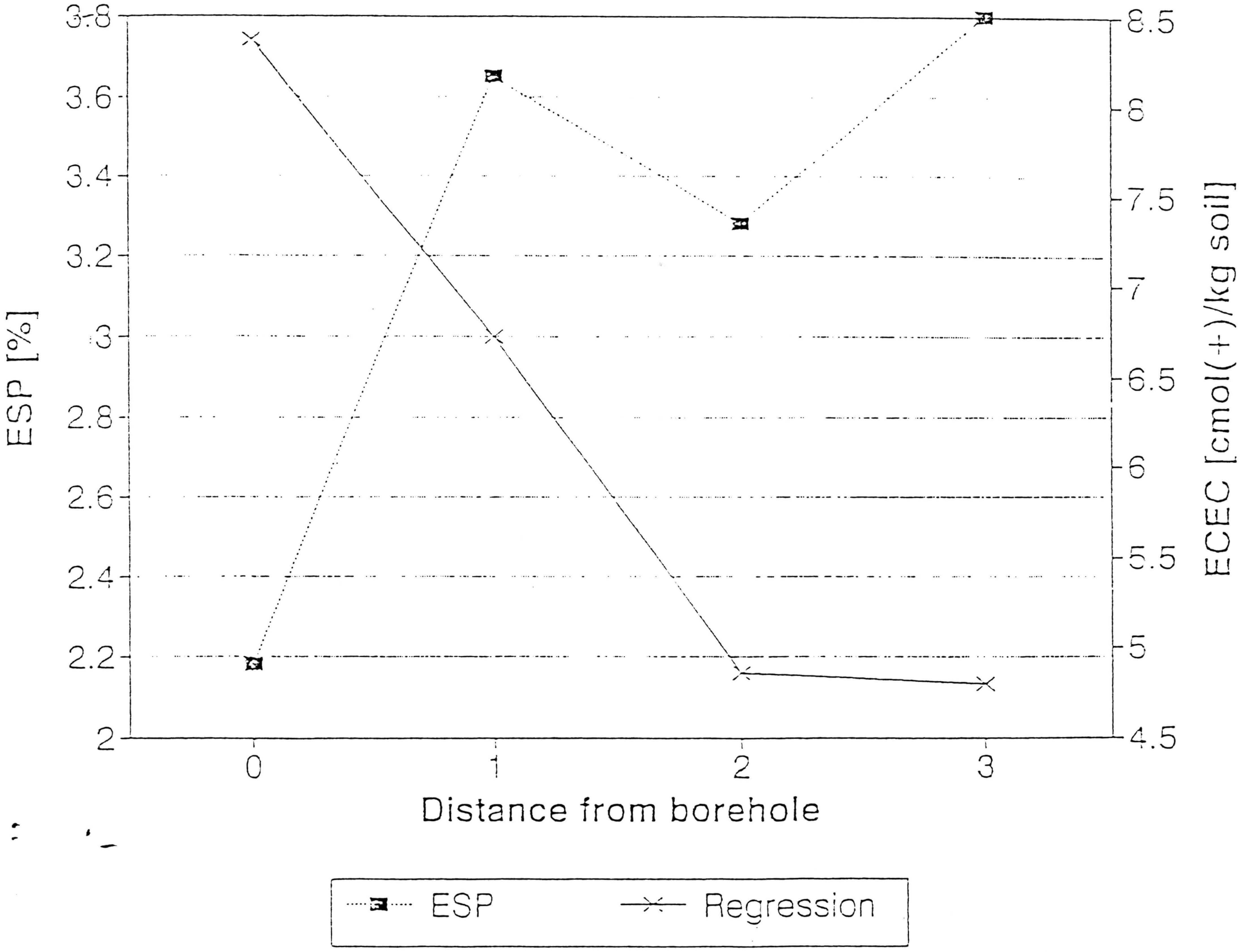


Fig. 3. Distribution of EC across a piosphere.

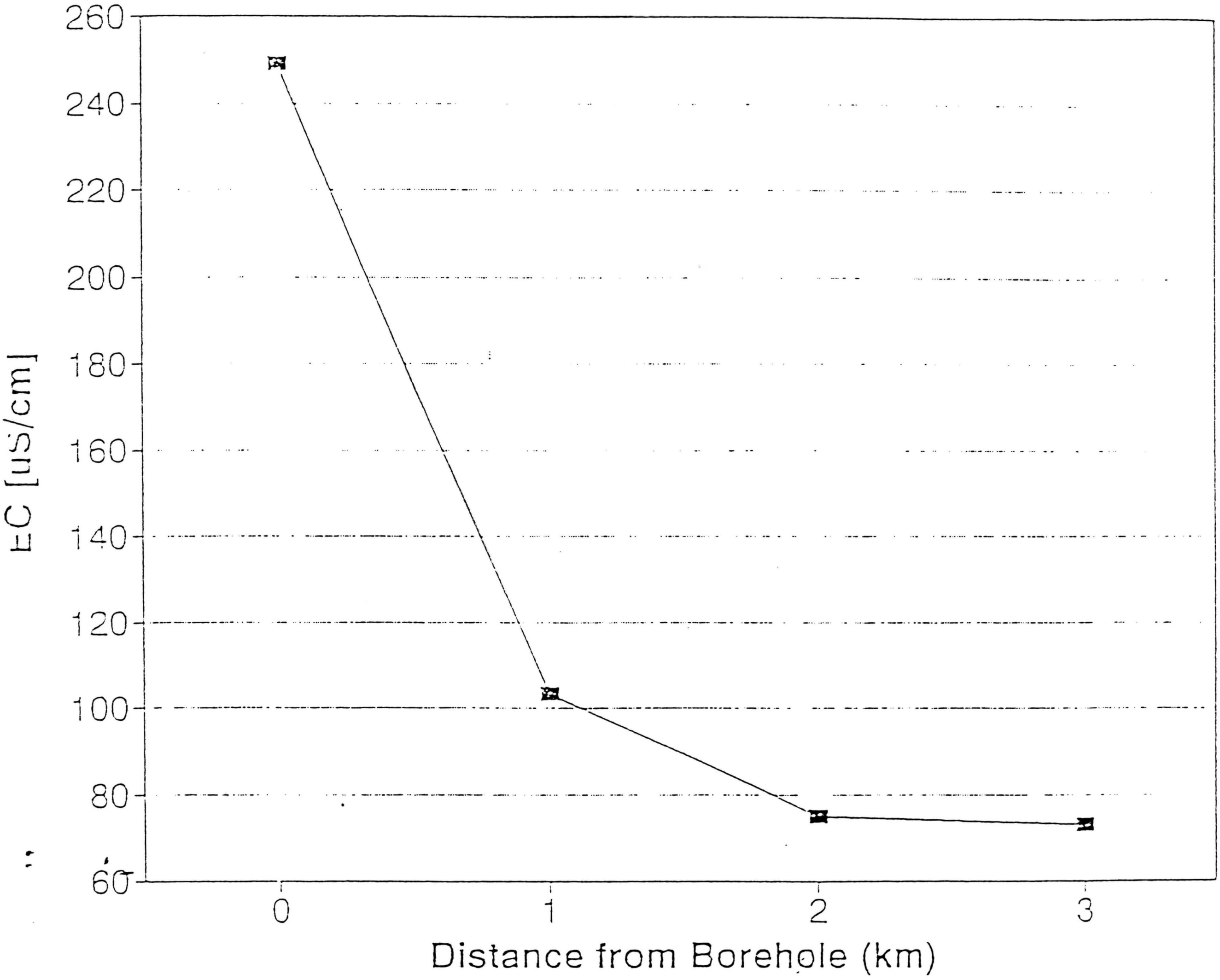


Fig. 4. EC at heavily and less heavily grazed sites.

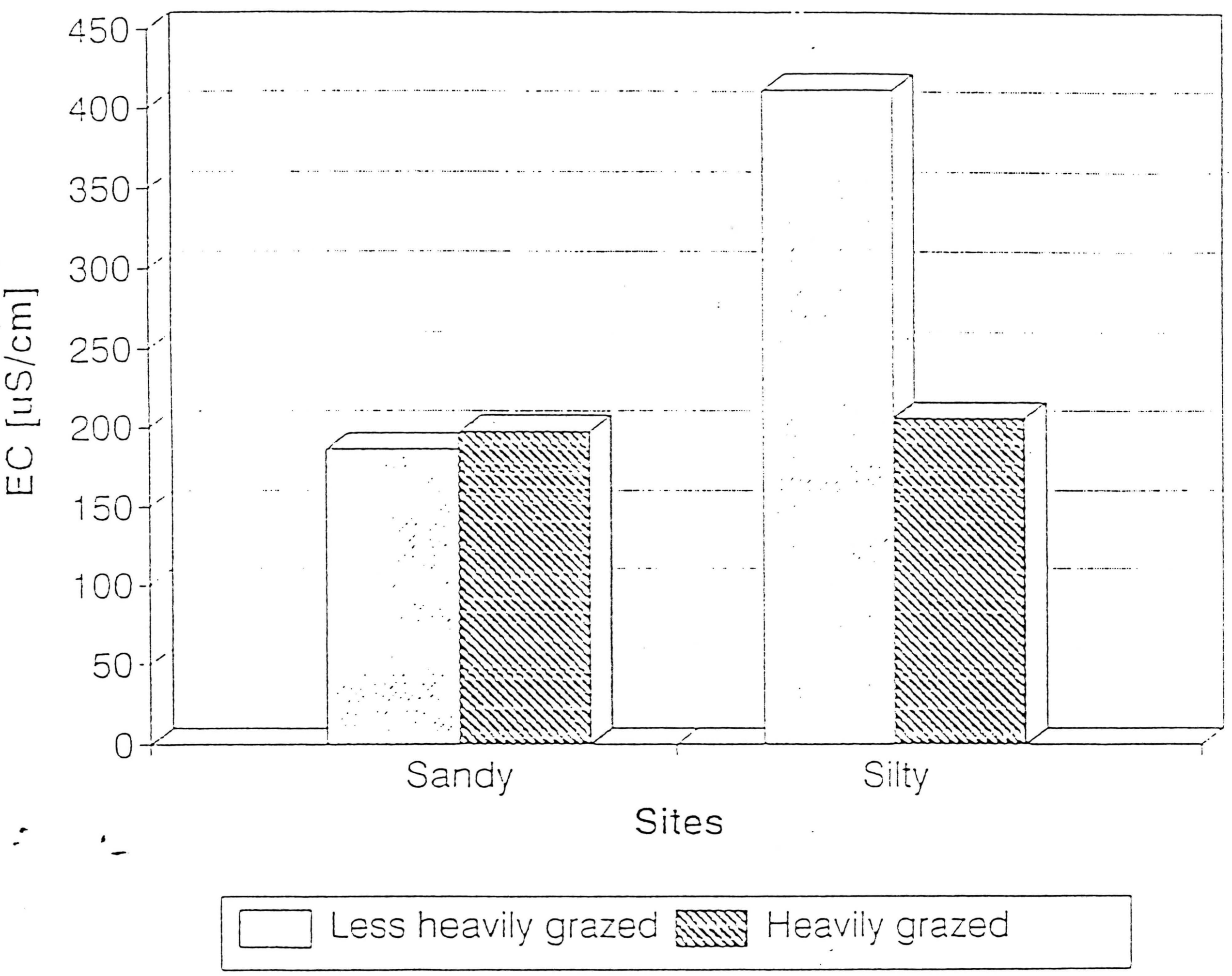


Fig. 5. ECEC at heavily and less heavily grazed sites.

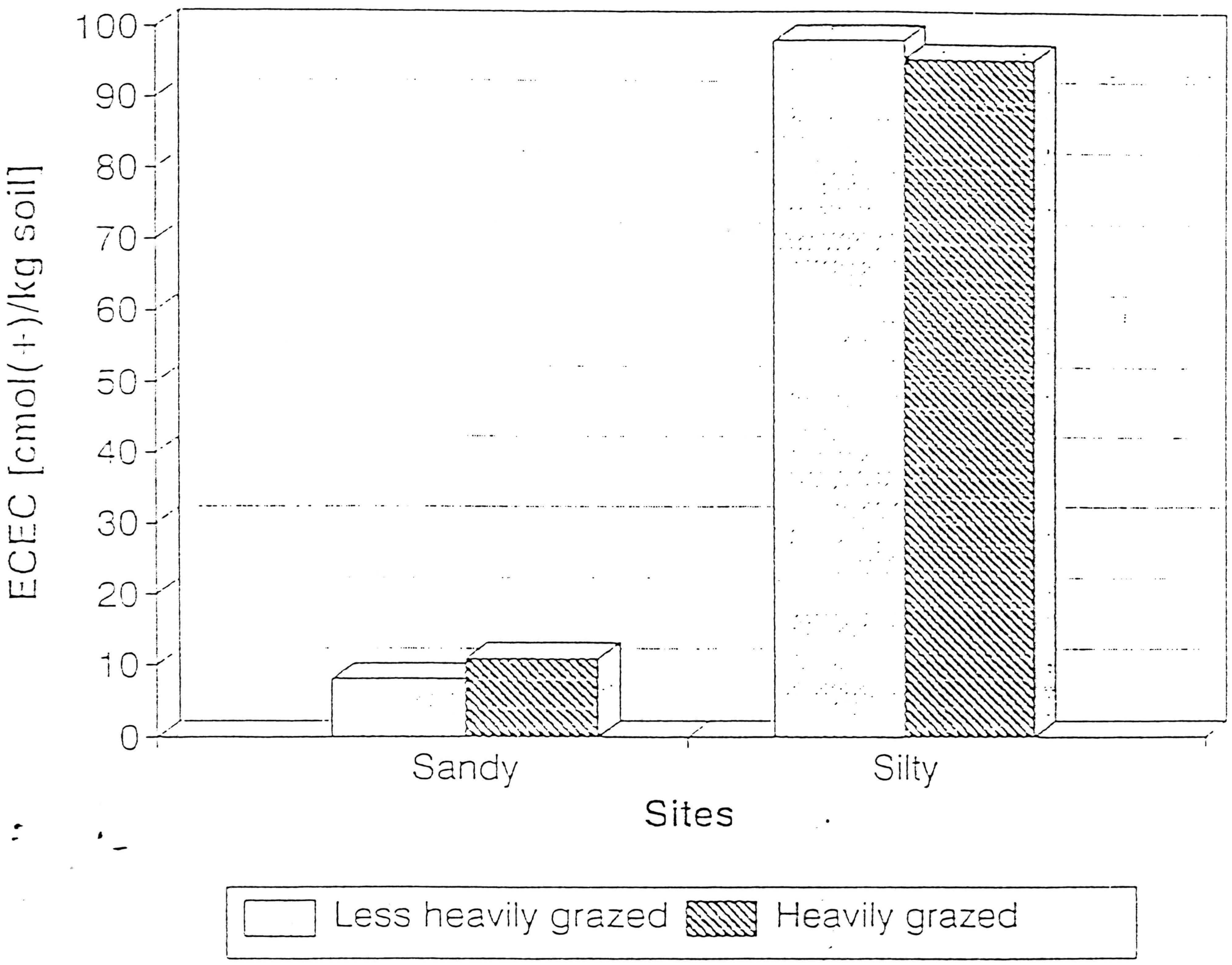


Fig. 6. Available P at heavily and less heavily grazed sites.

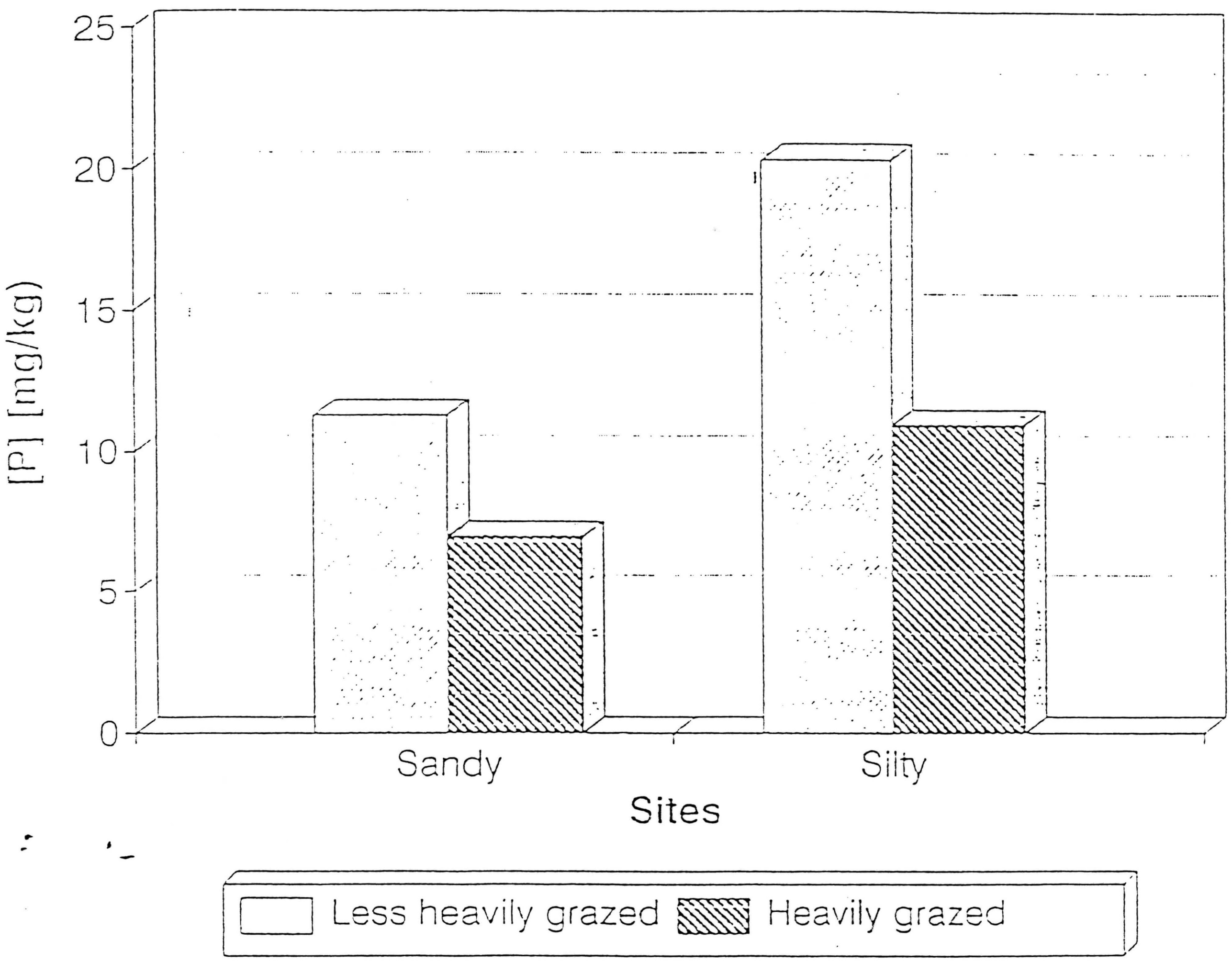
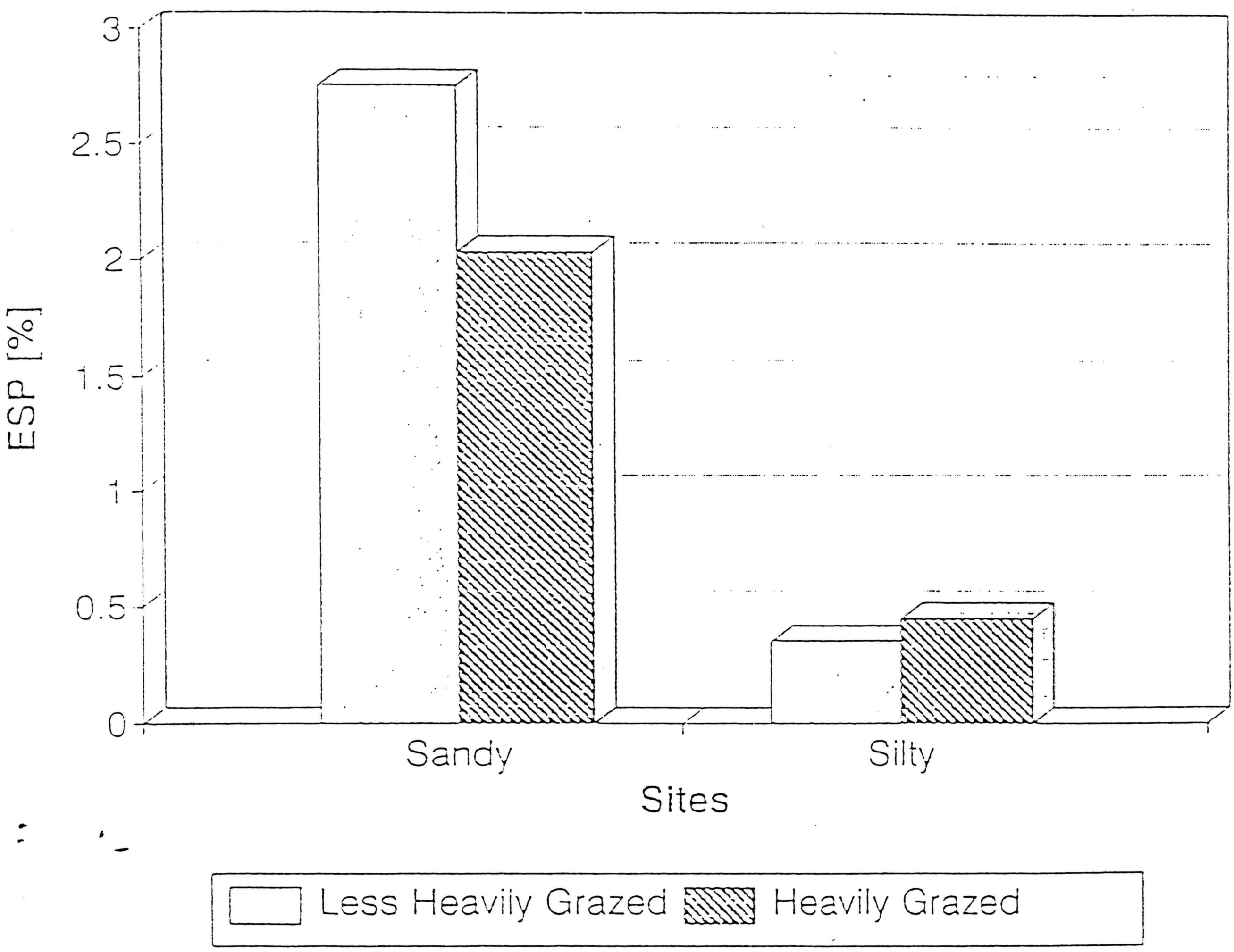


Fig. 7. ESP at heavily and less heavily grazed sites.



BOTANICAL COMPOSITION AND PRODUCTIVITY UNDER DIFFERENT GRAZING PRESSURES IN NORTHWESTERN NAMIBIA

P. Jobst

ABSTRACT

Soil degradation is partially dependent on the type and quantity of vegetation cover, which in turn is influenced by both land use management and climate. In northwestern Namibia drought may influence the appearance of the vegetation cover, causing the landscape to look bare and degraded. However, after a good rainy season if the seed bank is intact, the vegetative cover may return to a pre-drought state. Therefore, it is important to consider both long and short term plant parameters. This study examined standing species composition and productivity at the start of the rainy season in northwestern Namibia. Study sites were selected to represent different grazing intensities. The quadrat counting method was used to measure plant parameters such as biomass and biodiversity. At sites with higher grazing pressure, the species richness was lower, but not necessarily the biomass. Independent of grazing pressure, it appeared that plant communities on sandy soils had a higher resilience than those on silty loam soils. These results were supported by soil analysis and plant growth experiments using soil samples from the same sites (see Mouton and Kambatuku, this vol.). Further work is needed to fully examine the vegetation dynamics in the area.

INTRODUCTION

'Desertification is only one extreme aspect of the widespread deterioration of ecosystems under the combined pressure of adverse climate and agricultural exploitation' (FAO, 1986). The Kunene and Erongo regions in northwestern Namibia are at the fringe of the Namib desert and are classified as semi-arid (van der Merwe, 1983). The main characteristic of this area is the low and erratic rainfall with mean annual precipitation (MAP) of 100 mm/year. This MAP variability has a large influence on the plant communities and can result in marked inter and intra-annual vegetation changes. Desertification is, therefore, often confused with drought induced changes, but may be distinguished from the latter when the productivity of the land does not fully recover after drought (Rowland, 1993; and Hoffman and Cowling, 1990). In overgrazed rangelands it is common that perennial grasses are replaced by less palatable annual grasses and thorny, stunted shrubs (*Acacia mellifera*). Both of these less palatable groups are characteristic of less productive ecosystems in drier climates (Grainger, 1992).

The vegetation of northwestern Namibia decreases progressively, with the rainfall, from east to west, turning into semi-Namib vegetation in the west (Köhler, 1959). Most of the year it is characterised by *Acacia spp.*, dry perennial grasses, *Commiphora spp.*, *Sterculia spp.*, *Boscia spp.*, *Euphorbia spp.* and *Colophospermum mopane* (Craven and Marais, 1992; Bob, 1934). In addition there are linear oases of ephemeral rivers, like the Huab, with *Acacia erioloba* and *Faidherbia albida* which support man, livestock and wild life (Jacobson et al., in press). After rain events, usually between January and April, numerous annual species add to the species spectrum, many of which are grasses and lilies; resprouting herbaceous shrubs also become apparent. In the dry season, the land in many parts looks barren with the only vegetation being *C. mopane*. These areas are highly vulnerable to wind and water erosion due to a lack of herbaceous ground cover.

The human population of the communal lands of the Kunene and Erongo regions is increasing and, with them, the livestock numbers (Rohde, 1994). As a consequence, the wildlife such as giraffe, elephant, rhinoceros and lion are slowly decreasing, because they have to compete with people and livestock (Jacobson et al., in press). This area is too limited to sustain high human, livestock and wildlife numbers without being degraded. Adding to the problem is the lack of systematic livestock management in this communal area. The objective of this study was to determine if vegetation degradation had occurred at a series of sites which have experienced different grazing intensities. Biomass and biodiversity were used as indicators of plant community degradation status.

MATERIALS AND METHODS

Eight sites were selected in the Kunene and Erongo regions representing two common soil types - sandy and silty loam soils (see Mouton, see this vol.). The criteria for selecting the sites were to cover a range of apparent grazing pressures. At each site plant and soil parameters were sampled and observations made of potential biological indicators. The soils and biological indicator data are presented in other chapters of this report. Plant samples were identified in the field or at the Namibian National Herbarium. One difficulty encountered by sampling at this time of the year was the lack of flowering plants which made it difficult to identify species and occasionally even genera.

Site 1 was near the village of Otjivero where there was good rain during the last rainy season. Villagers who were interviewed reported sufficient grazing for the approximately 3000 head of livestock in this area. At Site 2, the first locust outbreak in this area had been reported following the last rainy season. This has decreased the fodder availability for the approximately 2000 head of stock from the nearby village Omihana. Sites 3-6 are sample sites along a piosphere, a zone of attenuating animal impact away from a given watering point (Andrews, 1988). The four sites; which are on a slight topographical incline, are located 3, 2, 1 and 0 km respectively from a 55 year old borehole. Approximately 200 cattle and 3000 small stock water at this borehole from the nearby village Okaumbaaha (H. Zamuee, 1994 pers. comm.). Sites 7 and 8 are 15 km out of Twyfelfontein on the road to Torra Bay. Site 7 is south of the road, at the site of a deserted livestock post, with essentially no vegetation cover. On the other side of the road, Site 8 has the same soil but there is still vegetative growth.

Sites 1-6 are on sandy soils while Sites 7 and 8 are on a silty loam soil. Table 1 shows the sites in relation to the soil type and the grazing intensity.

Quadrat counting was used to evaluate the vegetation at each site (Greig-Smith, 1983 and Krebs, 1989). At each site a 2500 m^2 plot was measured in which all trees were counted and identified. Within this plot, four 1 m^2 quadrats were randomly selected. In one quadrat/site the different species were determined and the number of individuals per species counted (Novellie and Strydom, 1987). In all four quadrats the standing dead biomass was cut at ground level and weighed. The number of species in each quadrat and the percentage ground cover was also noted. These measurements were used to determine species richness (O'Hare, 1988) and different sites were statistically compared using an ANOVA and Fisher's LSD test (Hintze, 1992). Sites 1 and 8 which were treated as lightly grazed, were compared with Sites 2 and 7 which were heavily grazed. Regression analysis (Zar, 1984) was performed for Sites 3-6 for parameters as a function of distance from the borehole.

RESULTS

The percentage of ground cover, plant biomass and species richness was low for all sites (Figs. 1-3), as can be expected at the end of the dry season in northwestern Namibia. Most sites contained shrubs, grasses and *Geigaria ornativa*. With the exception of Site 8, *G. ornativa* was present at all sites which had herbaceous vegetation. Site 1, which had the largest population percentage of *G. ornativa*, also had the highest percentage cover of grasses. The grasses present were perennials (*Stipagrostis ciliata*), which were beginning to resprout and annuals (*Eragrostis nindensis*) which in Afrikaans is commonly, and descriptively, called "Agtdaegras" (eight day grass). This site also had a high number of trees dominated by *Catophractes alexandrii* which is a good fodder tree as well as *Boscia foetida* (Fig. 4). The biomass was 255 (± 87.0) kg/ha for Site 1, while that at Site 2 was 196 (±249) kg/ha. Site 2 had no vegetation in one quadrat and the grasses throughout the plot were grazed to ground level. The shrubs *Osteospermum sp.* and *Indigofera sp.* had no leaf cover. The tree population was mainly comprised of *Terminalia sp.* and *Acacia senegal* which also looked heavily browsed.

Site 7 had no vegetation except for a few scattered *C. mopane*. In addition, there was no evidence of grass production from previous years and the soil had a surface crust. Site 8 had an average of four plant species/m^2 (Fig. 3) with a high percentage of forbs compared to Sites 1 and 2. At this site the most dominant species was the shrub *Sesbania sp.*, which formed dense patches, but did not contribute much to the ground cover. The biomass at this site was 563 (± 375) kg/ha.

Sites 3-6, the piosphere, showed a slightly significant correlation (P>0.10) between distance from the borehole and number of species (Fig. 5). The correlation coefficient between biomass and distance to the borehole was not significant, even at the P>0.10 level (Fig. 6). Site 4 had the highest number of shrubs (Fig. 1) and the highest number of trees, mainly *Acacia reficiens*, of the piosphere sites (Fig. 8). As a result, it has the highest biomass 680 (± 150) kg/ha. Site 3 had four grass species, *Stipagrostis obtusa*, *Schmidtia sp.*, *Aristida sp.* and an unknown species. There were two shrubs (*Dicoma sp.*, *Blepharis sp.*) at this site but in low numbers (Fig 1) which gave it a lower biomass of 597 (± 70) kg/ha. Site 3 also had a very low number of trees compared to the other sites.

Site 5 was the only site where the tree *Parkinsonia Africana* occurred. This site had a biomass of 507(± 370) kg/ha due to mainly one species of grass *Aristida adscensionis*. An even stand of this grass, approximately 1 m in height, covered over half of the 2500 m^2 plot. The other half was barren of herbaceous cover except for *G. ornativa*. At the borehole no herbaceous vegetation was observed but there was a high number of Acacias, especially *A. tortilis*.

DISCUSSION AND CONCLUSION

This study attempted to use plant communities as an indicator of degradation in NW Namibia. This is based on the concept that a plant community is strictly associated with particular environmental conditions and therefore its presence is indicative of the existence of these conditions (UNESCO-UNEP, 1994). Changes in environmental conditions can be examined by looking at existing communities, demographic dynamics (Sefe and Ringrose, 1994). Associated with demographic change in a community are fluctuations in plant biomass, productivity and species number. A decrease of these values occurs in Namibia during winter, autumn and drought years. If during this time the pressure through grazing and human impact is increased, it may reduce the ecosystem's resilience.

In the arid and semi-arid rangelands of northwestern Namibia, the pressures which appear to have the highest impact on vegetation are consumption and trampling by animals. One plant species which is an indicator of high grazing pressure, *G. ornativa*, was present at all sandy soil sites. It is an annual serotinous plant which remains visible for years after its active period (Günster, 1992). It is also a pioneer species which is toxic and spreads quickly in overgrazed land to the disadvantage of other plants (Nel, 1994). Its presence indicates that grazing pressure has been high at all sandy sites. Although Site 1 had the highest number of *G. ornativa*, at sampling the grass cover was also high (Fig. 1). This may be attributed to the good rains (150 mm) during the 1993/94 rainy season in that area (Tjimune, 1994, pers. comm.). Seven small *C. mopane* seedlings, without browse marks, were observed at the site. This indicates that there was enough grass for livestock so that they did not have to browse on the young trees. It can be assumed that this site was grazed heavily in the 1992 drought, perhaps resulting in the high number of *G. ornativa* observed. The recovery of the grass production and the *C. mopane* would indicate that the land's resilience is good and it is not yet desertified.

Sites 1 and 2 are both on sandy soils, but in comparison, Site 2 appeared to be more heavily grazed. A locust outbreak in the area of Site 2 also may have resulted in higher pressure on the grasses, leading to their over-use in the 1994 dry season. The consumption of the shrub foliage by the locusts and the high grazing pressure resulted in a low biomass for this site (Figs. 2). Sites 1 and 2 were also significantly different in species number (Fig. 3). These results could reflect the overgrazing of Site 2 which reduced litter and soil cover (Fig. 1) and which may have promoted a reduction in the number of grass species (Savory, 1988). Further evidence of degradation were the low number of perennial grasses observed at Site 2. In contrast, Site 1 even had the perennial *S. ciliata* which is a very good sandbinder (Gibbs et al., 1991). Perennial grasses are very important for sandy soils because they are the main source of soil cover which stabilizes the soil against wind erosion (Savory, 1988). At Site 2 one area showed signs of being an erosional surface with practically no plant cover. This lack of plant cover could have enhanced wind erosion on this sandy soil.

Sites 7 and 8 had silty loam soils that are susceptible to sheet erosion and crusting. This erosion may be the result of raindrop impact, decreased vegetation cover and cattle trampling, which caused the soil to compact and develop a crust. This hardened surface leads to reduced infiltration, increased overland flow and consequent development of rills and gullies (Sefe and Ringrose, 1994).

Sheet and gully erosion were evident at Site 7 while at Site 8 only a small amount of sheet erosion had occurred between the vegetation patches. The difference in vegetation cover between Sites 7 and 8 may be due to grazing pressure or the relative landscape positions of the two sites. Site 8 is located at a topographic low which may act as a water accumulation point. Higher water availability at this site could then sustain more vegetation growth for longer periods. This vegetation cover protects the soil at Site 8 from erosion, compared to Site 7, which is bare and susceptible to both wind and water erosion.

These results suggest that soil type plays an important role in the relative impact of grazing and vegetation removal. The sites with finer-textured soils (Sites 7 and 8) exhibited substantially more evidence of degradation, erosion, crusting and complete loss of ground cover than the sites (Sites 1 and 2) with the coarser textured soils. This reduces the probability of seedling establishment. If the crust is not broken it may not be possible to re-establish a ground cover without which the crusting and erosion will continue, resulting in a degradation feedback cycle (Schlesinger et al., 1990). This cycle does not establish as rapidly on sandy soil due to better infiltration. This shows that on finer-textured soils in drylands, the stocking rate of livestock may be more critical than that on sandier soil.

The first stages of piosphere development may also be the beginning of the desertification process (Andrews, 1988). Even if the animals are completely removed or the water point is closed, the piosphere pattern in at least some parameters, is likely to remain (Andrews, 1988). At Sites 3-6 one can see the piosphere pattern in the decreasing species richness and with increasing proximity to the borehole (Figs.5). Another trend is the shift from grasses (Site 2) to shrubs (Site 3), to unpalatable species and encroaching bushes (Site 4, to no herbaceous vegetation at the borehole. As grazing pressure increases, the competition from grasses for nutrients and water decreases, allowing woody seedlings to establish more readily (Walker, 1993). Over a range of 1 km from Site 3-4 ,the dwarf shrub population increased ten times (Fig. 1) which is an indication of vegetation degradation (Henning and Kellner, 1994). While *B. Foetida*, which is a slow growing, nutritious browse tree, made up most of the tree population at Site 3, it was nearly absent after 2 km at Site 5 and was replaced by the encroaching *A. mellifera* and *A. tortilis* (Barnes, 1994). Both were found in the seedling and full grown stage. This shift in the woody plants gives an indication that the land has been overused in the longterm. Through overgrazing, the grass cover is reduced, water and minerals can leach down to the roots of woody species, reducing the availability of these resources for grass seeds (Walker, 1993).

The regression coefficient with biomass (Fig. 6) is low, because of the high number of shrubs at site 3 and the presence of the unpalatable grass, *A. adscensionis*, at site 4. This may be another indication of the successional shift towards more shrubby and unpalatable communities which is an indication of land degradation through grazing. Under such conditions, biomass may not be the best indicator of range degradation.

Van Rooyen et al. (1994) found that the vegetation gradients around artificial watering points in the Kalahari Gemsbok National Park were not related to grazing intensities. However ,this could be due to the lower dependence of game compared to livestock and their better adaptations to arid conditions and dry land vegetation.

The main vegetation differences at the 8 sites seemed to be due to both soil type and grazing pressure. Finer textured soils like the silty loam of Sites 7 and 8 may be more productive when adequate water is available than a sandy soil, but it is very sensitive to grazing impacts, e.g. plant cover removal and compaction, which can easily result in erosion. Sandy soils may be easily changed by management practices towards woody communities (Walker, 1993). However, the resilience of the system on sandy soils following high grazing pressure seems to be better than that of a silty loam soil. More data is needed from other years and seasons to confirm the results found in this study.

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FIG. 1. Percentage ground cover at the eight study sites. Values are means of four quadrats; means with the same letter are not significantly different.

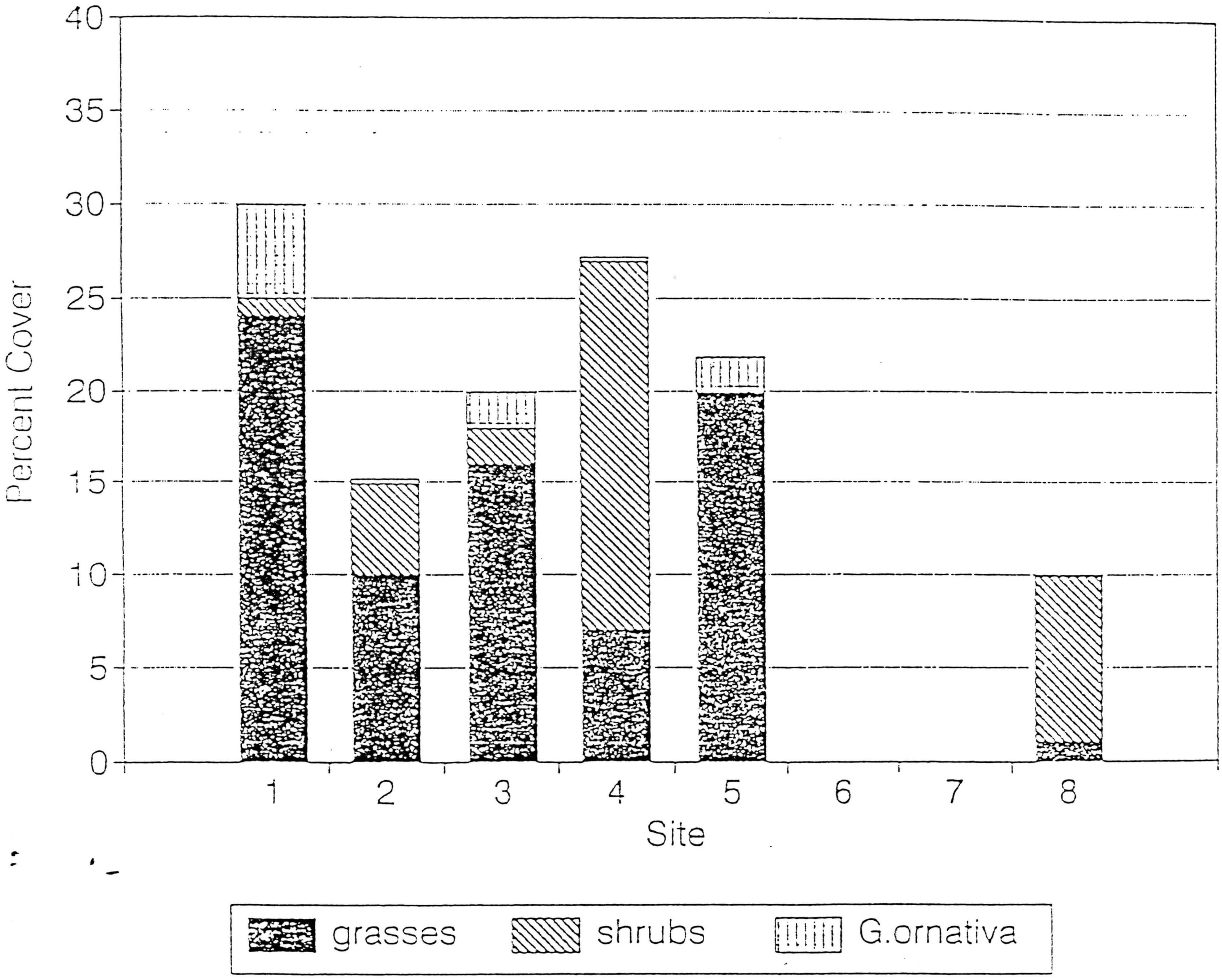


FIG. 2. Total biomass production at the eight study sites. Values are means of four quadrats; means with the same letter are not significantly different.

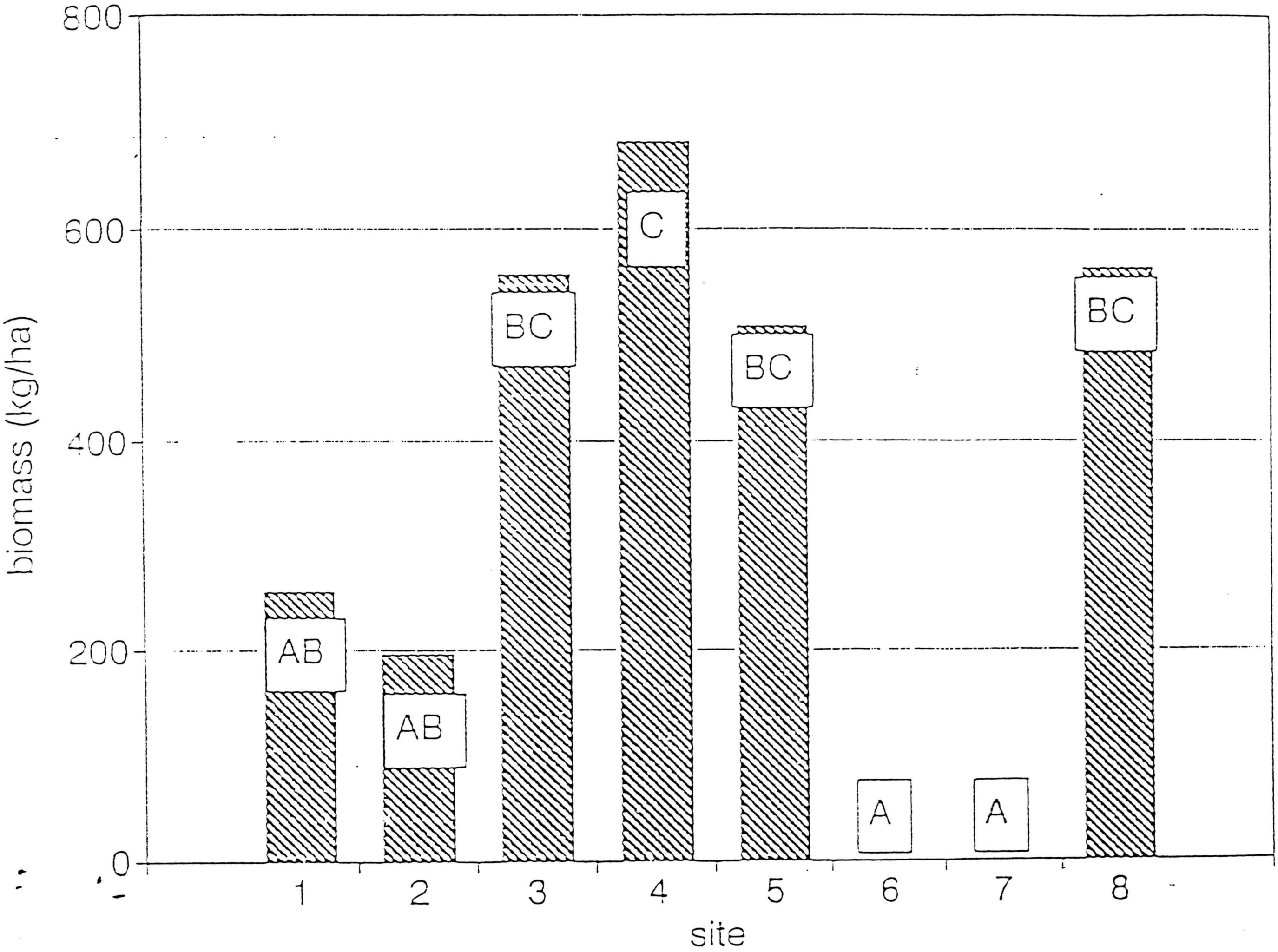


FIG. 3. Total number of species at the 8 study sites. Values are means of four quadrats; means with the same letter are not significantly different.

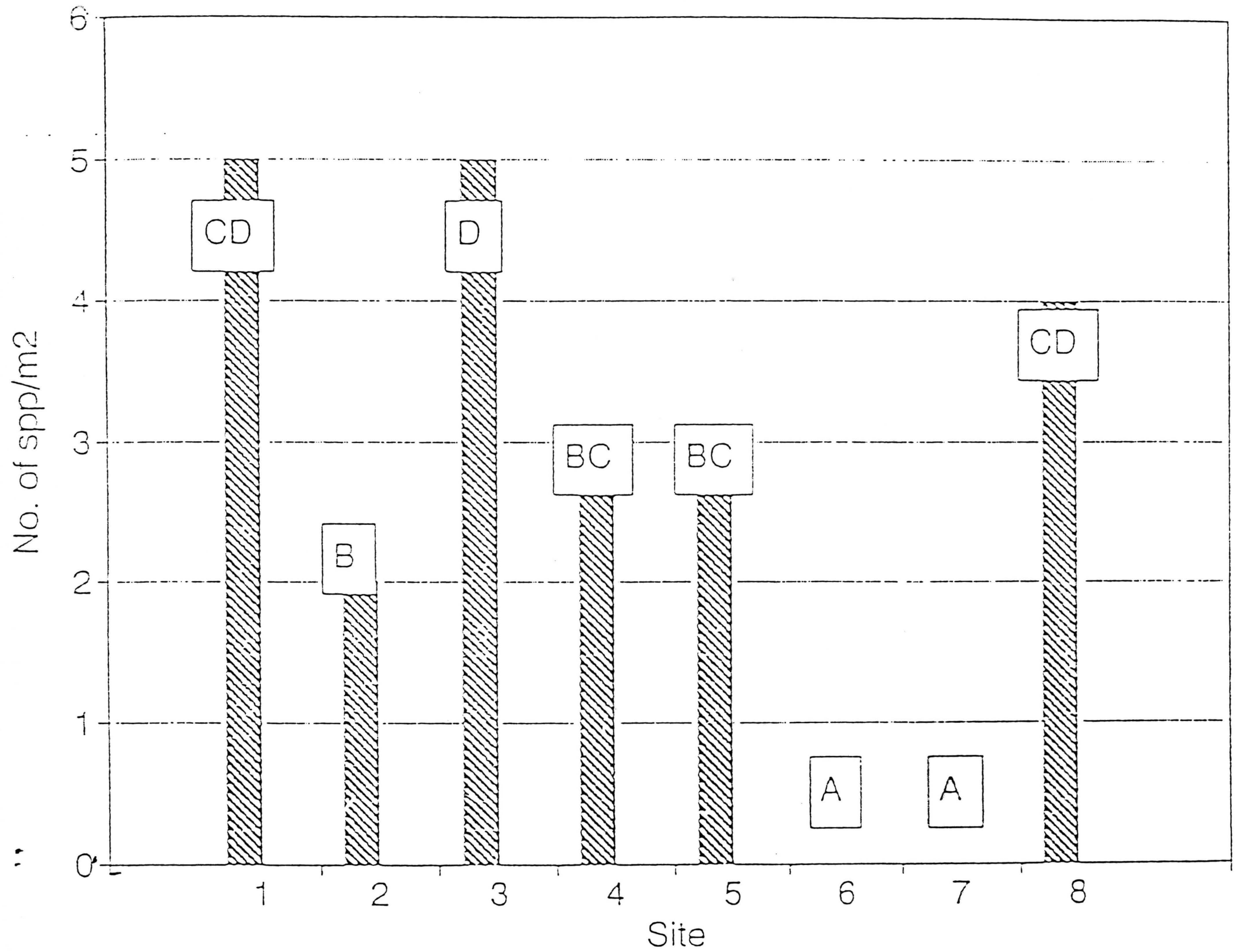


FIG. 4. The number and species of trees at each 2500 m² study site. Sites 1 and 8 are lightly to moderately grazed and Sites 2 and 7 heavily grazed.

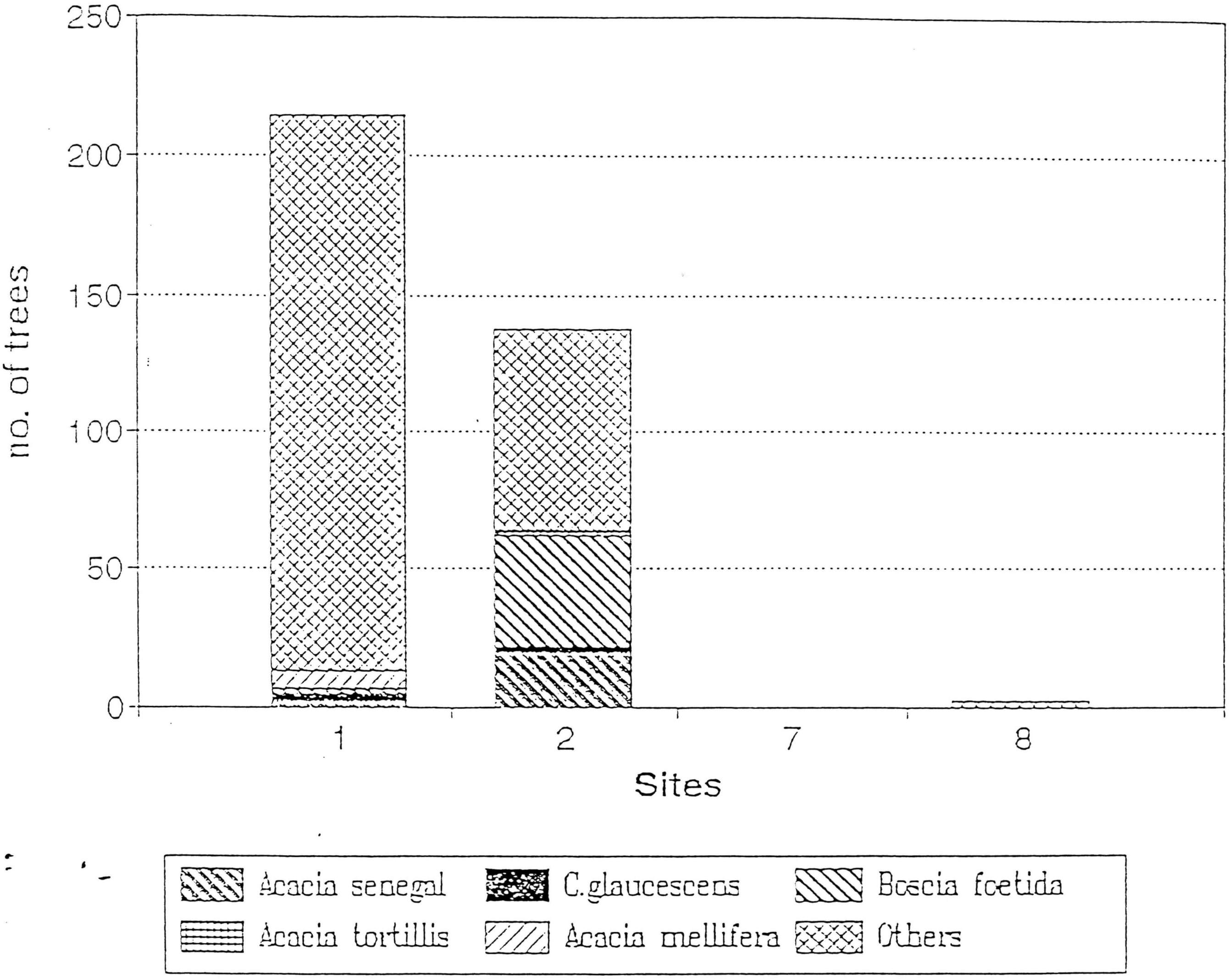


FIG. 5. Species richness as a function of distance from the borehole. Values are means of four quadrats.

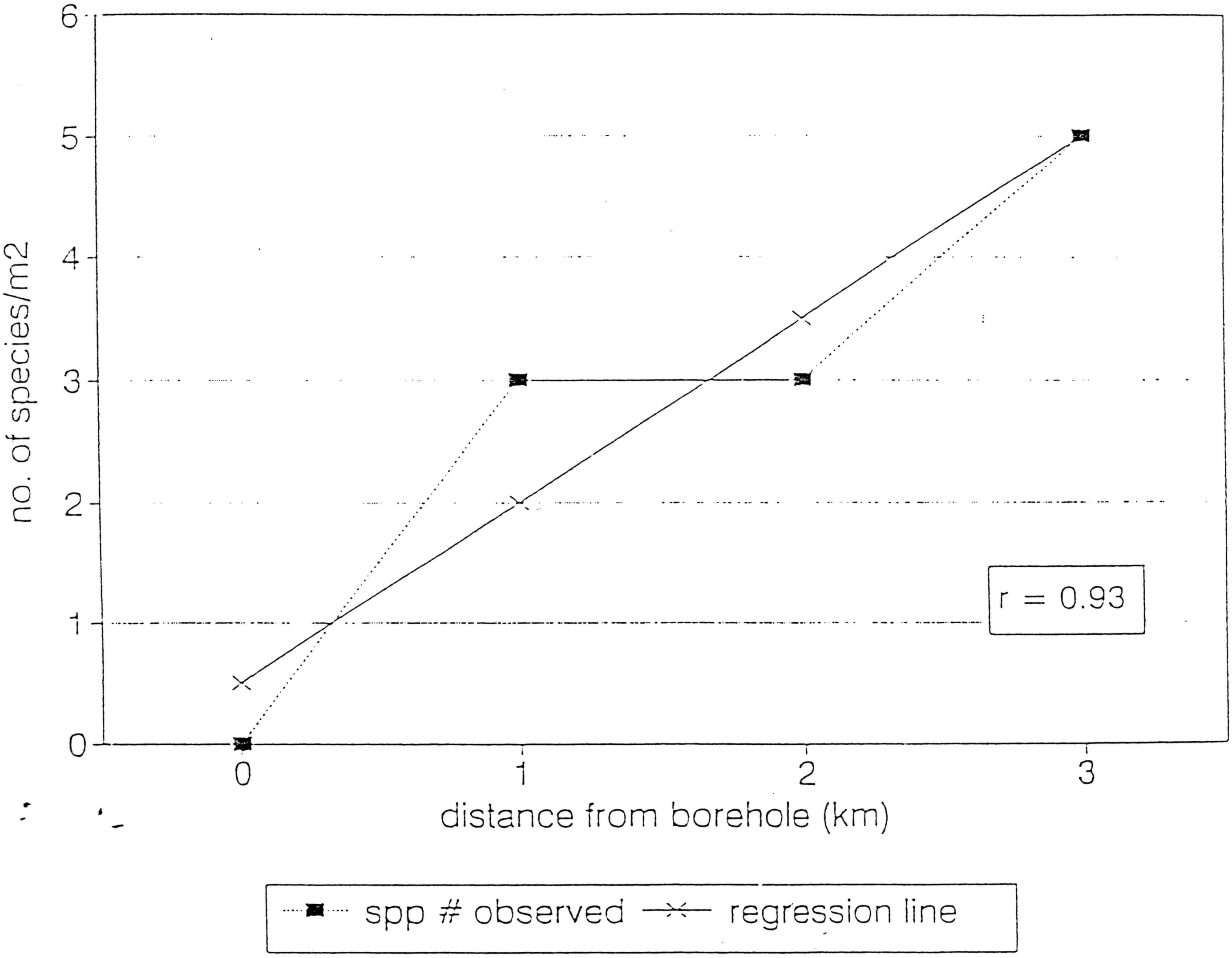
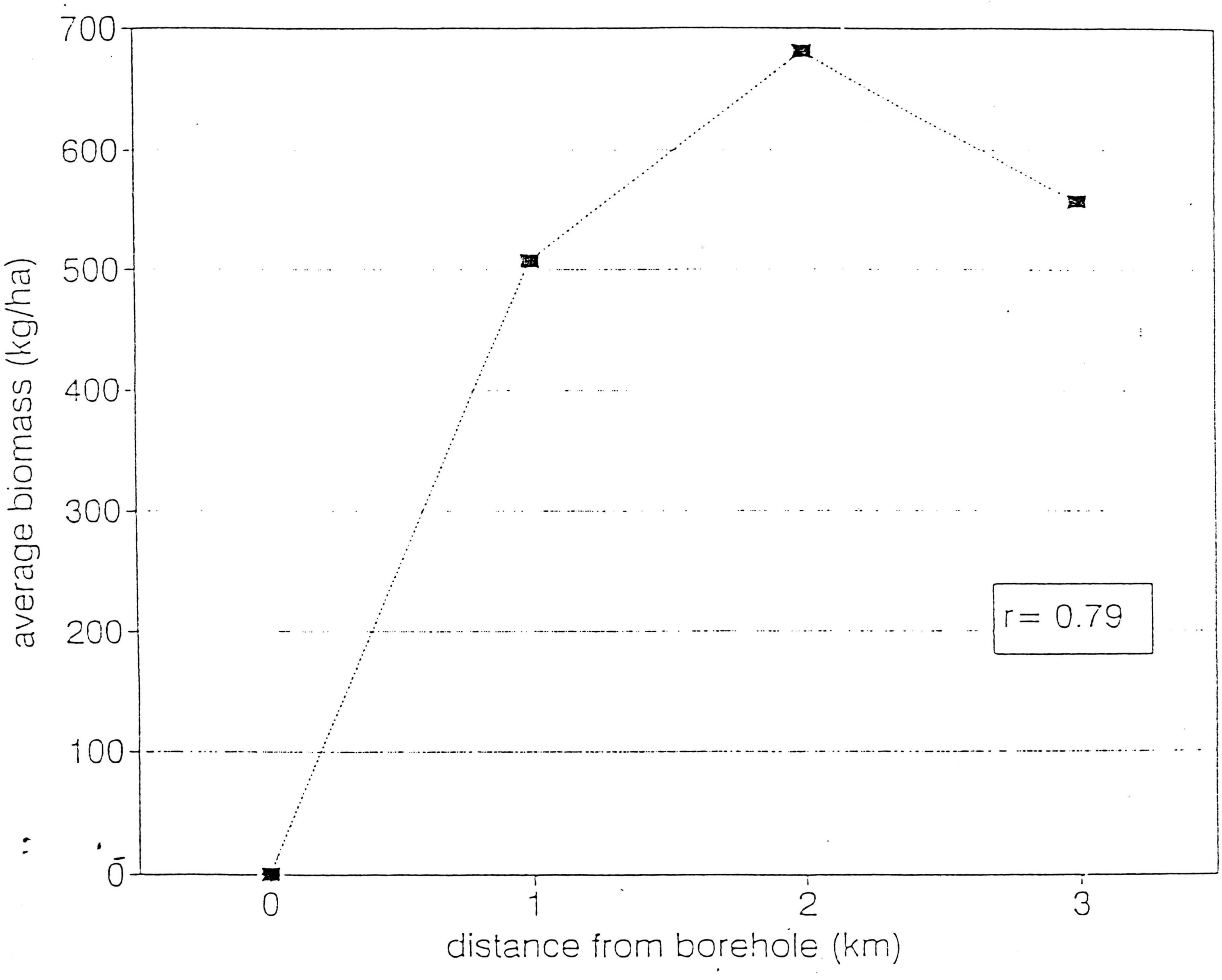


FIG. 6. Total biomass as a function of distance from the borehole. Values are means of four quadrats.



THE EFFECT OF RANGELAND MANAGEMENT ON SOIL PRODUCTIVITY: USING PLANT GERMINATION AND GROWTH RATES AS A MEASURE OF SOIL PRODUCTIVITY

J.R. Kambatuku

ABSTRACT

Namibia's naturally dry climatic conditions have produced striking plant adaptations that make it hard for observers to distinguish land degradation from natural vegetation cycles in response to erratic rainfall. Therefore the degradation status of rangelands in Namibia, and the northwest in particular, can not be assessed by field observations alone.

It was therefore the objective of this study to measure the extent of land degradation, or other processes generally believed to lead to desertification, through experimentation. A comparison was made between several rangeland sites subjected to varying intensities of grazing. Plant germination and early plant growth were measured in soils collected from this suite of land use sites and the results were used as indicators of soil productivity.

The results exhibit a trend of lowered germination and early plant growth on degraded or intensively used lands as compared to relatively intact ones. This may hint at a gradual decline in soil productivity and possible degradation with increasing use.

INTRODUCTION

Namibia's only perennial rivers demarcate its national borders and with the sea forming its western boundary, the geographical position of the country seems defined by water deficiency: where the water begins, Namibia ends. The total absence of perennial rivers in the interior, combined with extremely low and variable rainfall, makes for the driest conditions in Sub-Saharan Africa (Marsh and Seely 1992; Dealie et al., 1993).

The western part of the country epitomises Namibia's arid conditions as it receives the lowest precipitation in the country. Severe and lengthy dry periods are the rule rather than the exception in this section of the country. In response to this aridity, plants have developed striking adaptations (Günster, 1994). Therefore, the area can appear to be barren for years, producing no vegetative growth as seeds lie dormant for long periods. However, adequate and timely rains may produce a new flush of plant growth and the area may then display rich flora. This is indeed a characteristic phenomenon of all scorched regions the world over (Charley and Cowling, 1968).

Such ecological complexities make it especially difficult to distinguish land degradation from normal annual (or longer) dry cycles by simple field observations. Charley and Cowling (1968) note that the said vegetation responses to rain have bred the skewed belief that arid soils lack only water to be productive. However, marked changes in species composition, notably from palatable perennials to unpalatable annuals, are induced by intense grazing pressures in savanna rangelands (Walker, 1993). This not only results from differing defoliation of the grasses by grazers, but also from changes in soil conditions (Noy-Meir and Walker, 1986). It is humans, through their use of the land and natural resources, who prompt these predicaments which can lead to land degradation.

The Erongo and Kunene regions constitute the mountainous northwestern part of Namibia. Plains that incorporate scattered hills and inselbergs (van der Merwe, 1983) intercept the Erongo mountain range, from which the area derives its name. Post-Damara granite and Swakop schist are the predominant geological attributes of the area and these generate the generally weakly developed soils of the area: deep, red, sandy loams to sandy clay loams (Dept. Water Affairs, 1971). The two regions can be divided into three rainfall regions. The coastal section, which comprises the famous Skeleton Coast Park, may receive from a low of 1 to a high of 63 mm rainfall per year (Dealie et al., 1992). Towards the interior, rainfall increases slightly and is sufficient to support erratic patches of desert and semi-desert vegetation. Rain, which falls during summer (between September and April), varies from 150 to 250 mm annual mean for the study area. Giess (1971) placed the area in the "semi-desert and savanna transition and mopane savanna" category in his classification of Namibia's natural vegetation.

The principal land use in the fragile Kunene and Erongo regions is sedentary livestock rearing under a communal tenure system (see Kakukuru in this volume). This system allows for a limited scope of natural resource management and tends to result in intense uncontrolled grazing of the sparse sporadic foliage. Traditional systems of land tenure were adopted through close interactions with the variable environmental conditions of the savannas, but Werner (1994) argues that it is the added effect of changing demographic, economic, technological and political trends that make this system incompatible with the environment.

Examples of the different land tenure systems are usually separated by fences. The sharp contrasts observed where dissimilar land use practices border each other offer good sites for comparing management effects on the environment. The magnitude of grazing and trampling, especially in communal land, has been described as a function of the distance from the watering point (Katjiua et al., 1993; Andrews, 1988). The further the distance from the water point, the less severe the grazing and trampling. In the absence of fences, distance may provide a measurable gradient of varying grazing pressures on the environment.

This study, together with others in this project, attempts to assess the state of the rangelands of this area using vegetation characteristics as indicators. This is in line with the overall project objective of verifying the occurrence of land degradation and other processes that are believed to lead to desertification in northwestern Namibia. The experimental hypothesis is that the rate of seed germination and early plant growth is directly related to the degree of land degradation and trampling.

MATERIALS AND METHODS

The study area comprised communal farming areas in northern Erongo and southern Kunene (21^{o} 21 '20' S ; 15^{o} 30'10" E ; 19^{o} 40' 29"S"and 13^{o} 50'33" E;) regions. The Omatjete district in northern Erongo has been under communal tenure for more than a century. The southern part of the Kunene was transformed from privately-owned to government-owned farms for lease before eventually being converted into communal land following the recommendations by the Odendaal Commission (Köhler, 1959). The study area encompassed four villages and an abandoned cattle post nicknamed the Moonlandscape due to its stark physical appearance.

Site selections were based on presumed differences in grazing pressures that expectedly would reflect dissimilar environmental conditions or degradation status of the rangelands. The places where fields were sampled were as follows:

OMATJETE AREA

Otjivero (OT):

This is a village located northwest of Omatjete with eleven homesteads and an estimated 3000 head of livestock, both large and small. The sample site was 15 km northwest of the village. Dry stands of both annual and perennial grasses, shrubs, including the dominant *Catophractes alexandrii*, were sighted in the reddish, moist sandy soil of this area.

Okaumbaaha (OK):

This is a settlement along the main road from Omatjete to Torrabaai, about 24 km west of Omatjete. Sampling near this village was done across a piosphere with increasing distance from the borehole. Four sites- OK-A, OK-B, OK-C and OK-D (3, 2, 1 and 0 km south of the water point, respectively) were selected in order to provide a use gradient with distance from the water source. The three sites (away from borehole) were all situated on a slight, north-facing slope and had various vegetation stands comprising grasses, shrubs and *Acacia spp.*, none of which were actively growing (see Jobst in this volume). The borehole was drilled on the flood plains of a small river and hence the bare soil at OK-D was an alluvial soil.

Omihana (OM):

Located 45 km from Okaumbaaha, this site was 5 km south of a watering point. In addition to high grazing pressure, this is the only village in the area to have suffered a locust outbreak this year. Soils were sampled south of the borehole where inhabitants claimed the locust problem had been most intense. Grasses here were level with the ground while the shrubs and trees were stripped bare of leaves, allegedly by the locusts.

TWYFELFONTEIN AREA

Moonlandscape (*MO*):

This was an abandoned cattle post 15 km west of Twyfelfontein along the main road, possibly abandoned due to extensive degradation. The soil surface was completely bare and sealed with a silt crust. The subsurface was compacted below a depth of about 10 cm and evidence of both gully and sheet erosion were visible. This site was subdivided into two sampling locations: the area south of the road (MOS), where erosion is apparent and no herbaceous vegetation is found and the area north of the road (MON) where water appears to collect in a small depression, allowing some grass and forb production. A few scattered and conspicuously old *Colophospermum mopane* trees grow on MOS and shrubs of genera *Sesbania* appear to thrive on MON.

A 2,500 m^2 plot was established at each of the sites. The top 10 cm of soil was sampled at four randomly placed quadrats (see Jobst in this volume). The samples were weighed and sieved through a 2 mm mesh sieve. The coarse fragments were weighed to determine the percent coarse fragments at each site. The sieved samples were mixed to provide one, homogenous sample per site.

Preliminary germination trials were carried out on the garden grass Kikuju and a wild grass species to determine the percent germination and germination rate for both species. Based on these results, the Kikuju grass (70% germination in three days) was used as an indicator of grass response to soil conditions.

The soil sample from each site was divided into twelve 7.5 cm diameter pots to provide four replicates for each of three harvests. The pots within a harvest were arranged in a completely randomized block design. Twenty five seeds were planted in each pot at a depth of 1 cm.

The pots were watered daily for the duration of the experiment. An average total volume of 750 ml deionised water was applied evenly to all 96 pots each day using a spray bottle. Spraying was done in a fashion to simulate rainfall.

The experiment was monitored every morning for germination. Seeds were considered to have germinated when a plumule emerged above soil surface. A set of four replicates per site were harvested at weekly intervals for three weeks following planting. Plant fresh and dry weights were measured at each harvest. The changes in dry biomass over time were used to calculate daily production rates and Relative Growth Rates (RGR) (Blackman, 1919) for each site.

Statistical evaluation of percentage germination, biomass production and RGR was done by means of an ANOVA. When significant differences were found, the means between sites were compared with a Fisher's LSD test. A regression analysis was used to test for correlations between germination, biomass production and RGR, and distance from the watering point at the borehole series (OK A-D).

RESULTS

GERMINATION

Seedlings of the grass *Stipagrostis spp.* (Leistner, 1991) and an unidentified dicotyledon were observed in some pots two days after planting. These were seeds present in the soils and not the experimental plants. They occurred in a few pots with soils from all sites except those from MOS and MON.

The planted seeds, Kikuju, started germinating on the third day after planting for all but two sites, MOS and MON. Germination at all sites exhibited a sigmoidal curve over time (Fig. 1 and 2). The lag time prior to the logarithmic phase for the MO sites was relatively longer (6 days) compared to all other sites (3 days). Total germination (Fig. 3) was highest at Okaumbaaha (OK) (85.33%) and lowest at MOS (40 %). This represents a difference of more than 50% between the highest and the lowest germination.

Piosphere results did not demonstrate a specific trend of correlation with distance (Fig. 1). The percentage germination over time was not significantly different between the sites in the borehole series. Significant differences (P>0.05), however, were detected when sites with varying grazing pressures were compared (Fig. 2)

BIOMASS PRODUCTION

Overall, the OK sites attained the highest total plant biomass (31.455 mg) followed by OT (25.52 mg) whilst MOS only produced 7.42 mg after 22 days (Fig.4). OM yielded the highest biomass (14.12 mg) at the first harvest (Fig. 5) while MOS had zero. However, OM did not show an increase in biomass between the second and third harvests (Fig. 5). Only sites OK and OT showed a consistent linear increase in biomass production over the three harvests (Fig. 5). The remainder of the sites all show a decline in biomass production between the second and third harvests (Fig. 6).

Although the piosphere results (OK) showed a trend of decreasing daily production with increasing distance from the borehole (Fig. 7) these differences were not significant (P>0.01) at the first and second harvests. At the third harvest OK A (at the borehole) was significantly higher than the others (Fig. 7) at the third harvest. Daily production at sites OT and OM only differed significantly from the MO sites at the first and third harvests (P>0.01) (Fig. 6).

RELATIVE GROWTH RATE (RGR)

The RGR for the borehole series showed an increasing trend over distance from the borehole (Fig. 8). The RGR decreased with every harvest for all but one site, MON (Fig. 9). This site showed an increase in RGR between the first and second harvests, but decreased from the second to third harvest. More peculiar among these results is MOS which showed no RGR at first and second harvests and a negative growth rate at third harvest.

DISCUSSION

GERMINATION

The "wild seedlings" that germinated in some samples indicate the presence of a viable seed bank in those soils. This seed bank could be used for assessing the degree of degradation, as the make-up of a seed bank will determine the subsequent vegetation (van der Walk and Pederson, 1989). Therefore this seed bank could be considered an indicator of rangeland quality. If a seed bank was composed of seeds of an undesirable plant species (for a given management system), it would indicate deterioration of the rangeland. Unfortunately, it was not possible in this study to recognize and distinguish all the plant species which germinated. This lack of comprehensive plant identification hindered a complete appraisal of rangeland conditions based on seed banks because the fodder quality of the plants was not known. They could thus indicate either good pasture or a deteriorating rangeland.

Germination is a function of various physical, chemical and biological properties of both the seeds and the medium (Mayer and Pojakoff-Mayber, 1989). These components may act *en masse* in bringing about germination of seeds (Baker, 1989) but the combination of temperature and water is the most critical (Mayer and Pojakoff-Mayber, 1989). Since the seeds were homogenous, the soil properties should have played the major role in germination differences.

The most prevalent differences between the soils was in their textures. The soil from the MO sites was finely textured and silty, in contrast to the more coarsely textured sandy soils from the rest of the sites. These differences have a profound bearing on the water relations of soils. Water moves unobstructed through porous sandy soils and much slower through the smaller pores of silty soils. The resulting effect is that sandy soils drain faster to field capacity than silts or clay (Day and Ludecke, 1993). In addition, the fine texture in this soil caused crusting that occurred at each watering. Such crusts also slow water infiltration. This assertion is supported by Grainger's (1992) contention that silts and compaction make soils less permeable. It can therefore be expected that it took longer to saturate the 1 cm seed bed in the MO sites than the sandy soils.

Harper and Benton (1966) mention that the most essential prerequisite for germination is water uptake by seeds, such that deficient and delayed hydration results in slow germination. This disruption in water infiltration and permeation could explain the longer lag in the MO sites. Due to their similarity in texture, the germination rate between the other sites was not significantly different.

Efforts to avoid crusting of soils through watering proved to be futile on soils from the MO sites. Such a crust might have been hard for the plumules to crack and emerge above surface. This might have caused the low total percent germination for these sites since germinated seedlings that failed to emerge would not be counted. These results are in line with findings by Bloom (1976), which showed a low percentage of seedling emergence from compacted soils.

BIOMASS PRODUCTION

Unlike germination, the production of biomass by plants is more a function of soil fertility, nutrient composition and availability (Charley and Cowling, 1968), rather than water uptake. The nutrients recognised as the most frequently limiting are nitrogen (N) and phosphorus (P), though it is often not their total quantity but their availability that is important (Charley and Cowling, 1968).

Shoot biomass is positively correlated to soil N and water (Klinkhamer and de Jong, 1985). Nutrients and water interact in their effect on plant growth. Water plays a principal role in nutrient uptake by plants (Turner and Kramer, 1980) and water use efficiency decreases in plants under conditions of nutrient stress (Trumble and Wooddroffe, 1954).

Nutrient acquisition by plants involves the exchange of elements between the soil solution and plant roots. Important elements in this regard are calcium (Ca), potassium (K) and sodium (Na) (Singer and Munns, 1987). The soils used in this study differed significantly in many of these nutrients but was not limiting in any of them (Mouton in this volume). As an example, the silty soils from the MO sites had higher P and pH values, possibly due to the high concentration of accumulated salts and the silty texture. However, the poor water permeability could make the P unavailable to plants. Thus low nutrient availability, not quantity, may have resulted in low biomass production on these soils compared to the other sites.

The borehole series at Okaumbaaha (OK), with the exception of OK D, suggests a productivity gradient with distance from the borehole. The anomalous behaviour of OK D may be attributable to the proximity of the borehole, where livestock spends a lot of time waiting to be watered. These animals deposit nutrients into the soil in the form of dung and urine while simultaneously trampling any plant sprouts. The end result of this is an increased nutrient content but little vegetation (See Jobst and Mouton in this volume) to exploit this nutrient source.

Romney and others (1994) suggest that urine and manure are the only available external nutrient inputs in agricultural smallholdings. The nutrients incorporated in dung must first be broken down into inorganic forms whereas the N in urine is immediately available (Romney et al., 1994). Furthermore, the watery dung produced by cattle decomposes very slowly, so that most of the available N at the borehole site is probably from urine. The increase in dry weight of site OK D (Fig. 7) might have resulted from these high available N levels in the soils. Day and Ludecke (1993) report that ample N boosts rapid plant growth and development, primarily during early growth. These levels of N can not be expected at the sites further away from the borehole. These sites exhibited a slight degree of acidity relative to OK D (Mouton, this volume), which might signify the leaching of soluble salts (Day and Ludecke, 1993). Even if the leaching losses at OK D are similar to the other borehole site, the regular deposition of nutrients by livestock will maintain a high content.

The decrease in biomass production by OK D (Fig. 7) at the third harvest might be explained by the high volatilisation of urinary N (urea) (Ryden et al., 1987). High pH, coarse texture and low ESP favours volatilisation of NH_3 (Fisher et al., 1987). These parameters were all detected in soils at OK D.

Watering could also have played a role as unusual wetness reduces N availability (Fisher et al., 1987) through denitrification. Microbial activities consume N under good soil moisture conditions through microbial biomass production and denitrification (Westerman and Turker, 1978; Singer and Munns, 1987). However microbial biomass N levels drop during the dry season as some of these organisms die and release N (Bottner, 1985). Since no plants are actively growing and leaching losses are minimal during the dry season, the N released by microbial mortality remains in the system. With the first wetting, plants benefit, but as microbes multiply they may out-compete plants in N consumption.

These processes may explain the general decreasing trend in biomass over time (Figs. 6, 7, and 9). Sampling was done at the end of the dry season, therefore N could already have been released by dead microbes producing high soil N levels at the commencement of the experiment. Wetting the soils during the experiment would have revived the microbes and resulted in increased microbial N consumption with time. There is however no information on the exact time periods for this sequence of N cycling in this area. The microbial recovery time may take longer than the duration of this experiment.

The linear increase in biomass production at site OK A may be due to the high quantity of aboveground debris which could serve as a longer term source of organic N for the nutrient mineralisation. In addition, the nutrients at this site may have been sufficient to sustain continuous production of biomass as well as microbial activity.

RELATIVE GROWTH RATE (RGR)

Most of what has been advanced for biomass production is equally applicable to RGR, as this is nothing but a measure of the incorporation of nutrients into plant material. The trend of decreasing RGR observed over time for the sites (Fig. 9) may be due to changes in soil nutrients availability and increased competition from microbes.

A fresh seedling initially depends on stored food reserves in the seed before it starts to photosynthesize its own food. It is during this latter stage that drawing nutrients from the soil becomes vital. This may explain the relatively higher RGRs at the first harvest. As time progressed, the resource base in the soil might have become more limiting as microbial population increased, resulting in lowered RGR. The apparent increase in RGR of MON on second harvest is more an artifact of the low germination percentage at first harvest which produced a low first RGR.

There were no nematodes or termite activity and probably limited populations of other soil organisms at the MO sites (Nghitila, this volume). This would mean that upon depletion of available (inorganic) nutrients, mineralization of the organic forms would be limited. This may explain the negative RGR's of the MOS site. The forbs and grasses that were found at MON could provide an explanation for its difference to MOS. Nutrients could have built up from the decomposition of this vegetation over time.

The negative result for OM at third harvest may havebeen the result of the very high initial RGR, meaning that due to high growth in the first week, the plants had depleted the soil nutrients. Consequently there were not enough nutrients to sustain growth after three weeks.

CONCLUSION

All indications from this study of soil productivity point to the existence of desertification, or the active operation of the processes that may culminate in desertification, in the Erongo and Kunene regions. The mathematical results may not always show significant differences in these trends, but their ecological basis and implications are clear. A slight difference in annual production may culminate in critical differences over the years. If less and less vegetation grows to produce seeds and bank them in the soils, the accumulated effect over time might be the disappearance of those species from that area.

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Fig. 1. Seed germination in soils from the piosphere study area.

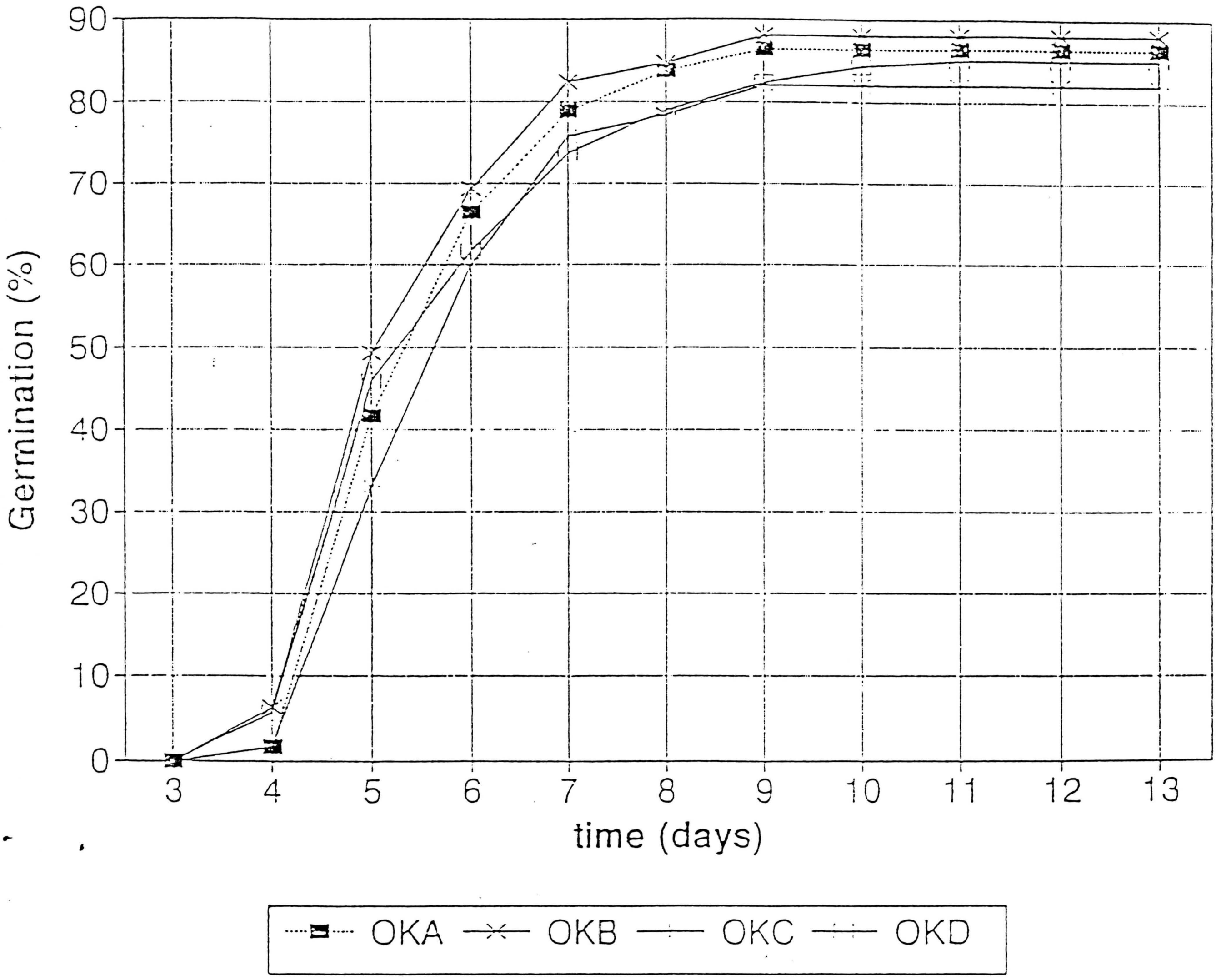


Fig. 2. Seed germination at heavily (MOS and OM), moderately (MON), and lightly grazed (OT) sites.

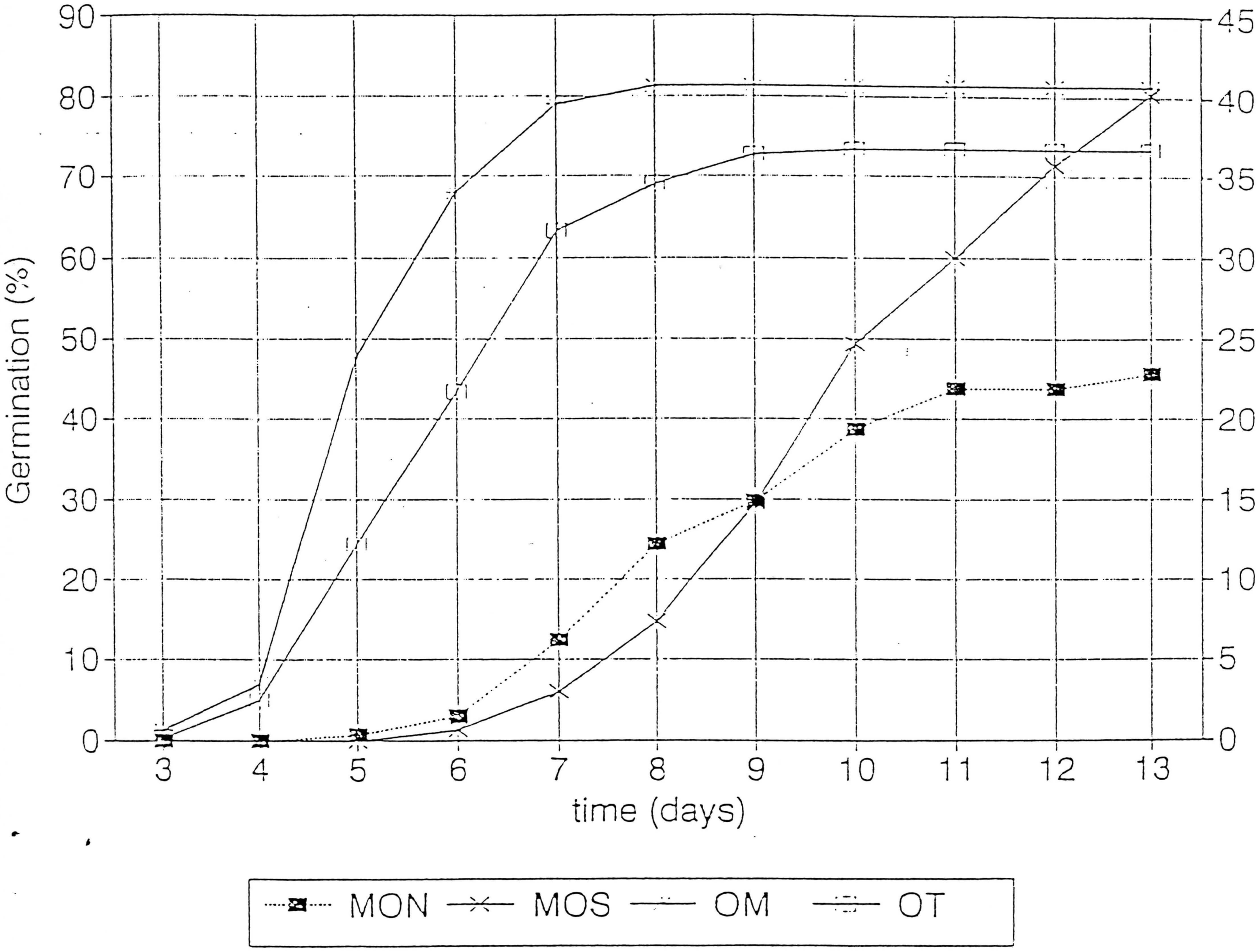


Fig. 3. Total average germination at the five study sites (OK is an average of the four piosphere sites).

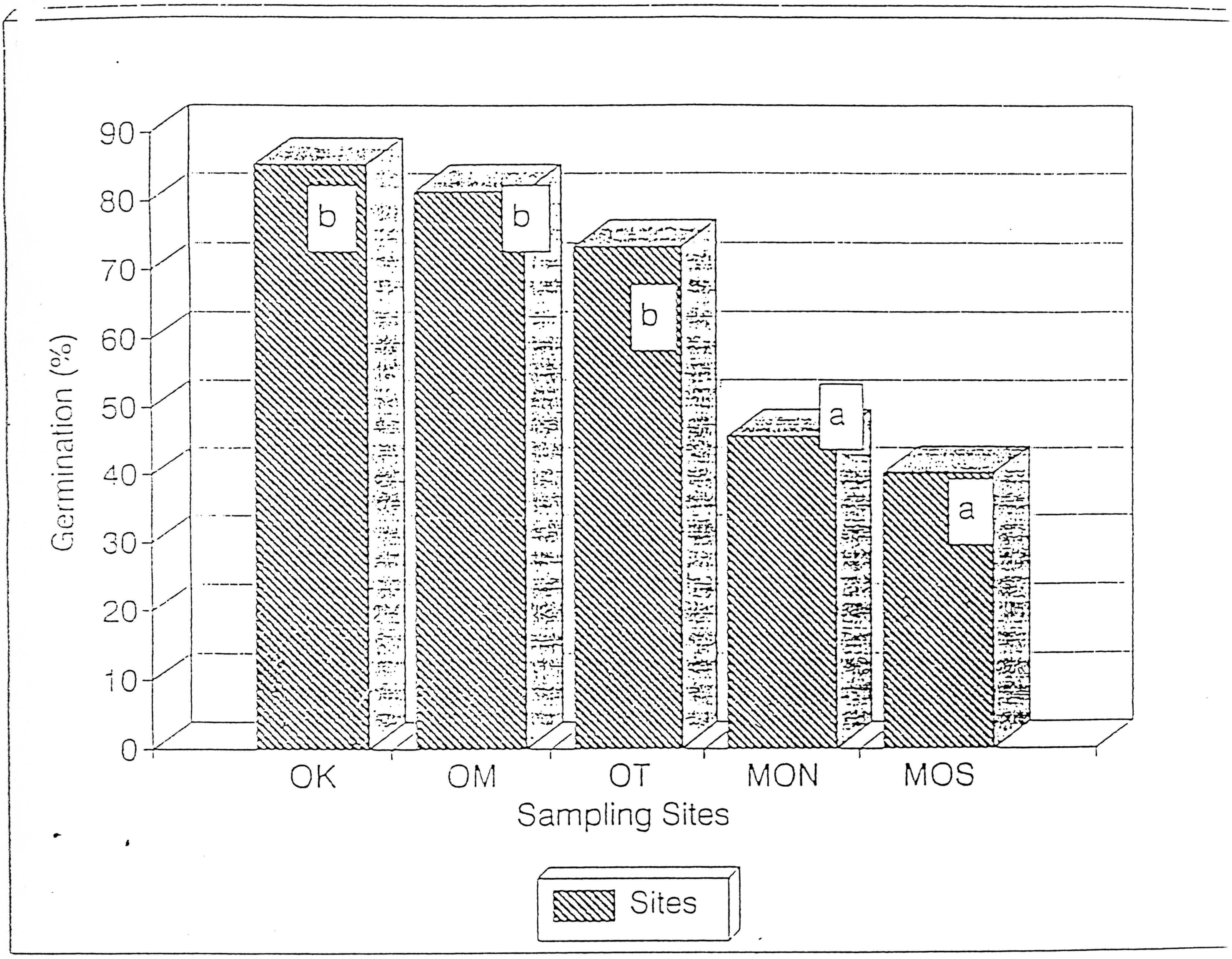


Fig. 4. Final average biomass production (mg/pot) at the five study sites (OK is an average of the four piosphere sites).

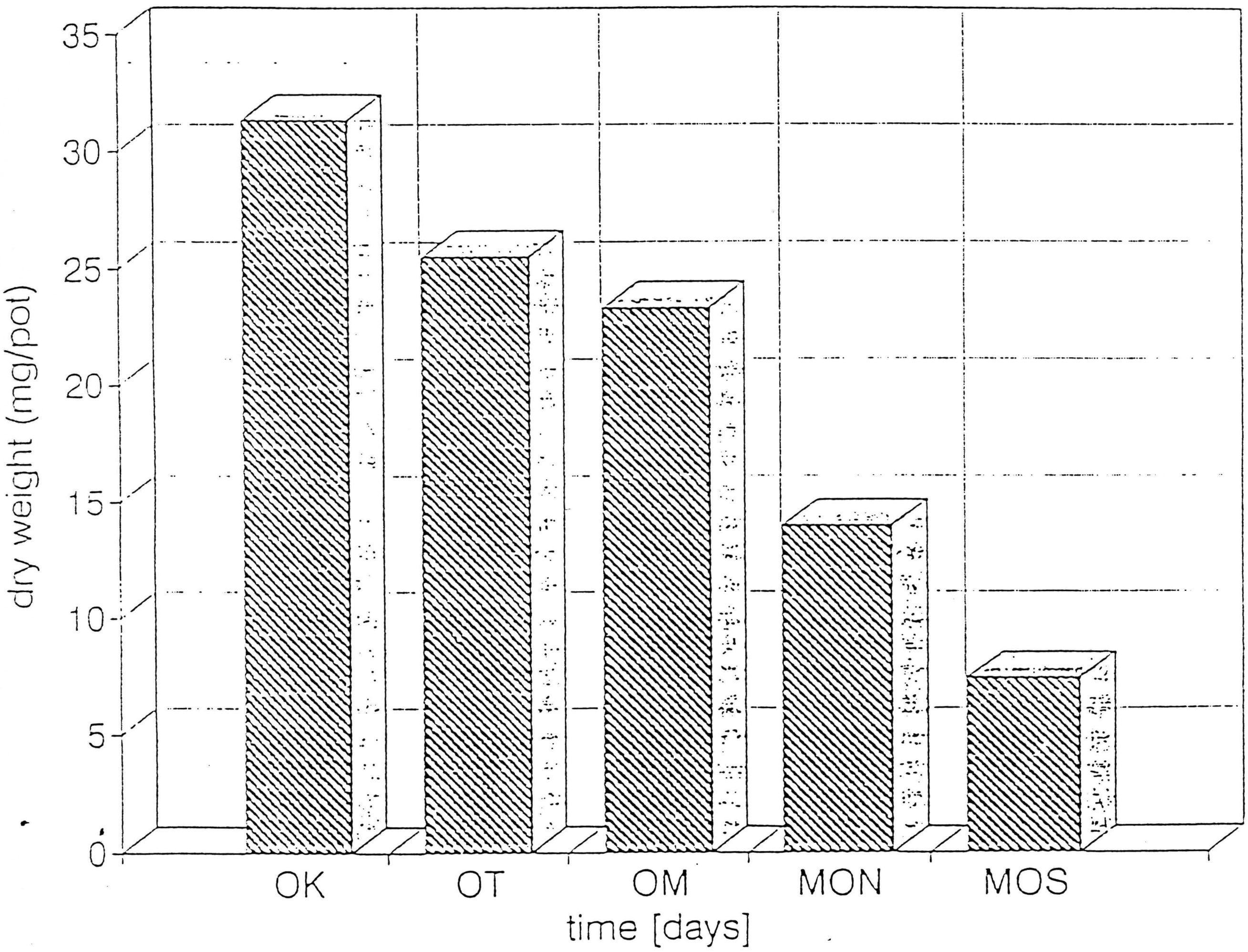


Fig. 5. Biomass production (mg/pot) over time at the five study sites (OK is an average of the four piosphere sites).

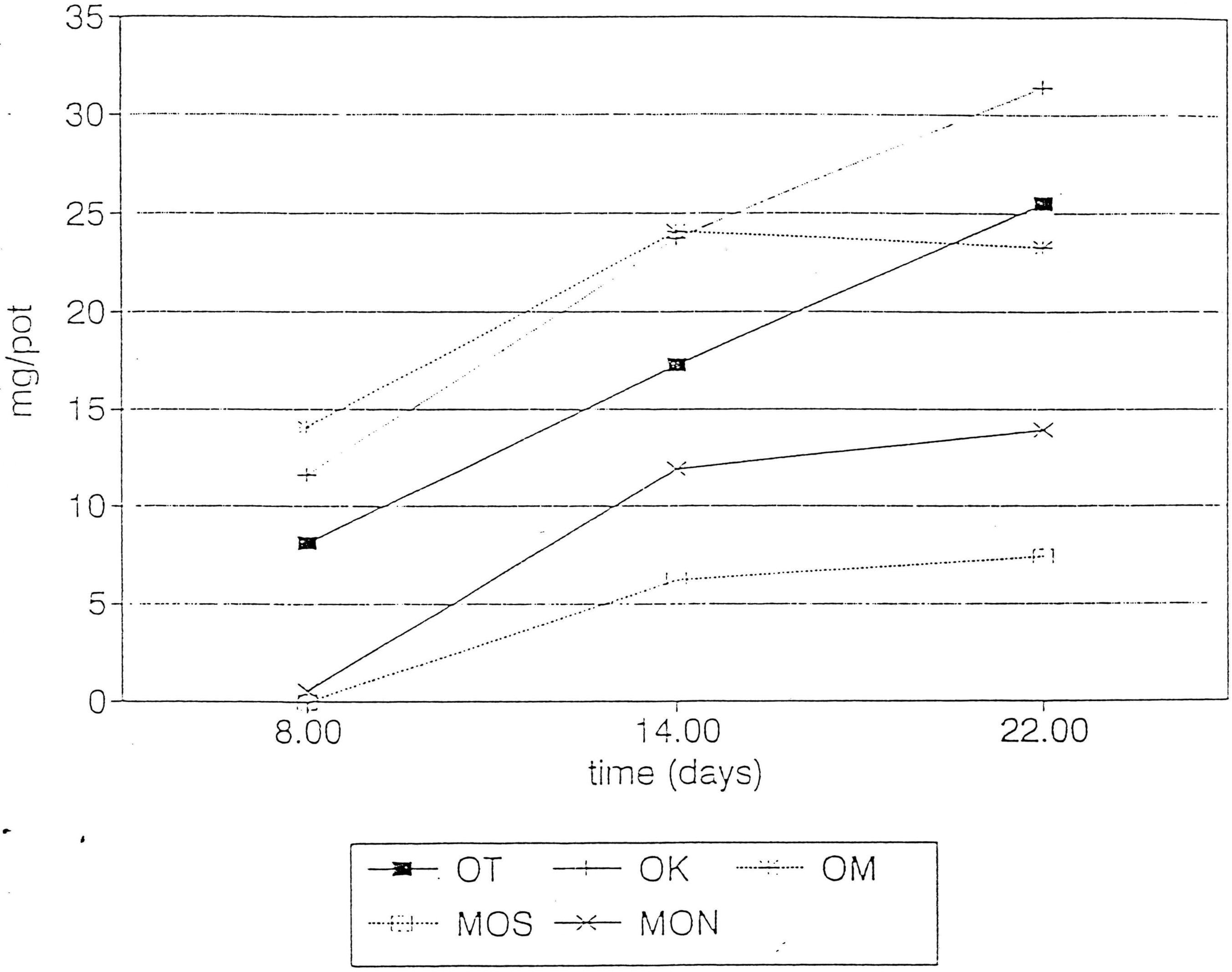


Fig. 6. Changes in daily biomass production over time at heavily (MOS and OM), moderately (MON), and lightly grazed (OT) sites.

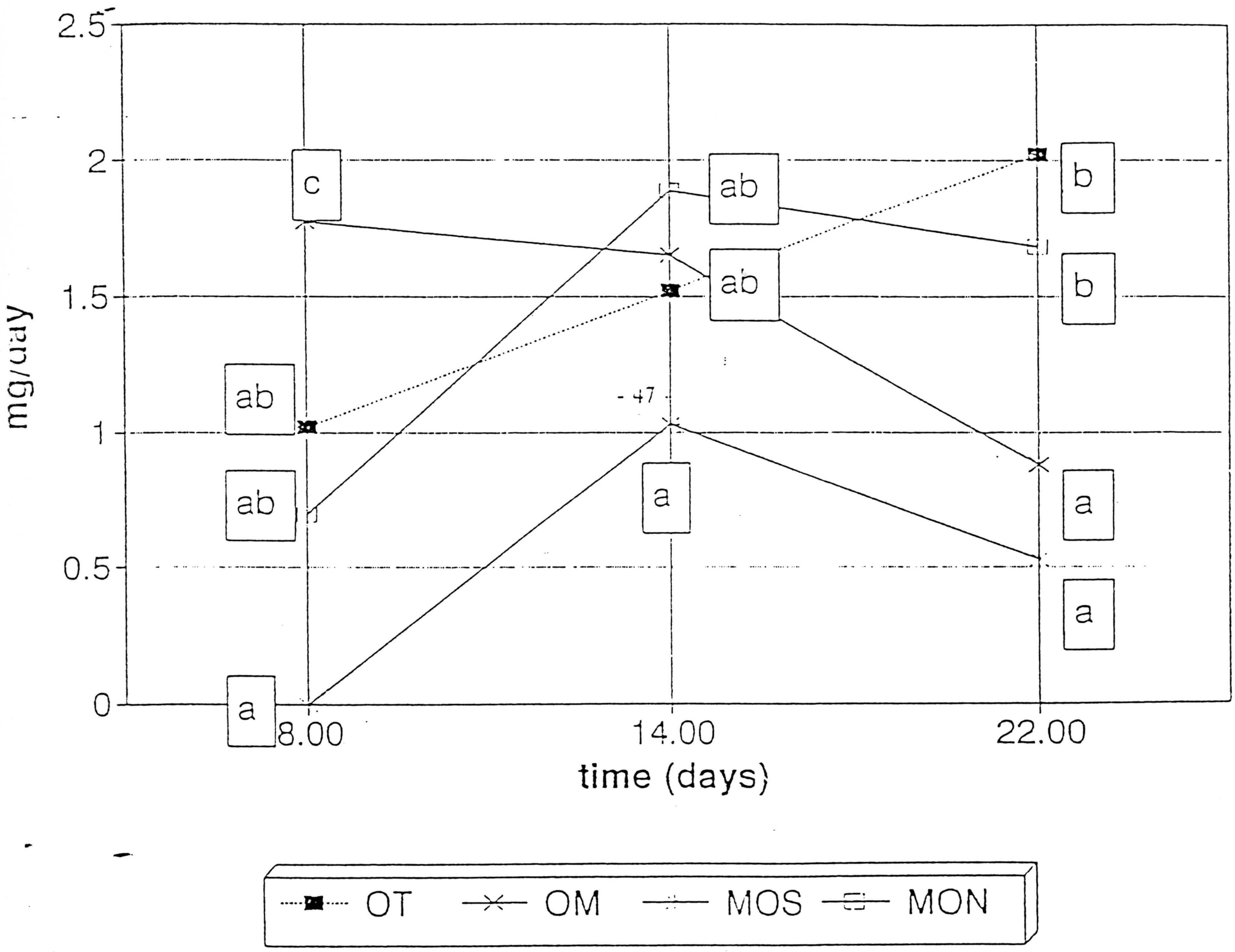


Fig. 7. Changes in daily biomass production over time across the piosphere site.

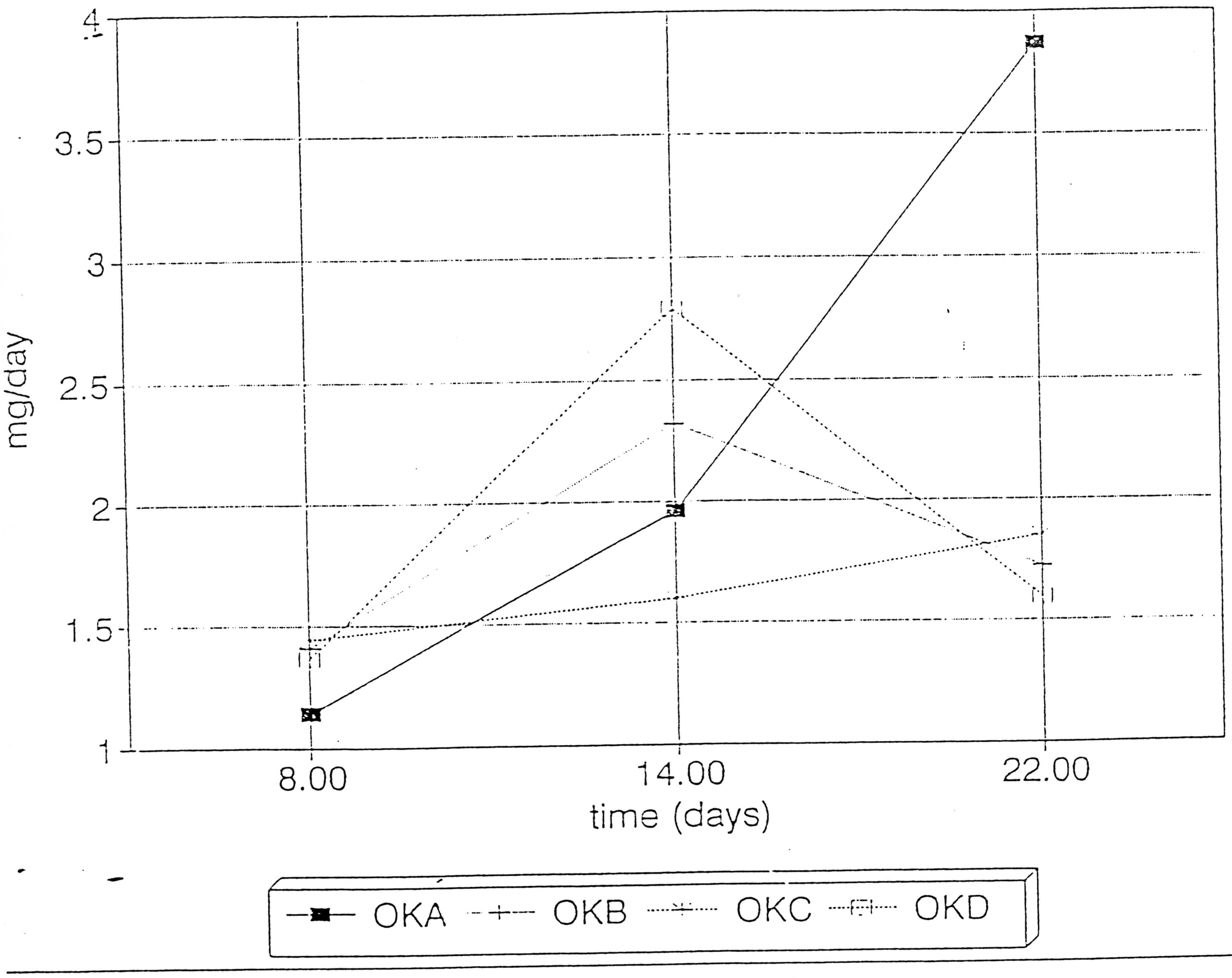


Fig. 8. Relative growth rates across the piosphere site.

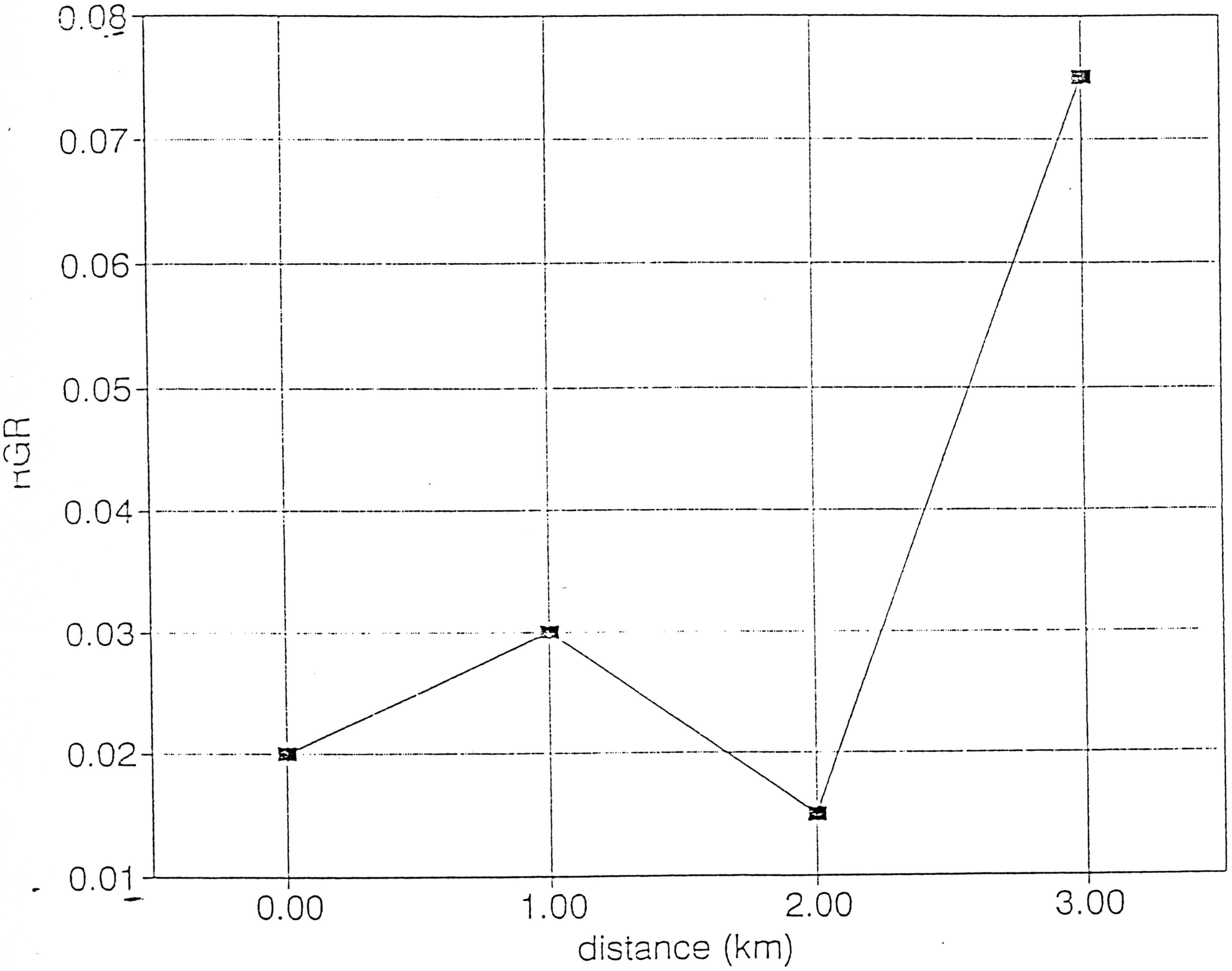
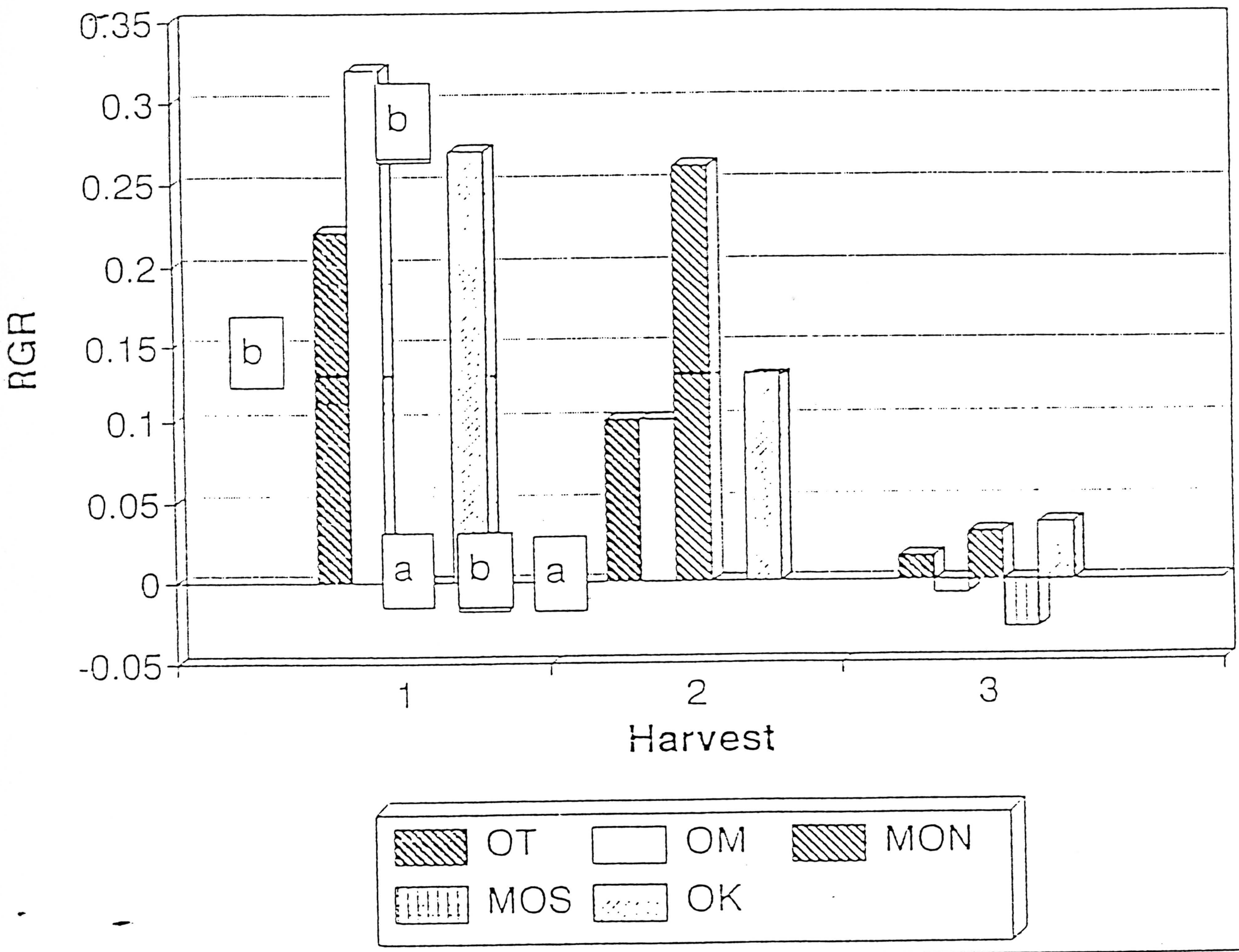


Fig. 9. Relative growth rates over time at the five study sites (OK is an average of the four piosphere sites).



SELECTED SOIL FLORA AND FAUNA AS INDICATORS OF BIOTIC INTEGRITY IN NORTHWESTERN NAMIBIA RANGELANDS

T.M. Nghitila

ABSTRACT

To assess rangeland conditions in Northwestern Namibia, some soil fauna and flora were sampled across a range of grazing intensities. This allowed a comparison of potential biological indicators for estimating rangeland degradation. Nematodes, seed banks and termite activity were used as indicators. In aggregate, these applications demonstrated the applicability of selected soil microorganisms as indicators of biotic integrity for evaluating rangeland degradation. This study showed a correlation of these soil parameters with rangeland degradation and grazing pressure.

INTRODUCTION

Indicator species have been used for decades as a convenient assay of environmental conditions (Landres et al., 1988). The ideal biological indicator would distinguish natural against anthropogenic variation. It would be sensitive prior to severe damage and to a range of stress types and levels, and hence help to identify the cause of degradation. Biota are good indicators because they integrate cumulative effects and temporal variations. Undegraded biological systems have distinctive structures and functions. The departure of ideal biological indicators from their pristine condition would be correlated with a certain degree of degradation (Angermeier and Karr, 1994).

Soil biotic communities are responsible for the decomposition of organic matter involved in many aspects of nutrient cycling. They also help develop and maintain pore spaces through which gases and water flow, and interact in both beneficial and detrimental ways with plant roots (Freckman, 1989).

Nematodes are a diverse group of roundworms that occurs worldwide in virtually every environment (Abu-Irmaileh, 1994). Under normal conditions (i.e. temperature, rain and nutrient availability), they are abundant inhabitants of the soil in a variety of ecosystem types. They play a role as primary consumers and hence help supply energy for the soil ecosystem (Yeates et al., 1993; UNESCO, 1994). Due to their generally ubiquitous presence, a lack of nematodes could indicate land degradation.

The soil seed bank is the aggregate of ungerminated seeds that are potentially capable of replacing adult plants (Roberts, 1981). Normally, annual plants germinate yearly from seed, while perennials only need replacement following mortality due to disease, disturbance, or consumption by animals including man. Increased seed consumption or a lack of replacement of existing seeds adversely affects the natural regeneration process. This can ultimately lead to environmental degradation (Parker and Simpson, 1989). In arid and semi-arid systems, vegetation cover can decrease significantly during drought periods, making them appear to be degraded. However, an intact seed bank can quickly restore this cover after recurrence of rain.

Termites are social insects that live in communities, large or small, within the limits of a nest system. They build their nests underground or within trees or tree stumps. A wide variety of plant material serves as food for termites, including living and dead wood, grasses, herbaceous plants and their debris, fungi, humus and dung. In habitats where most of these food sources are found, a large proportion of energy resources of the ecosystem are potentially available to termites (Kemberly et al., 1973). Termites are a common member of the detritivore community in the Namib Desert (Crawford and Seely, 1994). Termite activity in an environment indicates active cycling of nutrients (Kemberly et al., 1973). Therefore, a decrease in nematodes (Kemberly, et al., 1973), a small seed bank and a lack of termite activity could be indicative of land degradation, particularly if there is a simultaneous decrease in all three.

The western part of Namibia has an arid climate. It receives the lowest precipitation and is frequently subject to severe and lengthy dry periods (Jacobson et al., in press). Because of decreasing grass and vegetation cover in this region, it has been suggested that the land is being degraded. However, it is difficult to distinguish degradation from the normal vegetation fluctuations in response to low rainfall. This study attempted to correlate selected soil fauna and flora parameters with rangeland degradation and grazing pressure.

Nematodes, seed banks and termites were chosen as biological indicators of degradation because of their roles in ecosystem functioning.

MATERIALS AND METHODS

GENERAL SITE DESCRIPTION

The Erongo and Kunene regions are situated in northwestern Namibia. In these regions, surface water is mainly restricted to ephemeral rivers (Hoarusib, Unjab, Huab, Ugab and Omaruru). The landscape is dominated by mountainous terrain, hills and plains. The annual rainfall ranges between 100-300 mm and the vegetation is sparsely distributed (van der Merwe, 1983).

SAMPLING PROTOCOL

Soil samples were collected in December 1994 at the beginning of the rainy season. The first day of sampling followed rainfall of 12 mm and therefore the soil was moist; the remainder of the soils were dry at sampling. The sample sites were chosen to represent a range from low to high grazing pressure.

An area of 2500 m^2 was measured at each site. Samples were taken within this area at four randomly selected 1 m^2 quadrats. Soil samples were taken to a depth of 5 cm in each quadrat. Each site was also visually inspected for sign of termites, other animals and fungi. In addition, the woody vegetation was counted and most of the dominant herbaceous species determined and sampled. The soil samples were sieved through a 4 mm sieve and subsamples used for nematode and seed bank analysis.

LABORATORY PROTOCOL

One 50 g subsample/quadrat was incubated moist for three days. The sample was then wrapped in cotton gauze and submerged in water in a funnel with a tube attached. Nematodes that moved down the tube were collected and counted under a microscope at a magnification of 32X (Jacobson, pers. comm., 1994).

The flotation method was used to evaluate the grass seed bank at each site. A 100 g subsample from each site was suspended in a saturated potassium carbonate solution (de Villiers et al., 1994; Roberts et al., 1981). Inorganic particles were removed by draining, while the remaining solution, containing the organic matter, was sieved through a 1 mm sieve. The organic matter was examined under a stereo-microscope and grass seeds were counted.

Termite activity was determined by direct observation on-site and given a qualitative rating. Results were analysed statistically using an ANOVA. Then, the means of nematodes and seeds obtained for each site were compared using a Fisher's LSD test. The differences were considered to be statistically significant at $P>0.05$ level.

Description of Specific Sites

Omatjete Area:

Site 1. Otjivero:

Site 1 was located 15 km southeast of the village of Otjivero on a rocky calcareous surface. The sampling followed a rain of 12 mm and, therefore, the soil was moist. There was no watering point in the vicinity and this site was classified as a lightly grazed area.

Sites 2-5. Okaumbaaha:

Site 2.

This site was situated 3 km from a watering point and about 25 km south-southeast of the Otjivero village. It was also classified as a lightly grazed area.

Site 3.

This site was located 2 km from the watering point, and about 24 km south-southeast of Otjivero. This site is dominated by an uniform distribution of *Parkinsonia africana* bushes. The site is classified as moderately grazed.

Site 4.

Situated 1 km from the watering point and 23 km south-southeast of Otjivero. The dominant woody species at this site was *Acacia tortilis*. An unpalatable grass species, *Aristida adscensionis*, occupies a third of the site. There was evidence of some sheet erosion. This site was classified as overgrazed.

Site 5.

This site was at the watering point, within an alluvial flood plain, about 22 km south-southeast of Otjivero. The site was near a settlement as well as the borehole. The site was barren of vegetation except *Acacia tortilis* and was classified as severely overgrazed.

Site 6.

Site 6 was located about 50 km southwest of Otjivero and 15 km from a watering point. *Terminalia* sp. was the dominant woody species at this site. This site was attacked by locusts in September 1994 (Tjimune, pers. comm.). The site was classified as overgrazed.

Twyfelfontein Area:

Site 7 and Site 8.

This area was situated about 15 km from Twyfelfontein, and appropriately known as the Moonlandscape. Site 7 was south of the road. At this site there was evidence of a kraal, a garden, a homestead and an old watering point, suggesting that the site was once a farmhouse or cattle post. The soil had a fine-textured surface with little evidence of organic matter accumulation. The site had a crusted surface and evidence of erosion (both sheet and gully). All of this indicated past trampling and overgrazing. The site was barren and therefore classified as severely overgrazed. Site 8 was on the north side of the road and included a water accumulation area. There was some evidence of erosion between plants. The site was classified as moderately grazed.

RESULTS

The average indicator numbers at each of the eight rangeland sites are given in Table 1 and Figs. 1 and 2.

The observed termite activity at sites classified as overgrazed was less than that at lightly grazed sites. Site 1 had more plant cover which served as food, nest-building materials and heat protection from the sun. Sites 5 and 7 had no vegetation cover and therefore none of the preferred food for termites.

Table 1. Grazing intensity classification and termite activity at each of eight rangeland sites in northwestern Namibia.

Site	Grazing Intensity Classification	Termite Activity *
1.	Low	++
2.	Low	+
3.	Moderate	+
4.	High	++
5.	Very high	+
6.	High	-
7.	Very high	--
8.	Very high	+

* ++ high termite activity
\+ moderate termite activity
\- low termite activity
-- no evidence of termite activity

Site 1 which was classified as less grazed, had the highest number of seeds/100 g soil (4). Grasses, shrubs and trees were more abundant at that site compared with more heavily grazed sites, such as sites 5, 6, 7 and 8.

Site 2 which was considered moderately grazed had the highest number of nematodes/50 g soils (3). The most heavily grazed sites (Sites 5, 7 and 8) had significantly ($P>0.05$) lower numbers of nematodes than some of the less heavily grazed sites (Sites 2–4). However, the number of nematodes at Site 1, considered to be a lightly grazed site, were not significantly different from those at the heavily grazed sites. Further, Site 6, considered to be a heavily grazed site, did not have significantly lower nematode numbers than Sites 2–4.

DISCUSSIONS AND CONCLUSIONS

Although it is not possible to determine conclusively whether the indicators chosen were appropriate for determining the extent of rangeland degradation in this region, they did have some correlation with grazing pressure.

The sites studied exhibited different levels of degradation which could be explained primarily by differences in human and animal impacts rather than natural occurrences. The results that emerged for all three indicators generally supported other measures of degradation (see Jobst, Mouton, and Kambatuku, this vol.). There were smaller or non-existent seed banks in soils from apparently overgrazed sites (i.e. Sites 6, 7 and 8) compared to those believed to have lower grazing pressure (Sites 1 and 2) (Fig. 1). The same situation was true for termite activity (Table 1).

The nematode data was not as well correlated (Fig. 2) with other degradation parameters as the seed banks and termite activity. However, all but two sites (Sites 1 and 6) followed the pattern observed by the other two variables. The apparently anomalous results for these two sites could reflect a real lack of correlation between nematodes and degradation in these systems. Conversely, it could be due to unknown factors at these two sites or unknown sampling errors. Further research is needed to clarify the suitability of nematodes as indicators in this system.

These results suggest the existence of processes that may lead to land degradation or desertification in this part of northwestern Namibia. Although nematodes did not work well as indicators in this study, both the seed banks and the termite activity suggested that degradation is occurring. This is an example of the importance of using several indicators instead of just one to improve assessment of a system as complex as an ecosystem (Angermeier and Karr, 1994). Further study on the indicator effectiveness of the three soil organisms studied should be conducted. This information could then help the desertification assessment and monitoring in arid areas in general and in Namibia in particular.

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Fig. 1. Number of seeds at the eight study sites. Values are means of four quadrats, those with the same letter are not significantly different.

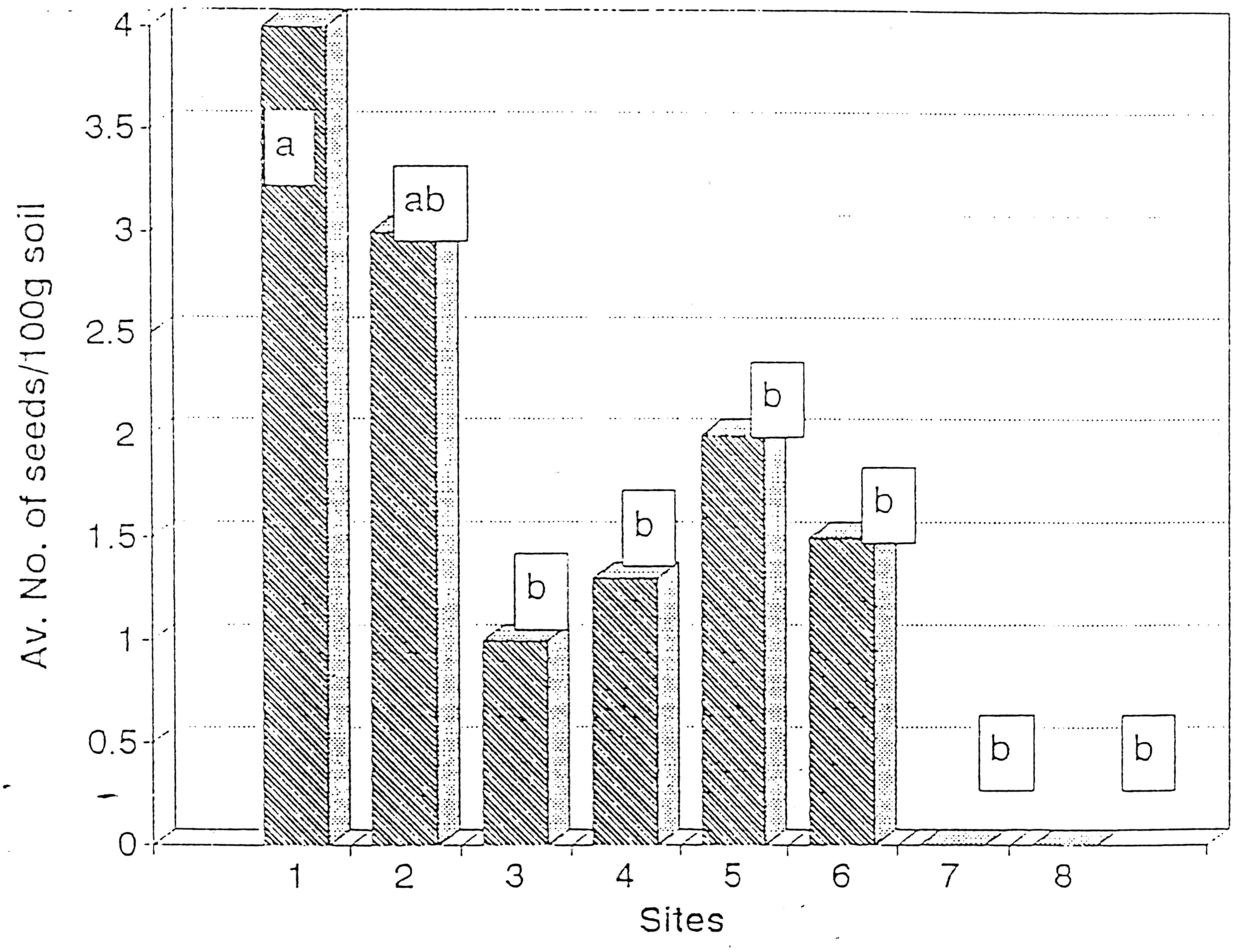
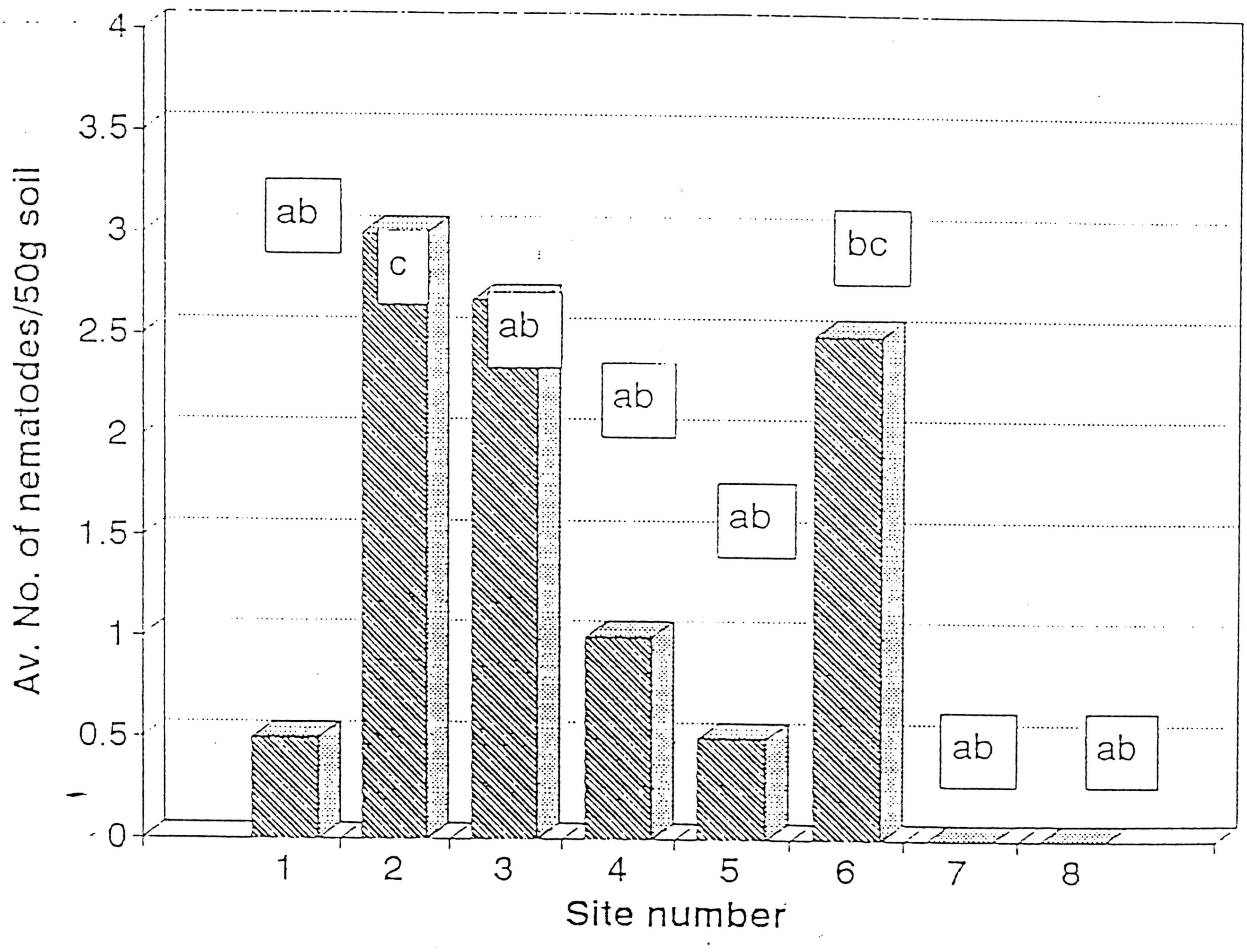


Fig. 2. Number of nematodes at the eight study sites. Values are means of four quadrats, those with the same letter are not significantly different.



RANGELAND DEGRADATION AND MANAGEMENT OPTIONS FOR NORTHWESTERN NAMIBIA: USING THE INTEGRATED SYSTEM FOR PLANT DYNAMICS (ISPD).

S.E. Shanyengana

ABSTRACT

Inappropriate land-use practices and policy, increasing population and demand for land, as well as unfavourable climatic conditions play a prominent role in rangeland degradation within the Kunene and Erongo regions in northwestern Namibia. This study explores the usefulness of a newly developed ecological model, Integrated System for Plant Dynamics (ISPD), in the development of sustainable rangeland management in communal areas within these regions. The ecological condition was assessed using qualitative and quantitative biophysical information. This information, plus information from the literature, was further used to develop both grazing capacity and management strategy models for the area. It is critical to avoid degradation in arid and semi-arid ecosystems. The ISPD system can serve as a useful tool in the development of sustainable rangeland management in northwestern Namibia, and Namibia at large.

INTRODUCTION

Ecological rangeland models have been used extensively around the world over the last few decades (Walker, 1993). They can provide a simplified interpretation of the condition, function and dynamics of rangeland ecosystems. Ecological models often help integrate purely scientific research with socio-economic work, thus acting as a research and decision support tool.

The Integrated System for Plant Dynamics (ISPD) model was developed from a combination of different computer software packages. The system examines rangeland condition and can be used to propose grazing capacities and management options suitable for a given rangeland (Bosch and Gauch, 1992). The model elucidates a degradation gradient based on biophysical data, which is used to assess the extent of degradation in a given rangeland.

The ISPD system has been used extensively to determine degradation in Southern African grasslands (Bosch, 1989). It is currently in use, either as a research or decision support tool, in several agricultural sectors and research institutes around the world (Booysen, pers. comm. 1995).

Southern Africa, and Namibia in particular, has recorded centuries of successful nomadic pastoralist land use systems, (Jacobson et al., in press; Marsh and Seely, 1992; Lau and Reiner, 1993; Kinahan, 1991). Nomadic pastoralism has been replaced with sedentary subsistence farming in the Kunene and Erongo regions of northwestern Namibia. The current subsistence farming system, however, appears unsustainable due to factors such as increased human population pressure, inappropriate national policies and land use practices, as well as natural resource management strategies. These factors are exacerbated by episodic drought events and the extremely low and variable rainfall in the area. All these factors impede sustainable rangeland management in the Erongo region.

Land-use practices in this part of Namibia include subsistence communal livestock farming, small and large scale tourist catering facilities and small scale vegetable gardening. However, the sustainability of these land use practices is unknown. The subsistence communal farmers in these regions are the people the most affected by this apparent lack of knowledge and proper management systems.

Inappropriate national policy on natural resource use, poor land use and management practices, uncoordinated donor aid, and the lack of base-line information on rangeland dynamics are principal contributing factors to mismanagement (Jacobson et al., in press). These factors have a severe negative impact on sustainable development in these communal areas (Seely and Jacobson, 1993).

This study assessed the ecological condition of the rangelands within northwestern Namibia using biophysical data collected in the field and the ISPD model. The objectives of the study were not only to assess the rangeland condition, but also to determine the grazing capacities and propose possible management options for the area based on this model. The study served as a trial for the ISPD system's applicability to Namibia's communal rangelands.

COMPUTER MODELLING

The degradation gradient used for the quantitative and qualitative condition assessments in ISPD stretched 3 km from a watering point. This gradient was reinforced by incorporation of additional sites within the study area which represented lightly grazed, moderately overgrazed, and severely overgrazed scenarios (Sites 1, 6, and 7 and 8, respectively). Although special attention was given to sampling a range of grazing pressures, time constraints limited the sample size below that which is preferred by the model.

Information from the literature and knowledge of the region were used to develop a grazing capacity module for the Otjihorongo and Okombahe areas. The calculated grazing capacity, with other literature values, was then used to develop a management strategy module specifically designed for use in communal farming areas.

RESULTS AND DISCUSSION

The soils and vegetation data from specific sites are presented in Tables 1 and 2.

Table 1: Soil characteristics at the sampled sites.

Site Nos.	Type	Erosion	Infiltration Rate
1	Sand	1	.072
2	Sand	2	.142
3	Sand	2	.168
4	Sand	3	.135
5	Sand	5	.222
6	Sand	3	.179
7	Silt loam	5	.074
8	Silt loam	4	.094

Table 2: Vegetation at the sampled sites.

Site Nos.	Relative % Cover	Dominant Grass	Shrub	Bush / Tree
1	81%	ERNI	INDF	CAAL
2	57%	STOB	DICOM	ACUR
3	100%	STCI	DECOS	PAAF
4	59%	ARAD	none	ACTO
5	0%	none	none	ACTO
6	40%	ERNI	INDF	TERM
7	0%	none	none	none
8	27%	unknown	SESB	COMO

Abbreviations:
ACTO: *Acacia tortilis*; ACUR: *Acacia urncinata*; ARAD: *Aristida adscensionis*; CAAL: *Catophractes alexandrii*; COMO: *Colophospermum mopane*; DECOS: *Decostachy sp*; DICOM: *Dicoma sp.*; ERNI: *Eragrostis nindensis*; INDF: *Indigofera sp.*; PAAF: *Parkinsonia africana*; SESB: *Sesbania SP.*; STCI: *Stipagrostis ciliata*; STOB: *Stipagrostis obtusa*; TERM: Terminalia sp.

DATA ANALYSIS:

The ISPD system has two ordination modules, i.e. DEtrended COrrespondence ANAlysis (DECORANA) and the Degradation MOdel Construction module (DMOC), whose functions are mainly to sort data and establish a degradation gradient. The first ordination (DECORANA) was to demarcate the boundaries of a relatively homogeneous grazing area (RHGA) within which differences in plant composition can only be attributable to grazing pressure. Sites 5 and 7 had to be eliminated immediately due to their barren nature. Then Site 8 was removed because its species composition appeared to be completely different from the other sites. The survey data from this site suggested a habitat different from the rest of the sites, perhaps due to the silty loam soil compared to the sand soils at the other sites.

Site 1 was also quite different from the rest of the sites, probably due to inadequate species data resulting from species identification difficulties encountered in the field. Removal of Sites 1 and 8 from the ordination produced an RHGA which included Sites 2–4, and 6. This RHGA had a grazing gradient extending from relatively less grazed to severely overgrazed.

The DMOC was then used to construct a degradation gradient. Refinement of the gradient involved removing species of relatively low frequencies or ones that were not indicative of degradation. This removal decreased the variability, as indicated by the second axis, resulting in an improved gradient (Fig. 1). Fig. 1 also lists the species that were used for the final gradient.

QUANTITATIVE CONDITION ASSESSMENT:

The degradation gradient established with the DMOC was based on the quantitative biophysical data recorded from the field, which was collected at the end of the dry season (early December, 1994). Species identification, especially after a long period of grazing after the last rains, was extremely difficult. Moreover, it is normal that unpalatable vegetation is more dominant during the dry season, compared to the growing season (Booysen, pers. comm., 1995).

Species distribution measurements were difficult because of the problems with species identification at this time of year. Consequently, the data set had to be augmented by published data (Gunster, 1993 and Nel, 1994) and prior knowledge of the area, which was then used in the qualitative condition assessment.

QUALITATIVE CONDITION ASSESSMENT:

A theoretical model of a good rangeland in the area was constructed with the aid of a qualitative condition assessment module within the ISPD package (Fig. 2). This assessment used information on species composition, species frequency and percentage bare ground from the field data, as well as published information, to build a theoretical grazing gradient. Sites 5 and 7 could not be qualitatively analyzed due to the absence of vegetation. However, it was assumed that their high percentage bare ground would position them close to zero veld conditions.

The Theoretical Site for good rangeland along this gradient was then compared to two of the sampled sites (Sites 2 and 3). The species composition and abundance reveal a better veld condition with high *Stipagrostis obtusa* and low *Geigeria ornativa* abundance compared to the higher *G. ornativa* abundance and lower *S. obtusa* for the low veld condition areas, e.g. Sites 2 and 3. The rest of the qualitative condition assessment results are provided in Table 3.

Table 3: Qualitative Condition Assessment results.

Site	Utilization Legend	Veld Condition	Confidence Level
1	Overgrazed	50.9%	51.3%
2	Overgrazed	48.8%	62.2%
3	Severely Overgrazed	40.1%	75.0%
6	Severely Overgrazed	40.1%	75.0%
4	Severely Overgrazed	40.1%	75.0%

The degradation process in semi-arid grasslands of Southern Africa is mainly characterised by changes in the ratios between palatable and unpalatable species (Bosch, 1989). The observed decrease in biomass of palatable and soil binding species such as *S. obtusa*, the consequent increase in biomass of unpalatable species, e.g. *Aristida adscensionis*, and the replacement of perennial with annual grass species, indicated overgrazing in the study area. *Geigeria ornativa* is restricted to the Namib/Karoo region (Nel, 1994). An Asteraceae, *G. ornativa* is very wind and drought resistant. It is however toxic and spreads with environmental deterioration, especially in overgrazed areas (Gunster, 1993; Nel, 1994).

Stipagrostis obtusa, unlike *Geigeria*, provides good fodder. It is also reportedly good for erosion control (Russell et al., 1991). However, the dynamics of these two species could not be confirmed by our study. As the level of degradation increased *Geigeria* decreased in abundance, from about 80% at the properly used (lightly grazed), to 30% at the severely overgrazed, and 0% at sites which were 80-100% bare ground. This phenomenon could be accounted for by the negative effect on plant growth of continuous trampling by stock around the watering point. *Geigeria* may also last several seasons after the grazing pressure has been relieved (Gunster, 1993; Nel, 1994), which could have made it difficult to determine whether the system was currently being overgrazed or had been in the past. The apparent behaviour of *S. obtusa* could also be attributed to sampling and identification problems encountered at the different sampling sites.

The predominance of *Geigeria*, presence of invasive bush species and the total absence of early palatable sprouts at several of the sites, indicates rangeland degradation. Degradation could be regarded as decreasing the productivity, resilience and stability of the rangeland. This model indicates that rangeland degradation was occurring within the Okombahe and Otjihorongo areas. The identified rangeland degradation was also supported by other studies within this project. The qualitative analysis revealed that the most lightly grazed study site would be considered "overgrazed" and the other sites designated as either "severely overgrazed" or "degraded beyond their resilience barrier" by the model.

GRAZING CAPACITY AND MANAGEMENT MODULES:

A grazing capacity module was constructed for the Otjihorongo and Okombahe area. The module is designed to be communal farming specific so it avoids expensive and difficult information gathering procedures and evaluations. It uses simple database inputs such as community stock numbers (LSU's and SSU's) at a given time, fodder consumption rates and the surface area of grazing land available to a community. The low game numbers, infrequent attack by insects, as well as the slow decomposition rate has negligible effects on the rangeland dynamics. Based on this observation, it can be assumed that livestock consumption plays the dominant role in vegetation consumption in the area.

These two modules used stock census data from the Department of Veterinary Services for the villages of Okombahe and Otjihorongo during June and December, 1993. In addition, a conversion factor of 6.7 was used to determine the numbers of LSU from SSU numbers. This calculation was based on the ratio of daily consumption figures estimated per stock unit (1.2 (SSU):8 (LSU) kg/day/stock).

Once the database questionnaire has been completed, the module can run continuously on two runtime questions: the time the survey was conducted (month) and the estimated duration of available fodder. These values are attached confidence levels (0-100%), as a measure of the accuracy with which they are estimated by the community. The model calculates a total daily consumption figure and available biomass. These values are then used to determine the grazing capacity required to sustain the stock till the end of the dry season. For the purpose of this model, the growing season was sub-divided into a rainy season (January - March), winter (April - October) and a dry season (November - December). The model uses an expert system to accommodate additional questions into the data base, as well as any other growing season sub-divisions that might be required to apply the model to another area.

The grazing capacity module calculated a grazing capacity of 25 ha/LSU for Okombahe during December 1994. This implies a reduction of about 0.6 LSU or 4 SSU be recommended in order to sustain the remainder of the livestock until the end of January 1995 (Fig. 3a).

However, a "what if" option suggested that without sufficient rains to provide more than one month of fodder, the grazing capacity would fall to about 270 ha/LSU from February to the end of the dry season. This scenario suggested a reduction in stock numbers of 15,640 LSU or 104,788 SSU, i.e. about 84% of total LSU numbers in Okombahe (Fig. 3b). Alternatively, the situation of a farmer, or community, farming below grazing capacity can also be addressed with the module as shown in the Otjihorongo example (Fig. 4).

An automatic calculation was then performed by the grazing capacity module to establish the required decrease or possible increase in stock numbers which forms the basis for the management strategy model. In the management strategy module, a series of yes/no runtime questions explores the farmer or community's possibility and/or willingness to move their stock to another area (emigration), buy supplementary feed (feed), or sell off the recommended stock numbers (reduction). Based on this information, advice can then be given to the user (Figs. 3 and 4). Two of the many possible advice scenarios from the management module are presented in Figs. 3 and 4.

CONCLUSION

Sustainable rangeland management demands flexibility from both resource users and planners. "Effectively managing rangelands is not a matter of adhering to a single conservative stocking rate, but rather a game of calculating probabilities" (Behnke et al., 1993). Due to the low and variable rainfall, episodic droughts and the present state of rangelands in Otjihorongo, opportunistic management should be re-emphasised in these areas. Such a management system should be aimed at seizing opportunities while avoiding hazards.

The ISPD system proved to be a potentially useful tool in rangeland assessment in Namibia. An ISPD approach could encourage community participation, which would create a sense of ownership and potentially easier acceptance of changing land use and management practices. The system could be implemented on selected communities, which would then refine and update it in order to better simulate the actual ecological and socio-economic situation of the area. This statement is supported by the authors of ISPD, who suggest that development of a database on long-term grazing trials is the most ideal situation for ISPD rangeland modelling.

The ability to identify, estimate and even prevent ecological degradation is a major concern in rangeland science today. The ISPD model has the ability of working under very limited financial resources and baseline information. The immense potential of providing simple yet reliable results makes the ISPD system a useful research and decision support tool in Namibia's effort to combat desertification.

ORDINATION: Survey Indexes USED MEM

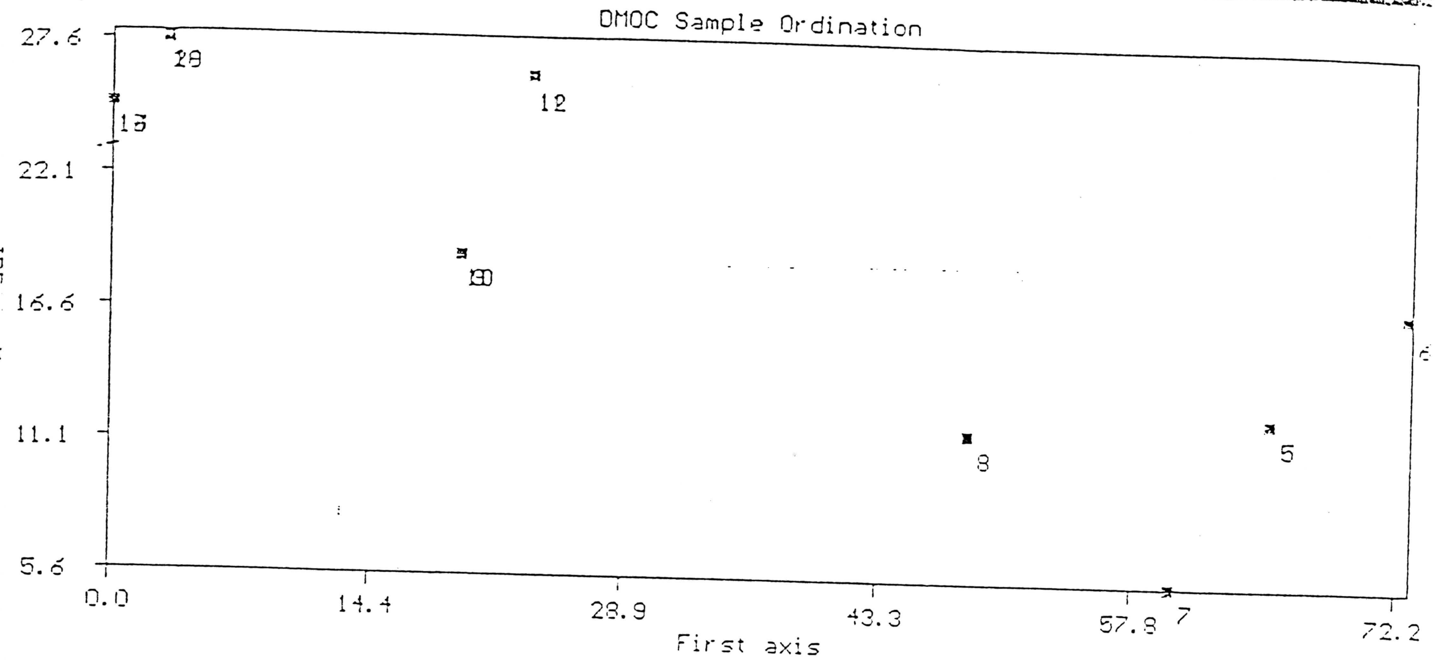


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Fig. 1. Quantitative condition assessment gradient with Sites 2-4, and 6, plus the list of species used in the gradient construction.

RHGA Name : SDP grazing area

Last ORDINATION : Decorana.

Spp Name	Root/Mean	Score
EIG ORN	54.06	0.60
STIP OBT	3.85	0.59
CHM SP	0.35	0.57
GRAS SP1	1.16	0.63
DICO SP	10.71	-0.38
BLEPH SP	0.35	0.57
STIP SP	9.85	-0.51

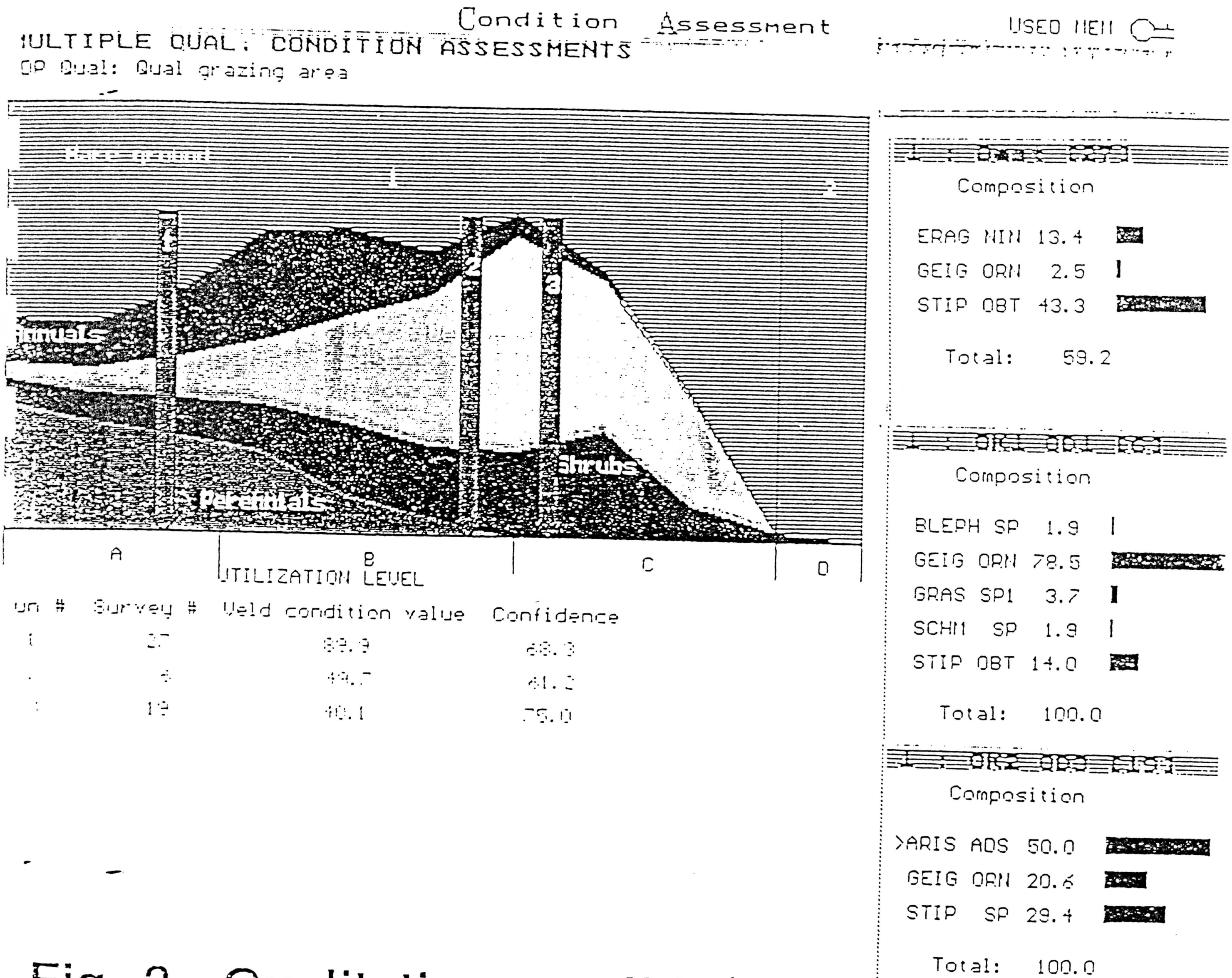

Fig. 2. Qualitative condition assessment Theoretical Good Site, Site 2, and Site 3 (Survey # 27, 6, and 19, respectively) and the comparison of species composition at each of the three sites.

Fig. 3. Grazing capacity results for Okombahe if fodder will have to last a) one month or b) eleven months, followed by a suggested management strategy.

3 Consultant result: Damaraland

Final_result:
Grazing Inc/Dec (Animals) -0.58 (64)
Parameters:
Community census: Okombahe - December 1993

Runtime questions:
Fodder duration (# months) 1.00 (50)
Current Month 11.00 (100)

3 Consultant result: Damaraland

Final_result:
Grazing Inc/Dec (Animals) -15640.963)
Parameters:
Community census: Okombahe - December 1993

Runtime questions:
Fodder duration (# months) 1.00 (19)
Current Month 01.00 (100)

2 Proposed management strategy

Please reconsider this decision
becouse if no reduction in
stock numbers is introduced
you will definately loose stock
and have no income from them

Parameters taken into account:

Stock numbers: Yes
Animal emigration: No
Feeding: No
Reduction: No

Fig. 4. Grazing capacity results for Otjihorongo, expressed as a recommended 9.4 increase in stock numbers, followed by a suggested management strategy.

2 Consultant result Damaraland

Final_result:

Grazing Inc/Dec (Animals) 9.40 (64)

Parameters:

Community census: Otjohorongo - June 1993

Runtime questions:

Fodder duration (# months) 1.00 (50)

Current Month 11.00 (100)

2 Proposed Management strategy

Please reconsider this purchase of additional stock against the possibility to rest the grazing. This will lead to an increase in veld condition which implies a better species composition and more palatable species.

Parameters taken into account:

Stock numbers: No

Animal immigration: No

Reproduction: No

Funding: Yes

CURRENT LAND USE AND LOCAL PERSPECTIVES IN THE KUNENE AND ERONGO REGIONS

E.N. Kakukuru

ABSTRACT

The Kunene and Erongo regions of northwestern Namibia are communal areas where land is not privately owned. Livestock farming is the predominant agricultural activity in these two regions. This study was conducted to investigate current land use in these regions in order to assess the human impact or contribution to desertification. Information on land use was gathered by interviews conducted with local farmers and agricultural extension officers within these regions as well as through archival research and direct observations. Some of the problems which can lead to land degradation or desertification within these regions are overstocking, overgrazing, deforestation, poverty, poor land management as well as underdevelopment. This research suggests that farmers should use adaptable activities which could minimize some of these problems and, at the same time, maximize their productivity.

INTRODUCTION

The Kunene and Erongo regions are situated in northwestern Namibia and are predominantly communal areas. The combined area of the two regions is about 4.7 million hectares (Fiona and Wolfgang, 1990). The natural resources in such communal areas are, by definition, state property.

This area is largely rural with livestock rearing forming the principal economic activity. In addition to livestock, the area also has wildlife such as giraffe, gemsbok, springbok, elephants and rhinoceros which share grazing areas with local livestock (Jacobson, et al., in press). The natural environment of Namibia is defined as arid and semi-arid with low and variable rainfall. Although various factors, including climatic variations and drought, contribute to land degradation, the impact of human land use is considered by environmentalists and scientists to be of primary importance (Lau and Reiner, 1993). The inequality in land distribution during the colonial administration of Namibia may have exacerbated land degradation (Lau and Reiner, 1993). The division of the agricultural sector created a commercial sector, i.e. privately-owned farms, and a communal sector, i.e. areas with no private land tenure.

Poverty and underdevelopment in the communal areas contribute to population growth and population pressures on the land and resources (Quan et al., 1994). These increasing human and livestock numbers place increasing demands on the remaining forests and arable and grazing land (Quan et al., 1994).

The objective of this study was to investigate current land use in the Kunene and Erongo regions. The UNEP (United Nations Environmental Programme) definition of desertification states that desertification is caused by climatic conditions as well as human activities (Cardy, 1993). As a result, this socio-economic study addresses human activities with regard to land. This study is part of an overall project which examined the evidence of desertification and land use patterns in the Kunene and Erongo regions of Namibia.

METHODOLOGY

Information for this study was gathered through three primary means: personal interviews, direct observations, and archival research.

The specific areas visited for interviews were Otjivero, Omihana, Ozondati, Okaumbaaha, Losberg and Onverwag. These areas are very dry, with the landscape dominated by mountainous terrain, hills and plains. The vegetation is sparsely distributed with mopane trees as the dominant woody species of the area. A large number of dead trees was observed throughout the area.

The Kunene and Erongo regions have low rainfall which is unpredictable from year to year. Most of the rainfall occurs between January and March, with 50% of the area receiving less than 150 mm of rain per annum. The altitude of these two regions ranges from sea level to about 1500 m. The ephemeral rivers in the area have surface flow only for a short time each year. The main ephemeral rivers are the Omaruru, Ugab, Huab and Uniab. The principal water sources for agricultural purposes are boreholes though great difficulties have been encountered in finding boreholes away from river-beds (Fiona and Wolfgang, 1990).

Interviews were conducted with local farmers and agricultural extension officers with the help of prepared questionnaires. The farmers and extension officers were asked questions on land use. The interviews included individual as well as group discussions. Observations were also made in the field to collaborate information gathered during the interviews. In addition to the field information, historical research was also conducted in the Namibian National Archives.

RESULTS AND DISCUSSION

Research in this study identified three primary areas of concern regarding current land use and local perspectives in the Kunene and Erongo regions. These were a) demographic influences, b) land use and resource management, and c) water availability. Findings within these three areas are discussed individually.

DEMOGRAPHIC INFLUENCES

Demographics within the Kunene and Erongo regions have shifted with governmental changes over the years.

With the colonisation of Namibia in the late 1800's, indigenous populations were resettled in native reserves. The areas visited in this study fell under the Otjihorongo and Okombahe Native Reserves which were established in 1925 and 1906 respectively (Namibian National Archives). During the colonial administration, most of these villages were privately-owned farms. They were, however, occasionally leased to new settlers. People who left or entered the reserves had to submit their names and livestock numbers to Welfare Officers (Namibian National Archives). Residents were not allowed to leave the reserves without permission from Welfare Officers and permission was only granted for limited reasons, including medical or family leave. This type of control probably helped lead to sustainable land management as people were not allowed to settle in the reserve if there was not adequate grazing.

In 1948, the Chief Native Commissioner prohibited the addition of new stock to the reserve to prevent overstocking (Namibian National Archives). According to historical information, grazing was considered satisfactory from 1949 through 1956.

Figures 1 and 2 give an overview of stock numbers in the Okombahe and Otjihorongo reserves during the colonial administration. Figure 1 shows a gradual increase in stock within the Okombahe Reserve over a 10-year period. The considerable increase in 1951 was due to an influx of people from Kaokoveld (Namibian National Archives). In addition, 1951 was reported to be a good year for grazing because of high rainfall in the previous year (Figure 3). The drop in the number of cattle in 1953 was due to cattle mortality from botulism, a disease resulting from poisonous bacteria in food. The drop in 1956 was due to drought (Namibian National Archives). Figure 2 shows the stock numbers in the Otjihorongo reserve. The drastic drop in small stock from 61,000 in 1955 to 50,700 in 1956 was caused by a lack of grazing early in 1956.

Today, most of the land within the Kunene and Erongo regions is communally-held. This division of the agricultural sector into commercial and communal areas has continued to have a significant effect on the demographics of the regions. Under the communal system, the movement of people in and out of the areas is not formally monitored or controlled. Only one village out of the six visited, reported a traditional leader (headman) that still exercises the power to grant settlement rights to people. The headman's decision is made in conjunction with agricultural extension officers who determine if there is enough grazing land and water in the area.

The farmers reported that the lack of a policy on settlement results in an uncontrolled influx of people into the villages. This, in turn, leads to overpopulation and overstocking which cause problems with grazing and water use. Some farmers reported that they used to apply a rotational grazing system when there were fewer people in their respective villages. But, with the increasing human and livestock populations, this system has been impossible to employ.

The villages interviewed varied in size and demographics (Table 1). Approximately 50% of the farmers interviewed have lived in their respective village areas for more than 30 years. The rest have been in their village areas since at least 1980.

Table 1. Demographic statistics of interview sites by village.

VILLAGE	NO. HOUSEHOLDS	NO. LARGE STOCK	NO. SMALL STOCK	NO. BORE-HOLES
OTJIVERO	11	880	2000	2
OMIHANA	8	1200	1000	2
OKAUMBAAHA	21	200	2500-3000	1
OZONDATI	36	70 for 1 household	50 for 1 household	1
ONVERWAG	not asked	1000	1000	1
LOSBERG	7	32 for 1 household	151 for 1 household	1

It is clear that demographics in the Kunene and Erongo Regions are affected by changes in governmental systems. With the communal system, the human and stock populations have increased in such a way that farmers have lost many of their resource use choices. A farm which belonged to one person in the past, e.g. Onverwag, is now a village with many households and livestock. This increase in human and livestock numbers, in conjunction with the changing climatic conditions, makes sustainable land use decisions and management more difficult.

LAND USE AND RESOURCE MANAGEMENT

The main issues regarding land use and resource management include the lack of effective livestock and resource management strategies, the effects of drought and damage from wildlife.

None of the farmers reported having a specific strategy for managing their livestock. All the farmers interviewed let their small stock out of the kraals in the morning. The small stock feed unattended during the day and return to the kraal in the evening. The cattle do not spend the night in the kraals, except when they are calving.

The livestock graze wherever they find enough grass. Because the owners do not know where the livestock graze, they sometimes observe the stomachs of their animals, especially the goats, upon their return to the kraal. If their stomachs are full, they follow the animals the next day to find their grazing area. They then inform other farmers of the good grazing locations.

This type of system can worsen the condition of the land as no one observes the livestock as they graze during the day or decides upon changes in grazing patterns based upon the season or time of month. This leads to overgrazing of the better grazing areas as the livestock is not controlled.

Farmers reported few controls in place which effectively manage resources within the region. During the time of the reserves, conversely, there were some controls. Residents of the reserves paid grazing fees and sometimes these fees were increased to discourage people from owning horses and donkeys (Namibian National Archives). No trees could be cut in the reserves without permission and only dried wood could be used for firewood. Farmers were responsible for their fencing but applications had to be accepted for fencing. They were allowed to use wooden poles which had to be 18 m apart. Poles of the Baster-Kameeldoring (*Acacia maras*) were not allowed to be used (Namibian National Archives). Stock limits of 100 large and 300 small stock were imposed per owner to protect the veld.

At the time of the reserves, certain grazing areas were saved for use specifically during drought periods. Only the Welfare Officers could decide when these grazing areas could be used (Namibian National Archives). Today, the government provides farmers with fodder during drought periods. This can create problems for the farmers because, when the supply of fodder is diminished, the animals often will not leave the homestead to graze in the fields. As a result, they sometimes die of hunger.

Farmers also reported other options for grazing during drought periods. Often they use roadway corridors, including those between Outjo and Khorixas, and Kalkveld and Otjiwarongo, to provide grazing for their stock. The ephemeral rivers are also used where there is enough grass and browse. The communal farmers occasionally rent grazing land from some commercial farmers. The government subsidizes a portion of these rental fees through the drought relief programme. According to some communal farmers, this practice can lead to conflicts with commercial farmers if the government does not pay the subsidy timeously. The communal farmers can then be threatened with eviction and sometimes must pay the entire rental fee themselves. They can, thus, be forced by the drought to sell their livestock.

People in some villages, especially Onverwag and areas surrounding Palmwag, reported problems with wildlife, particularly elephant damage to gardens and water pumps. These villages are located along rivers, which are water points for wildlife as well as their livestock. The problems with elephants began in 1994. Farmers reported the problems to Nature Conservation officers in the area who then requested maintenance help from the Department of Water Affairs (DWA). The DWA provided trucks to the communities with which they could collect stones. Stones were then placed around water pumps in order to protect them from further elephant damage.

Most of the farmers interviewed were financially dependent on their livestock. They sometimes sell stock to pay for their childrens' school fees, food and medical expenses. They sell their animals at auctions or to individuals with permits. One contributing factor to the increasing number of livestock is that communal farmers keep their livestock for social and cultural reasons, with the result that only a small percentage of their animals is marketed.

WATER AVAILABILITY

According to the interviewees, the major water sources for livestock, gardening and human consumption in the Kunene and Erongo regions were boreholes, windmills and dams. The main issues identified regarding water sources, were inadequate quantity and quality, poor maintenance of the boreholes, and lack of community consultation.

Concerns with water quantity were reported as both low availability and a lack of access. This is a result of the decreased water table and underground water recharge, due to the decline in rainfall. All farmers interviewed were of the opinion that they experienced higher rainfall in the past. A slight decrease in rainfall was reported between 1987-88 by farmers at Okaumbaaha which then worsened in 1992. However during 1992, some parts of the two regions had good rains.

During wetter years, rivers were reported to flow for longer periods and surface springs were more in evidence. Both of these were major water resources in these regions. Although springs did dry up during drought years, water was still available when villagers dug near the dried springs or in the river beds. The quality of the water was also reported to be inadequate for human consumption at times.

Farmers also cited difficulties with boreholes as a water availability problem area. The major problem regarding boreholes stressed by interviewees, was poor maintenance service from the DWA, specifically the Department of Rural Water Supply (RWS). People reported waiting sometimes 3 to 4 weeks without water due to a broken pump at a borehole. In addition to poor maintenance service, they also mentioned that there is a lack of community consultation with respect to borehole siting. This has resulted in the drilling of unproductive boreholes at some villages. In addition, this can result in boreholes being drilled too closely and subsequent overuse of the area between boreholes. The community felt that their involvement through consultations would be helpful as they often know where water is available.

Some communities have elected their own water committees to deal with water problems and report to the DWA. Farmers noted that responses to these requests are always slow, if RWS responds at all. The interviewees felt that their inability to control their own water points was also caused by the absence of any land and resource use rights. This allows farmers from neighbouring villages to bring their livestock to water from boreholes in other villages, increasing the pressure on a given water source.

CONCLUSION

From the research conducted, a few major issues were identified regarding land use in the Kunene and Erongo regions. These included demographic influences, problems with water availability, and land use and resource management. The communal land system currently has no restrictions on settlement, leading to overpopulation as well as overstocking. This further results in inappropriate land management which, in turn, leads to overgrazing. These problems have been widely identified as causes of or contributors to land degradation.

With the evidence of these current land use problems and their impact on land degradation, it is advisable for farmers to diversify their activities. It is better for them to adapt their activities to the changing climatic and environmental conditions in order to maximize productivity, while at the same time considering the environment. It is in this regard that alternative economic uses of natural resources were examined as a part of this project (see Netha, this vol.). Nevertheless, because of the cultural importance associated with livestock, shifting to alternative economic uses will take time.

Much work still needs to be done to create national awareness about desertification. In addition, an approach for land use practices which are sustainable and halt land degradation must be designed. Still, training should be regarded as most important. With the establishment of Namibia's Programme to Combat Desertification (NAPCOD), there is hope that research and training will be carried out in the future.

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Fig. 1. Livestock census numbers for the Okombahe Reserve: 1947-1956.

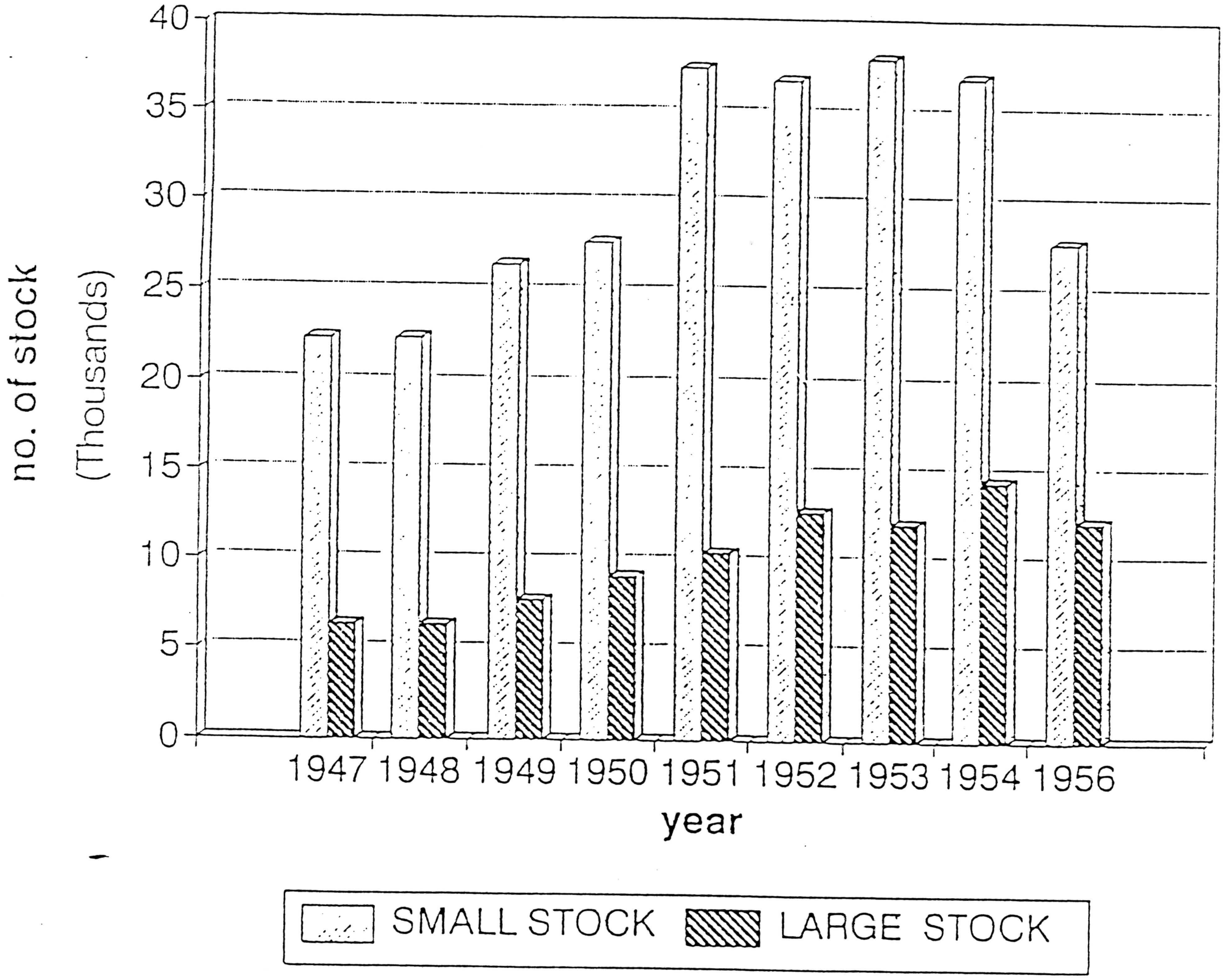


Fig. 2. Livestock census numbers for the Otjihorongo Reserve: 1944-1956.

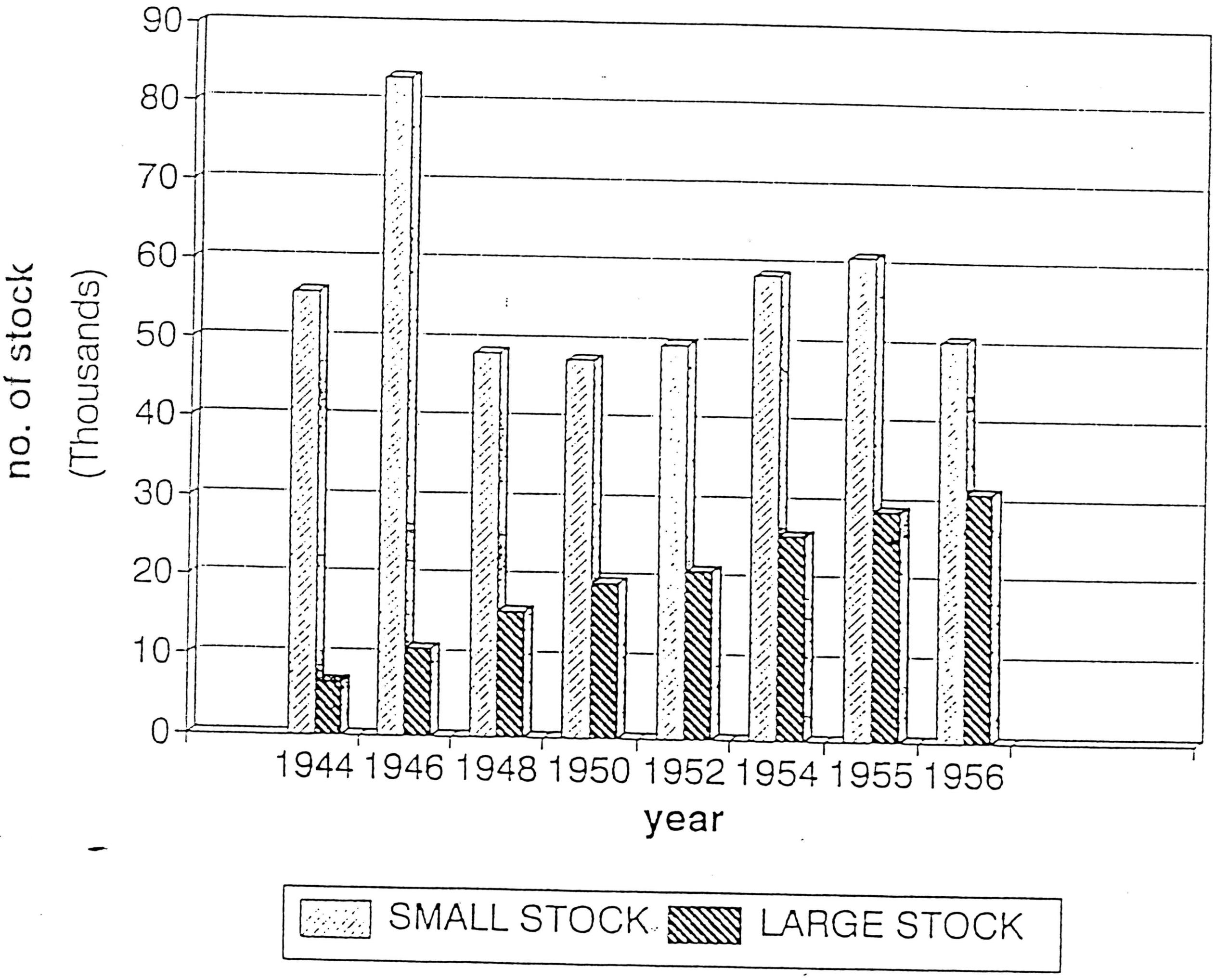
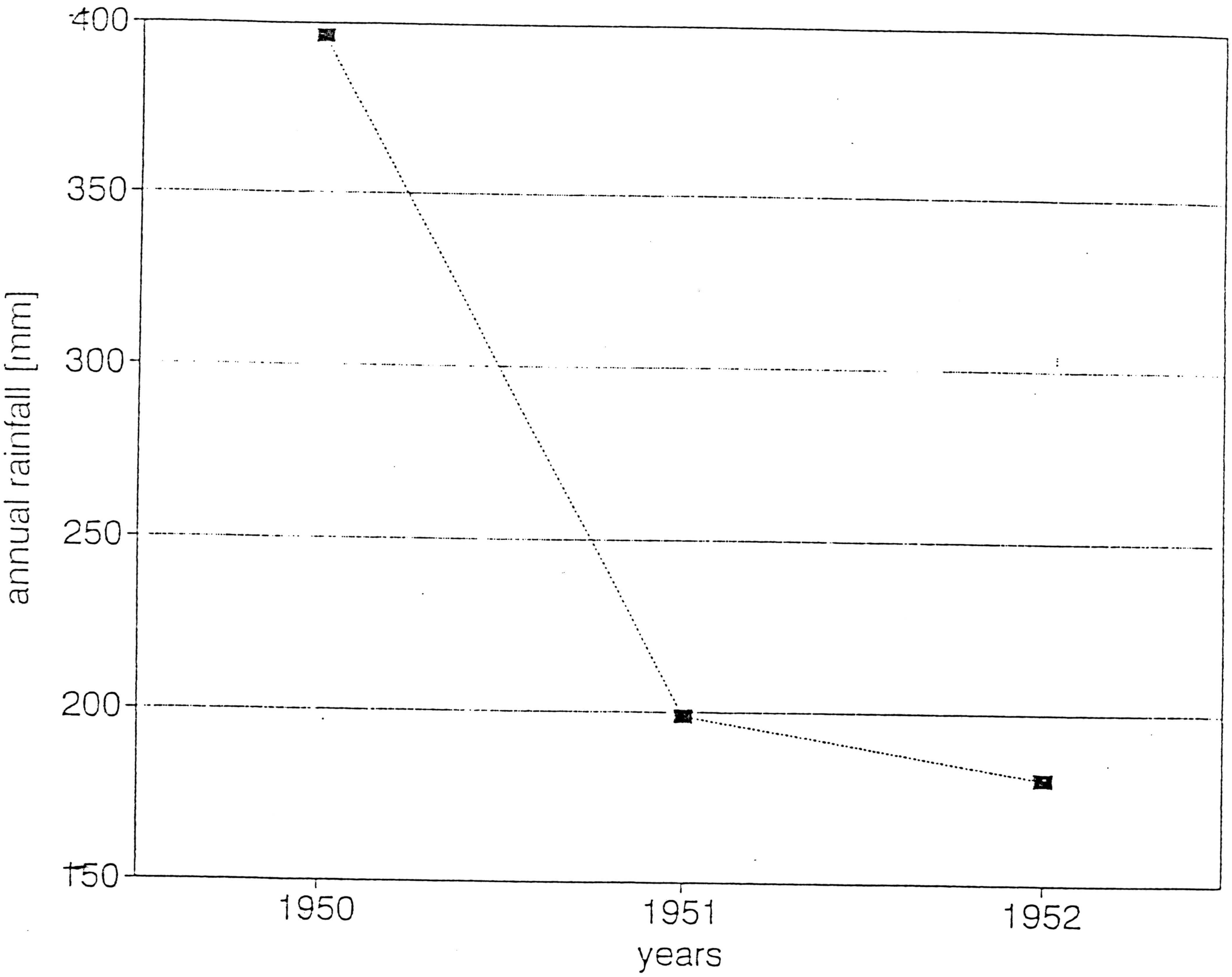


Fig. 3. Rainfall data for the Otjihorongo Reserve: 1950-1952.



THE ECONOMICS OF ALTERNATIVE RESOURCE USES IN ERONGO AND KUNENE REGIONS

L. Netha

ABSTRACT

The challenge of sustainable development is to allow people to maximize their long-term resource use for their own benefit and for that of future generations. In the resource-limited northwest of Namibia, it is important to understand the available resources and how best to use them. One approach that has been recommended is to evaluate how the inhabitants now use their resources and to study alternative uses. This research on alternatives targeted the Erongo and Kunene regions of Namibia. Data was gathered through interviews, observations, group discussions and questionnaires. This information allowed an economic assessment of alternative resource uses in the area, such as tourism ventures where investors share profits with communities. Other alternatives include arts and crafts, gardening, poultry and game farming.

INTRODUCTION

Desertification continues to be a worldwide environmental problem. Though research into desertification has been ongoing for decades, it has produced few solutions. The United Nations Environmental Programme (UNEP) defines desertification as: "Land degradation in arid, semi-arid and sub-humid areas resulting from various factors, including climatic variations and human activities" (Cardy, 1993). Since climatic variations are for the most part natural and cannot be manipulated, it is advisable to focus on human activities. Certainly one of the most significant of these is livestock farming.

People in northwestern Namibia depend on livestock farming -- e.g. cattle, goats, sheep, and some donkeys and horses -- for their livelihood. There are about 4,400 large stock and 13,550 small stock within the five villages consulted. Milk from goats and cattle contributes on average about one-third of each household's daily food requirements (Ashley, 1994). Livestock take-off rates are on average about 10%, with a cash return of about N$1,200 per year (Ashley, 1994). Livestock production in Namibia's communal areas accounts for 10-12% of the agricultural Gross Domestic Product (GDP), about 1% of the country's total GDP. However, its contribution to rural livelihoods in communal areas is much more significant. Additional sources of cash income are wages earned by herdsmen and civil servants, and government pensions. Even though such earnings are small, they play a significant role within the community.

The uncontrolled movement of people and livestock in search of better grazing has led to a decrease in the productivity of land, natural resources and livestock (Rohde, 1994). Also, the scarcity of water has forced some inhabitants to move long distances in search of water. A critical evaluation of potential, economically viable land-use alternatives is needed to help address these problems. The goal is to adapt human activities to changing climatic and environmental conditions. It is, however, not easy for people to change their productive activities, especially if those activities have become an integral part of their lives. It therefore remains a challenge to adopt sustainable land use practices, based on a diversity of economic alternatives, that will benefit the inhabitants of the area and the nation as a whole.

METHODOLOGY

Interviews were carried out through oral discussions with selected inhabitants of the Erongo and Kunene regions, either individually or in groups. Interpreters were used where appropriate. Separate questionnaires were designed for interviewing tourist facility entrepreneurs and communal farmers. Tourist facilities at Twyfelfontein, Palmwag Lodge, Huab Lodge and Khorixas were visited. These facilities cover a range of tourist services. In addition, the owner of the Sesfontein Restcamp was interviewed. Direct observations were used to corroborate interview information. Historical information was collected from the Namibian National Archives to determine previous land use patterns and compare them with the current potential.

DESCRIPTION OF STUDY AREA

Erongo and Kunene regions are situated in northwestern Namibia. The population is predominantly communal farmers but there are a few commercial farmers. According to the census of 1991, the population of the area is about 33,000 people, a number which reflects an increase of 40% since the last census in 1981 (Rohde, 1994). The annual rainfall in these areas is less than 150 mm, varying from year to year by as much as 50-70% above or below this mean (Rohde, 1994). However, 50% of the area receives less than this average and the yearly average decreases from east to west.

Due to this rainfall patchiness, farmers practice semi-nomadic pastoralism, moving to places which have had sufficient rain (Rohde, 1994). There are no perennial rivers within the regions but several ephemeral rivers, natural springs, boreholes and wells along the river beds. Inhabitants of these areas settle within access of water, farming and grazing land.

RESULTS AND DISCUSSION

In addition to livestock farming, people should consider other productive activities such as tourism, arts and crafts, gardening, and alternative farming options such as poultry and game. Some options may be more feasible than others, depending on the potential of each locality. A closer look at these alternatives will shed light on some of the issues worth considering when assessing their feasibility for an area.

TOURISM

Tourism facilities within these regions are a main source of employment, income, training, and development for the people. There is a variety of facilities, ranging from campsites to two- and three-star accommodation. The Huab and Palmwag Lodges are at the upper end of this range.

The Huab Lodge employs 24 people on an 8,000 ha ranch. It can accommodate a total of 16 tourists in eight double rooms, at a cost of N$500 per night per person, including all meals. Power generation through solar panels is pollution-free, and thus a model for others. Four boreholes and a few natural springs provide water. There is a swimming pool and the owner has plans to construct a place for fish farming. The lodge could sell fish to local people while buying vegetables from them. A number of game and bird species can be seen within the area and the owner has plans to acquire more land and other species of animals.

Palmwag Lodge, within the Uniab watershed, covers 1,000,000 ha and employs 18 people. The lodge charges N$170 per single and N$190 per double room per night, including breakfast and dinner. Campsites are also available at N$30 per night. According to the manager, the concession holder has the right to charge N$5 per person for permits to drive in the area. The concession offers some guided game tours in the form of 1-9 hour drives. The game population includes 30,000-40,000 springbok, approximately 10,000 gemsbok plus a number of elephants and black rhino.

Twyfelfontein offers one of the largest sets of rock engravings in Africa, estimated to be thousands of years old. The area boasts cultural relics of past inhabitants such as stone structures, tools, pottery and engravings. There are eight engraving sites depicting spoor and geometric shapes, as well as human figures, giraffe, rhino, zebra, elephant, lion and kudu. There are two circular walking routes that allow visitors to view the engravings when accompanied by a paid guide. There are also stands for selling art and crafts, including one provided for community members to sell things they have made.

Khorixas Restcamp opened in 1975 with 19 bungalows; there are now 40 with a total capacity of 130 people. Forty-eight people are employed here. The annual visitor rate ranges from 29,000-30,000, most of these being German tourists. The restcamp is run by the Namibiá Development Corporation (NDC), though there are a number of shareholders investing in it. Rates are N$200 per single and N$260 per double room per night, including breakfast and lunch. The campsite charges a N$35 flat fee plus N$10 per individual. Plans to build another camp 50 km from Khorixas have been hindered by rapidly declining ground water levels in the area.

Another problem is that tourist buses entering the area must be washed in accordance with a regional tourism agreement; though this washing generates money that is shared by the restcamp employees, it wastes the area's scarce water.

Tourism appears vital to the area because it employs a fair number of local people and gives them skills which could prove useful in undertaking new tourism ventures. It also contributes to the economic growth of the region, thereby raising living standards.

ARTS AND CRAFTS

The arts and crafts centre in Khorixas is a community-based project supported by the Save the Rhino Trust. Individuals within the community come here to sell curios, traditional clothes, sandals, and semi-precious stones. The centre has only been operating for nine months but profits are gradually increasing.

The centre shows that locally made arts and crafts can provide employment and income for the local population. The arts and crafts option seems viable as it uses commonly found things and converts them to good use, e.g. a piece of wood, rather than being burned, can be carved into something like an elephant and then sold.

GARDENING

A few individuals practise gardening for domestic consumption or for marketing on a small scale. However, some of these gardens have proved unproductive because of a lack of water or poor managerial skills. In Okombahe, vegetable gardens have been sponsored by Rössing Agricultural Services. These were meant to be a community-based project, with 0.5-1 ha of garden space allocated per individual. But a lack of knowledge about both gardening and finances compelled some individuals to quit their gardens. The manager is now encouraging people to garden not in groups but as individuals. This is proving to be successful and investors have been encouraged to fund these projects and to teach necessary gardening skills. Unfortunately, all the sponsored funds are channelled through the Rossing Foundation, instead of going directly to the projects to help develop them.

Gardening in other parts of the regions is not always as suitable as in Okombahe because soil and irrigation water quality varies; some soils are too saline. As part of the overall desertification study, the salinity of two garden soils was measured by gauging their electrical conductivity (EC). At Okombahe the EC was about 400 μS/cm, while at Onverwag it was about 3000 μS/cm. While these values show that both soils have salt accumulations, Onverwag is much more saline after only one season of gardening.

Though soils can be treated to decrease their salinity, this may prove too expensive to be economically feasible. However, gardening should be studied further as an alternative land use because people can derive food and income from it. In addition, garden projects can help people acquire additional useful skills in such areas as finance and management.

ALTERNATIVE FARMING

Another alternative is to farm with different animals, such as poultry and game. Poultry farming can be very important because chickens produce eggs, meat and manure. Chicken manure can be used not only as fertilizer but also to produce a very nutritious cattle fodder. Game can be harvested for consumption or used for tourist viewing. Many people do not know what elephants look like in their natural environment and are willing to pay to see and photograph such sights. The skins of harvested animals can also be used to produce commodities like leather products.

The entrepreneurs involved in these alternative uses caution, however, that people must have the necessary skills and knowledge in order to earn a sufficient profit from these types of activities. Nevertheless, poultry and game farming remain potentially profitable and sustainable land uses, in the sense that they can provide incomes over long periods without degrading the environment. Another benefit is that these alternatives do not necessarily require a lot of water, so in times of drought they may not be as threatened as livestock farming.

CONCLUSIONS

Economically viable alternative resource uses are not fully exploited in this area. This could be due to prevailing cultural trends or a lack of knowledge, or both. The marginal productivity of livestock is deteriorating because of pressure on the land and competition for forage areas.

Government, Non-Governmental Organizations and educational institutions must try to encourage communal farmers to adopt new ways to use their limited resources in an efficient and sustainable manner. Through schools, colleges and the university, necessary skills and information can be given to communal farmers, an approach that has proven successful in Botswana (Doreen and Janet, 1992). Foremost is the need to improve the level of education about alternative uses and their benefits, for example by disseminating information on such topics as the benefits of keeping wildlife instead of livestock, and the potential for poultry farming. Education would also help the population understand the long-term economic value of diversifying their land use options.

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THE IMPACT OF GOVERNMENT POLICIES ON LAND IN THE KUNENE AND ERONGO REGIONS

M.S. Siyambango

ABSTRACT

Namibia is one of the driest countries in Africa. As a consequence, Namibia may prove to have problems of desertification. Therefore it is of great importance to understand potential degradation problems associated with the various land use practices. It is also important to determine the effect of government policies on these practices and how policy may contribute to either sustainable or unsustainable resource use.

This study examined the historical background and government policies that affect land use practices in the Erongo and Kunene regions. The policy influence was evaluated by interviewing local and national government officials and inhabitants of the region. In addition, pertinent historical documents were studied to provide background information. The study gave evidence of the need for addressing the lack of land tenure and multi-sectoral planning in light of regional resources.

INTRODUCTION

Desertification arises from the fragility of dryland ecosystems. Excessive use, pressure or changes in land use can cause a loss in ecosystem productivity and the ability of a system to recover (UNESCO, 1994). The United Nations Environmental programme (UNEP) defines desertification as, "land degradation in arid, semi-arid and sub-humid areas resulting from various factors, including climatic variations and human activities" (Cardy, 1993).

As part of an increase in environmental awareness worldwide, the Namibian government has encouraged an environmental awareness campaign and an environmental research program (Wolters, 1994). Human activities are one of many factors contributing to land degradation and governmental policy provides the context for many human activities, e.g. land resource management. Thus it is important to understand what role policy plays in influencing and combatting desertification in Namibia. Some land-use policies, which were implemented in Namibia before independence, are still in existence, while others are no longer enforced. For example, a pre-independence policy which allowed the fencing of large tracts of land in communal areas is no longer recognised.

Policy research in Namibia could be used to help inform policy makers and land managers of the importance of policy in resource use. Policy can act as a support for sustainable land management and as an aid to reduce the current trend towards desertification.

The Kunene and Erongo regions are situated in northwestern Namibia. The area has no permanent rivers but there are several ephemeral rivers including the Omaruru, Ugab, Uniab and Huab rivers. These rivers flow seasonally and serve as the major ground water recharge source in this area of poor rainfall (Jacobson et al., in press). Fifty percent of the area receives less than 150 mm per annum (Rohde, 1994).

The dry period is longer than the wet period in this area (Rohde, 1994). The vegetation is semi-desert with mopane savanna (Van der Merwe, 1983). The human population in this area was approximately 33,000 during the census of 1991 and is predominantly livestock farmers (Rohde, 1994). Livestock, therefore, is the main source of income and means of financial investment as well as a symbol of status in the community (Jacobson et al., in press). Therefore the accessibility and availability of grazing lands and water influences the mode of settlement.

Extension officers from the MAWRD are charged with providing advice to communal farmers on land management and water use, and for mobilising them towards self-development. For example, rural water supply officers help communities establish water committees and regulate the construction of earth dams. These regulations are designed to help avoid overcrowding of people and livestock that might result in overgrazing around water points. They also advise communal farmers, through their traditional leaders, on issues concerning land use practices and settlement.

The Department of Veterinary Services (DVS) restricts animal movement among regions, and any farmer who wants to transport or sell livestock must acquire permission from the department. Government officials highlighted that the lack of a land tenure policy leads to overgrazing because of uncontrolled human and livestock movement, as farmers search for better pasture.

Policy implementation in the past did not evaluate the policies in the light of available resources. This resulted in resource degradation in the native reserves. The current lack of a cohesive land tenure policy has continued these problems, as populations continued to increase and their movements are controlled. The drought relief policy should take into account the longer dry period experienced by this region, as the fodder supplied to farmers has proved to be not sufficient. There is a need to increase the quantity of relief supplied to farmers.

Regional and Multi-sectoral Planning and Management

Policies concerning a number of issues are essential for sustainable use of Namibia's variable, arid environments. Those policies dealing with natural resources must take into account the climatic and environmental variability of Namibia. While broad, general policies can successfully be developed on a national basis, those that deal with natural-resource use and management, including especially land, land tenure, water and the resources associated with them, must take regional differences into account. Policies appropriate for the north-eastern, higher rainfall areas of Namibia cannot be the same as those which would be effective in the arid northwest, just as the overall carrying capacities of these two areas are distinctly different.

Policies dealing with natural resources are often promulgated on a sectoral basis. This is one of several reasons why use of natural resources in Namibia is often unsustainable, as highlighted by some government officials. Policies concerning land tenure must take into account land use potential of an area, water availability, rainfall, natural resources present, management practices in an area and infrastructure potential. This means that policy planning, development and implementation must be multi-sectoral. To this end, the Ministry of Lands, Resettlement and Rehabilitation (MLRR) has established the Inter-Ministerial Standing Committee for Land Use Planning (IMSCLUP) which is taking the first steps toward encouraging multi-sectoral planning and coordination. IMSCLUP meets once a month and reviews projects and programmes from member Ministries. Some government officials reported that, although sanctioned by Cabinet, the lack of legislative backing for IMSCLUP restricts its ability to ensure that multi-sectoral planning takes place as needed.

An example of the effects of a lack of planning, is that presented by the repatriation of Otjiherero-speaking people and their cattle from Botswana to Namibia. The decision to repatriate the large number of people and cattle involved was taken without any land use planning. Only after implementation had been initiated, was consideration given to the natural resources available in the Gam area for support of the people and livestock. Water was already known to be limited in the area concerned. Recent, renewed efforts to find sufficient water have continued to be unsuccessful. Moreover, the grazing available in the area is also insufficient for the number of cattle involved. Only several years after the original decision was taken, has multi-sectoral planning been initiated. The planners have also been given the task of finding appropriate areas for relocation of the people and livestock. Not only water but also roads, communications, education, health, agriculture, and veterinary sectors are affected by this premature decision. Officials are, belatedly, attempting to rectify a difficult situation caused by a lack of multi-sectoral planning (Seely, pers. comm.).

An example of relatively successful multi-sectoral planning has been the Trans-Caprivi Highway. Early in the development process, the Department of Roads commissioned an environmental study of the potential effects. At the end of the initial assessment a workshop involving a number of Ministries met to discuss the potential influence of the highway (those involved were Health, Agriculture, Water, Infrastructure and Wildlife) .

It waits to be seen how successful, overall, this multi-sectoral approach will be. Much will depend on the continuation of the multi-sectoral approach to implement and manage the development. (Seely, pers. comm.)

In the parts of northwestern Namibia where the present brief study was focused, multi-sectoral planning and management will be particularly important in view of the inherently low overall productivity of the area and the scarcity of water. Despite the limitations of the environment for large scale livestock production, the people of the area have expectations that exceed the carrying capacity of the land. With populations growing rapidly and with the frequent, natural occurrence of dry periods, multi-sectoral and regionally relevant planning and management will be essential to curtail the reduction of productivity currently taking place.

DISCUSSION AND CONCLUSION

Evidence suggests that government land and resource-use policies sometimes conflict with traditional survival strategies. For example, the drilling of boreholes as a drought-relief measure has disturbed traditional transhumance patterns by encouraging people to settle near water points, leading to overgrazing in those areas. This leads to communal livestock farming systems continuing to be classified as unproductive and environmentally damaging. If communal resources are to be conserved, appropriate policies must be developed that link traditional farming strategies with sound resource management (Ehui and Lipner, 1993).

At present in Namibia, a lack of policy on settlement has brought a considerable amount of uncontrolled communal movement. This often results in overstocking and overgrazing. As water and grazing lands are becoming scarce, there has been a lot of livestock movement and settlement of the communal areas in the Erongo and Kunene regions. The search for green pastures continues to be the struggle of farmers.

Solutions to some problems experienced in the Erongo and Kunene regions may be addressed by the reduction in stock number to suit the land available, improvement of extension services (particularly borehole maintenance), and the control of human movement. These direct approaches may solve the immediate problems, however policy needs to be structured to provide a stable environment for continued good land use management. In particular, current policy and current policy development needs to be evaluated in the light of regional resources and their related appropriate land use systems. In summary, any land use policy evaluation, development and implementation should be regionally based and multi-sectoral in approach.

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THE SDP RECOMMENDATIONS FOR THE NATIONAL PROGRAMME

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In 1994/1995 summer university holidays, the DRFN, with the assistance of eight Namibian university students, investigated aspects of desertification in the northern Erongo and southern Kunene regions of northwestern Namibia, in the Ugab and Huab river catchments. During the course of the activities, particularly discussions with people living in the area held during the field excursions, a number of ideas were generated concerning activities that might be incorporated into Namibia's Programme to Combat Desertification. The following suggestions are based upon experiences gained by students and staff during interviews with community members, extension personnel and other people living in the area. The ideas represent the combined efforts of the students and staff as they discussed the most appropriate approach to helping prevent further loss of productivity in this arid area.

1 - Facilitate a workshop on regional governmental functions and responsibilities for extension workers, farmers associations and the community in general. Regional and locally active national Non-Governmental Organizations (NGO) should be included in the workshop.

2 - Develop a simple brochure describing the functions and responsibilities of government officials, extension workers and NGOs active in the region. The brochure should include addresses and telephone numbers to facilitate networking between agencies as well as improve access for the community.

Suggestions 1 and 2 are based upon many observations that indicated people on all levels simply were unaware of the responsibilities and functions of the various government officials. Even within the same Ministry, people were not aware of the responsibilities of people in other Directorates. People seemed to be clearer about the (more limited) responsibilities of the NGOs.

3 - Facilitate development of a basic environmental information resource centre for the area. The centre should include, inter alia, the long term rainfall records from the area, evaporation data, range condition and grassland species occurring in the area, woody and other vegetation species and their uses. Information on seasonal and inter-annual biomass changes under different rainfall conditions could be very useful. The centre should contain books, published and unpublished reports and other sources of information and data for the area.

These suggestions arose after it was discovered that government officials in the area do not have access to basic information (even reports from their own Ministries about the area) that would help them with management of natural resources.

4 - Facilitate general environmental awareness workshops, materials preparation and information exchange.

These suggestions arose as the students and staff began to recognise the lack of information (and understanding) concerning sustainable use of natural resources in the area. A number of misconceptions are commonly held by people living in the area, such as the idea that the entire area is underlain by water and boreholes need only be made deep enough to tap this unlimited source.

5 - Facilitate improved data gathering by government officials through assistance with, for example, diagnostic surveys of rangeland in the area. Assist people from rural communities to help with data gathering, e.g. rainfall and position of water table at boreholes. Facilitate data collection, storage and processing and making the results derived from the data available to people in the area, in a way that is easily understood.

6 - Facilitate and encourage appropriate research on biophysical aspects such as soils, vegetation and water, as the essential background to sustainable resource management. Facilitate and encourage appropriate research on social, economic, political and frame conditions affecting sustainable resource management in the area. Facilitate and encourage integration of this research and data gathering so that it is available on all levels, e.g. for land use planning, for establishing appropriate management systems and for providing indications of carrying capacity in the variable environment. Facilitate wide distribution of the information derived to encourage awareness amongst decision makers on all levels.

Suggestions 5 and 6 arose from our own observations and from interviews that highlighted the lack of basic data available or being collected in the area. Where data is being collected or research being carried out, it often is not stored regionally but sent to Windhoek or to regional head offices, or published only in the scientific literature. Meanwhile, reports derived from data of this sort, including models of natural resource availability, are not available to people in the regions who could use them.

The above suggestions are just a few of the many considered during the field excursion and afterwards. All would contribute to the objectives of NAPCOD as elucidated at the National Workshop in July 1994. All could contribute to better understanding of the environment and thus to more sustainable use of the limited natural resources in this arid area. Moreover, all are within the capabilities of individuals or groups to implement, such as the DRFN and Namibian university students, as well as government staff.