HUMAN DISTURBANCES AND VEGETATION DYNAMICS IN THE NAROK DISTRICT OF KENYA

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Declaration

I declare that this Thesis has been composed by myself and is all my own work

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Abstract

This thesis is an examination of human impact on plant species composition and vegetation structure of the Narok District, Kenya. This is achieved by comparing the vegetation on disturbed and undisturbed sites. A literature review suggests the influence of seasonal migration of humans and animals, loss of land, firstly, to *white highland* development and, secondly, to cultivator immigrants and agricultural developments, which have little involved the local people, on vegetation changes. Analysis of satellite imagery, provides synoptic evidence of rapid expansion of cultivation since the 1970s.

Field data indicate that no disturbance type is uniformly distributed and, that the disturbances are becoming increasingly permanent and predominantly large-scale due to increasing human population and changes in Maasai lifestyles.

Analysis of floristic data shows that human disturbance has had only little impact on most communities. Closely located sample pairs, with compositionally similar species, have higher association than those geographically far apart with less similar species. *Alpha* diversity indices suggest that medium human disturbances increase species diversity while (a) extreme disturbances reduce species diversity through resource monopolization (for low disturbance) and (b) destruction of re-establishment potential (for high disturbance).

Examination of floristic and plant structural data suggests that total wood cutting, continuous browsing and severe burning reduce the number of woody species and the volume of wood. Dominance of woody species in woody communities is attributed to low disturbance whilst in grassland sites it is associated with bush encroachment due to overgrazing. In contrast, medium human disturbances attract both successional and climax species. An inhibition model is proposed to explain species composition at different height categories. That is, species variation is either due to (a) the exclusion of seedling recruitment by resource monopolization in undisturbed sites or (b) suppression of recruitment of plants to the next stage in highly disturbed sites.

Sample ordination based on species association shows a pattern which is explained, firstly, by moisture gradient, organic carbon, nitrogen and zinc. Secondly, the pattern suggests the influence of human disturbance, mainly between disturbed and undisturbed forest and bushland sites. Sample classification using both average linkage and furthest neighbour algorithms produce clusters which are explained on the basis of sample closeness, suggesting a continuous rather than a discrete distribution of species. Diffuse similarity between sample pairs from the same disturbance characteristics and from the same plant community is attributed, firstly, to the relatively recent human influence which has had little influence on plant composition and, secondly, to plant resilience to human impact on vegetation.

In view of the findings, alternative strategies of manipulating human disturbances, for the management of vegetation, are proposed and discussed.

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CHAPTER 1 : GENERAL INTRODUCTION

1.1 INTRODUCTION

The Narok District of south western Kenya is undergoing rapid changes in landuse. Cultivation is expanding significantly, seriously challenging wildlife, and pastoralism which has been the mainstay of the Maasai. From 1960, cultivation began a steady increase which continued through the 1970s and 1980s. Although its impact on the environment has not yet been well documented, cultivation has been advanced as one of the causes of vegetation change (Karime 1990; Lamprey 1984; Dublin 1986). Other factors include the loss of land by the Maasai to the colonial government (Sindiga 1984; Lamprey 1984), the compression of livestock and wildlife (Caugley 1976; Laws 1970; Field 1971; Dublin 1986; Lamprey 1984), burning (Dublin 1986; Lamprey 1984) and wood cutting (Msafiri 1985; Lamprey 1984).

Concern over the ways in which recent human activities are affecting Narok's plant communities has been exacerbated by information on the loss or decrease of valuable plants (Karime 1990; Olang 1985), increase in soil erosion and increased awareness of our inadequate knowledge of successional processes of vegetation development. Scientific knowledge of the impact of human activities on Narok's vegetation is still rudimentary because of the limited understanding of the effects of man on the East African vegetation (Norton-Griffiths 1979; Bazzaz 1984; Hughes 1986; Ross 1985). The response of vegetation to man-made gaps is well documented in temperate plant communities where studies of demographic and physiographic plant ecology have been concentrated (Bazzaz 1984; Pickett 1983; Brokaw 1982a). Similar studies in the tropics are few and examples include Lawton and Putz's (1988) and Denslow's (1980) studies in disturbed tropical forests and Lamprey's (1984), Mwaloysi's (1990), Dublin's (1986) and McNaughton's (1979) studies on human and ungulate activities in the Serengeti-Mara ecosystem.

The present research began to fill gaps in knowledge on these aspects. Lack of an understanding of vegetation dynamics was perceived as the overriding obstacle in predicting human impact on vegetation. Uhl and Murphy (1982), for instance, argue that an understanding of the processes and speed of recovery following disturbance provides a benchmark against which human impact on vegetation can be assessed. Therefore, the purpose of this thesis is to examine the impact of human disturbance on the vegetation of the Narok District. Viewing the impact from both an historical and a contemporary perspective, disturbances acceptable for the management of vegetation are proposed.

The suitability of Narok District for this study are :
Firstly, the District is among the areas classified as a reserve, during the colonial era. Since it was isolated from the *white* highland development, agricultural development on the Kenya highlands conducted by Europeans, it is a suitable area to examine the influence of colonial and post-independence administration on ecological change.

Secondly, the rapid changes in landuse and increasing human population characteristic of Narok District enable the impact of both indigeneous and modern landuses on vegetation to be investigated. The types of landuse include pastoralism and wildlife conservation/tourism in the semi-arid plains, and mixed and monoculture farming in the areas of medium and high potential.

Thirdly, Narok District contains a wide-ranging biophysical environment which spans the semi-arid region in the southern and central parts of the plains to the humid region in the Mau uplands in the north and Trans-mara in the west. This contrasting environment supports a wide range of plant communities which vary in composition and structure (Chapter 3). The wetter uplands and most river valleys support thick montane and riverine forests, respectively. The plains contain mainly the grassland and scattered intermediate woody communities commonly referred to as savannas (Jacobs 1963). It is therefore a suitable area to examine human influence on a spectrum of vegetation.

1.2 BACKGROUND TO THE STUDY

Since Kenya's independence in 1963, socio-economic and administrative factors, and increasing accessibility have led to rapid changes in landuse in Narok District. In particular, they have favoured the expansion of cultivation at the expense of pastoralism and wildlife conservation, and are drastically affecting natural vegetation. In order to bring human impact on vegetation into perspective, an understanding of development projects in the study area is needed. A brief outline of the context is provided in the following two subsections while subsection 1.2.3, reviews the potentials and limitations of these projects.

1.2.1 **Historical Factors and Agricultural Development**

At the beginning of this century, Narok District lost about three-quarters of its land to the colonial government (Chapter 2). The loss of land meant reduction in grazing resources. By the 1930s (see Sindiga 1984; Evangelou 1984) reports from various parts of Maasailand reflected adverse effects of land pressure and vegetation destruction. Official neglect of Maasailand, or, indeed, other 'African areas' could no longer be afforded. Different commissions were appointed and development programmes instituted with a view to ousting nomadic pastoralism (Evangelou 1984; Sindiga 1984). The latter, according to the colonial government, was the principal cause of land resource deterioration. In an attempt to deal with land problems in the country, the Kenya Land Commission (hereafter, KLC) was appointed in 1933 (Great Britain 1934). This commission recommended rehabilitation schemes for the Narok District, but failed realistically to assess the intricacies of land damage problems such as the loss of grazing land. Instead, the damage was simply attributed to nomadic pastoralism and overstocking. Different authors (e.g. Sindiga 1984; Spencer 1973; Evangelou 1984) have ruthlessly attacked and convincingly demonstrated the inadequacy of the KLC in dealing with land reclamation in Maasailand. According to Sindiga (1984:29), "the KLC failed to recognise the limitations and problems of Maasai pastoralism". In 1945, the African Land Development Programme (hereafter, ALDEV) was then formed to effect the proposals put forward by the KLC.

In an attempt to modernise the pastoral economy, the ALDEV identified overstocking as the salient problem in Maasailand. 'Betterment schemes' were recommended with the intention of improving pastures, destocking, providing veterinary and water services, and combating tse-tse fly outbreaks (Kenya 1955; Evangelou 1984; Sindiga 1984). These schemes led to increases in livestock numbers but never reduced resource degradation, and particularly the destruction of vegetation (Perberdy 1969). For instance, water resource improvement led to increases in livestock numbers. The lack of a concurrent limitation of livestock numbers to a particular area's grazing capacity, increased grazing pressure. Provision of veterinary services contributed to unprecedented increases in livestock and further deterioration of land resources. In 1950, the Kenya Meat Commission (hereafter, called KMC) was formed to help reduce overstocking. The Maasai were, however, reluctant to sell their animals as they value cattle number (see Chapter 4) and because the commission was underpricing their livestock. Furthermore, the commission concentrated on buying cattle from Europeans, with only a few from the Maasai (Evangelou 1984; Sindiga 1984). In 1952, the African Livestock Marketing Organisation (ALMO) was formed to assume sole responsibility for marketing African cattle. Lack of marketing channels, particularly due to movement restrictions necessary for a reduction in the transmission of diseases (Evangelou 1984; Sindiga 1984), made the ALMO no more successful than its predecessors.

Livestock development went hand in hand with land issues. In dealing with land ownership as part of national development, the Swynnerton plan (1954) proposed changes for agricultural development in the African areas. A major thrust of the plan was a call for destocking to estimated carrying capacity in pastoral areas. To replace the customary law specifying communal land ownership, group ranches were designed for communally grazed Maasai rangelands. This move contracted free range grazing (see Lamprey 1984), a situation which was further complicated by the loss of land in 1945 for the establishment of the Maasai Mara Game Reserve (hereafter, called MMGR).

To summarize, one may say that historical developments in Narok District focused on improving the livestock industry. The failure to achieve this satisfactorily, has been ascribed to the lack of reconciliation and limited knowledge of the components involved in specific projects (see subsection 1.2.3). In chapter 2, the present status of Narok's vegetation is attributed to historical factors associated with interference in nomadic pastoralism.

1.2.2 **Recent Agricultural Development**

While historical development focused on pastoralism, development in the post-independence era is characterized by the expansion of cultivation. Wright's (1967) description of Narok District as remote and an area lightly used by modern man is therefore open to question even at this early stage. For the last three decades, the District has served as a buffer zone for the country's densely populated areas. In the post-independence era, more and more cultivators have been attracted to the District through different systems of land leasing, provision of loans and better infrastructure (Sindiga 1984; Lamprey 1984; Narok District Development Plan, NDDP, 1984; see also Chapter 2). For instance, the local people who have no interest in cultivation or have limited capital and virtually no access to loan facilities, lease land to commercial farmers. Consequent expansion of cultivation has led to further shrinking of grazing resources for pastoral use and has restricted livestock and wildlife movement. Seasonal livestock movement, for example, between the lower and higher altitude areas following rainfall distribution and timing, is either restricted or has died out. The extension of wheat farms from the highlands to the plains (Chapters 2 and 5) is evidence of the District's transformation from purely pastoral activities to pastoralism with cultivation.

With the realization that Narok's population could not be supported by a purely pastoral economy, the Narok Development Agricultural Project (NDAP) was established in 1978 (NDDP 1984). The 15-year project is intended to reduce or substitute food imports into the District, and indeed into the country. In order to increase agricultural production, large-scale farming systems have been favoured at the expense of shifting cultivation which is widely accepted as being unsuitable for an increasing population (Watters 1971).

The preceding review (see also Chapter 2), indicates that development in the post-independence era, has been characterized by the expansion of cultivation. The following section, is a critical review of both the historical and recent development in the study area based on published and unpublished literature.

1.2.3 The Nature of Development

In this section it is argued that development projects in Narok District have frequently encountered failure either because they are based on inadequate knowledge of the available resources or because they ignore the interests of the local people. The 'betterment schemes', for instance, treated the symptoms of land degradation, such as soil erosion and bush encroachment, rather than the underlying causes. For example, they failed to address the causes underlying overstocking such as reduced grazing land, marketing and transport facilities, and the poor Maasai response to destock. Since development problems were not understood, the schemes ended up destroying the resources they were meant to improve. For instance, it will be recalled that the provision of water and veterinary services led to overstocking and overgrazing since marketing and transportation facilities were inadequate, and also because the Maasai were unwilling to destock.

A second dilemma has been that the introduced developments have scarcely involved the local people. The Maasai reluctance to destock implicitly reflects lack of understanding and communication between the government and the local people. This is because, firstly, most developments are capital-oriented; and secondly, because they are a threat to traditional pastoralism and are therefore received with suspicion. The will of the local people to observe and effect development is important for the success of any project (Hughes 1986).

In the post-independence era, development problems have continued to be compounded by inadequate knowledge of the resources and the impact of development on the environment. Referring to a site study for the potential of wheat growing in Mau Narok, Mbuvi and Njeru (1977:1) wrote " any land that could be used for wheat growing was already grown with wheat". Also, the recommendations of phase one of the NADP, which were implemented in 1979, have not measured up to expectations. This failure is also attributed to inadequate knowledge of the Narok environment. For instance, it has been indicated (see NDDP 1984:11) that

"the project paper implicitly assumed that the natural resources, environmental balance and social structure were adequate for the project task".

These two cases reflect a marked lack of central control of planning in the District and a lack of a landuse policy.

As in many developing countries, the lack of landuse policies and supporting guidelines are primary issues behind problems of agricultural development in Kenya. The debate on landuse in

Kenya has been around for some time (Sindiga 1984; Lamprey 1984; Endangered Resources for Development, ERD, 1984). It may be argued that there is no more time for discussion on such a vital issue. The situation is chaotic in Narok District which is experiencing spontaneous human migration and expansion of cultivation. Two issues that have not been satisfactorily addressed are land ownership and the optimum type of landuse.

For a long time, Narok District has been occupied by the Maasai. All land except the land near settlements, which was reserved for the owners' calves and old animals (Narok District Environmental Report, NDER, 1986), was communally owned. Following the Swynnerton plan of 1954, which split the District into group ranches, the Kenya government in 1978 launched a campaign to privatize land. Presently, all land falls under the Trustland category. Less than half is available for smallholder registration and this is either individually or communally owned. Whilst it is hoped that all land available for registration will be individually owned by the year 2000, no attention has been given to types of landuse which is one of the key issues to resource management.

Different development problems are associated with communal landownership and, non-gazetted land. They include two main causes of tension among the Maasai and between the Maasai and immigrant cultivators (Chapter 4). Firstly, are conflicts associated with uncontrolled leasing of communal land to immigrants by individual members. This leads to accumulation of monetary wealth by individuals, pressure on grazing resources, and sometimes unexpected, forced, withdrawal of tenants (Chapter 4). Secondly, is lack of land registration which has led to illegal buying and selling of non-gazetted and/or communal land (NDDP 1984; NDER 1986). These transactions have been exacerbated by the high influx of land hungry immigrants (Chapter 2). The consequences include massive destruction of natural vegetation. In the 1970s and early 1980s following influxes of immigrants into Narok District, selling of land extended to non-gazetted reserved areas. The upland forests were the most affected. Gazetted forests such as Olposumoru and the Narok County Council (NCC) forests, erroneously declared adjudicated areas, were hit to the extent that it was feared they were becoming extinct (NDDP 1984,1989; NDER 1986). Some immigrants moved into forest land without the local peoples' knowledge. After clearing large pieces of land, the settlers built wooden houses and "... continued to fell trees as fast as possible to give room to farming and livestock keeping" (Odiyo and Kwayera 1986). Olikirikiria, Sakutiek, Sasimua and Enengetia which once were totally covered by trees were turned into pockets of settlements.

During the time of this study, land selling was going on, often without registration. The latter is associated with land disputes which are getting complicated because of clashes on some borders (Chapter 4). On the whole, the Maasai are being displaced into the neighbourhood of the MMGR, and many of them are already landless (Ogutu 1990). Those who have settled near the MMGR, are threatening tourism and wildlife conservation. Therefore, the present pattern of development is characterized by spontaneous expansion of cultivation and settlements, increasing cases of rural poverty and landlessness.

As a result of development strategies, generally characterized by inadequacy, recent human activities have led to different effects on vegetation. The most important of all is the disruption of vegetation recovery and rapid depletion of plants locally identified as valuable for medicine, fuelwood and building (Chapter 4).

1.3 THE CONCEPTS : HUMAN DISTURBANCE AND VEGETATION DYNAMICS

This thesis uses the term 'human disturbance' to refer to human activities which promote or reduce species diversity of a vegetation unit and destroy plant structural characteristics (Connell and Slatyer 1977; Reiners 1983; Bazzaz 1983). It includes both livestock and wildlife activities because of the increasing influence of humans on animal impacts on vegetation.

Vegetation, in Narok District, has been influenced in different ways by man (Chapters 2 and 4). The expansion of cultivation has affected the woody communities through total or selective tree cutting and the grassland communities by ploughing. Wood harvesting for charcoal burning, fencing, building and as fuelwood is reducing woody communities, while grazing associated with trampling and reduced burning are reducing the grasslands.

Unlike natural disturbances, recent human disturbances are predominantly long-lived and large-scale, and environmentally damaging (Chapter 5). In particular, they alter the site conditions and reduce the sources of plant recolonization. For instance, overgrazing and permanent agriculture are attracting opportunist plant species and/or slowing down the rate of site recolonization by removing sources of regrowth in close proximity as well as destroying the seed-banks and root-stocks *in situ*. While human activities are predominantly deflecting or retrogressing the development of vegetation, on some occasions they can also be useful for the management of vegetation (see Chapter 7).

In the pre-colonial Narok, disturbances such as shifting cultivation, seasonal grazing, selective wood-harvesting and nomadic pastoralism were less destructive because they have built-in mechanisms which permit vegetation recovery (Chapter 2). According to Reiners (1983) and Whitmore (1983), these disturbances mimick small-scale natural processes of succession in size and impact. McNaughton's (1979) and Boutton *et al.*,'s(1988), studies in the Serengeti-Mara ecosystem support the claim that light grazing promotes palatability of pastures and vegetation productivity. In the absence of grazers and seasonal fires, productivity of above ground biomass declines spontaneouly due to post flowering senescence of herbaceous species. Also, the accumulation of dead litter reduces herbaceous recruitment and regrowth even during the rainy season or simply through subsequent severe burning. Woodland clearing and regular fires have also been necessary for the maintenance of pastures in Narok District (Kenya 1955; Lamprey 1984). The use of fire to improve pastures in the tropics is particularly widely documented (see Dublin 1986; Ross 1985; Egunjobi 1973; Pratt and Gywnne 1977). Egunjobi (1973) demonstrated that biomass on burnt *Andropogon* savanna in Nigeria exceeded the unburnt one by 30%.

Human disturbances directly or indirectly, through animal compression, are therefore responsible for Narok's vegetation dynamics, a concept synonymous with vegetation change or succession (Miles 1979; Drury and Nisbett 1971,1973). In this thesis, the term 'vegetation dynamics' is used to refer to fluxes which lead to progressive or retrogressive change in plant composition and structure. Thus, it involves death and recruitment, as well as temporary suppression of plant components which lead to spatial and/or temporal differences in vegetation. In this context, the distinction of vegetation into seral stages is an abstraction. Continuous creation of gaps and their recolonization attract pioneer species into a mature community (Begon *et.al.*,1990; Bazzaz 1984) making communities less distinct from each other. Plant communities influenced by man tend to overshadow the vegetation continuum characteristic of natural communities (Whittaker 1975) as gap creation and recolonization, which are characteristic of natural communities, are interrupted. As a consequence, sharp boundaries, devegetated sites, and homogeneous structural and floristic composition become prominent (Ashton 1989; Holzner *et .al.,* 1983). However, manipulation of human disturbance may lead to communities less contrasting with those influenced by natural disturbances.

Clearly, successful management of vegetation requires knowledge of 'which communities can be managed by which disturbance regime'. Therefore an understanding of the impact of the disturbance type on vegetation is of prime importance. In the face of increasing demand for land and wood resources in Narok District, this information is necessary in order to reconcile conservation for tourism and wildlife, wood-harvesting, cultivation and pastures.

1.4 HYPOTHESES, QUESTIONS AND OBJECTIVES OF STUDY

Within the context of the nature of development and landuse changes, this study decided to examine four hypotheses:-

1. that the disturbance regime in each plant community has changed since the turn of this century;

2. that species richness is greatest in communities experiencing medium human disturbance, a hypothesis attributed to Connell and Slatyer (1977);

3. that plants from disturbed communities are physiognomically different from those of undisturbed ones and

4. that some human disturbance characteristics may be more beneficial for vegetation development than it is usually thought.

Within this framework, this study addressed the following four questions :-

1. What is the nature and impact of human disturbance on Narok's plant communities?

2. Are human disturbance characteristics spatially, and perhaps temporarily, similar?

3. What plant responses show specific disturbance characteristics?

4. Which human disturbance characteristics are important for the management of vegetation resources?

The following research objectives were therefore put forward:-

1. To identify the roots and the evolution of human disturbances on Narok's plant communities so as to isolate the uniqueness of recently introduced disturbances.

2. To identify the characteristics of human disturbances in the different plant communities.

3. To determine vegetation characteristics under each recorded disturbance so as to make inferences on the relationship between them.

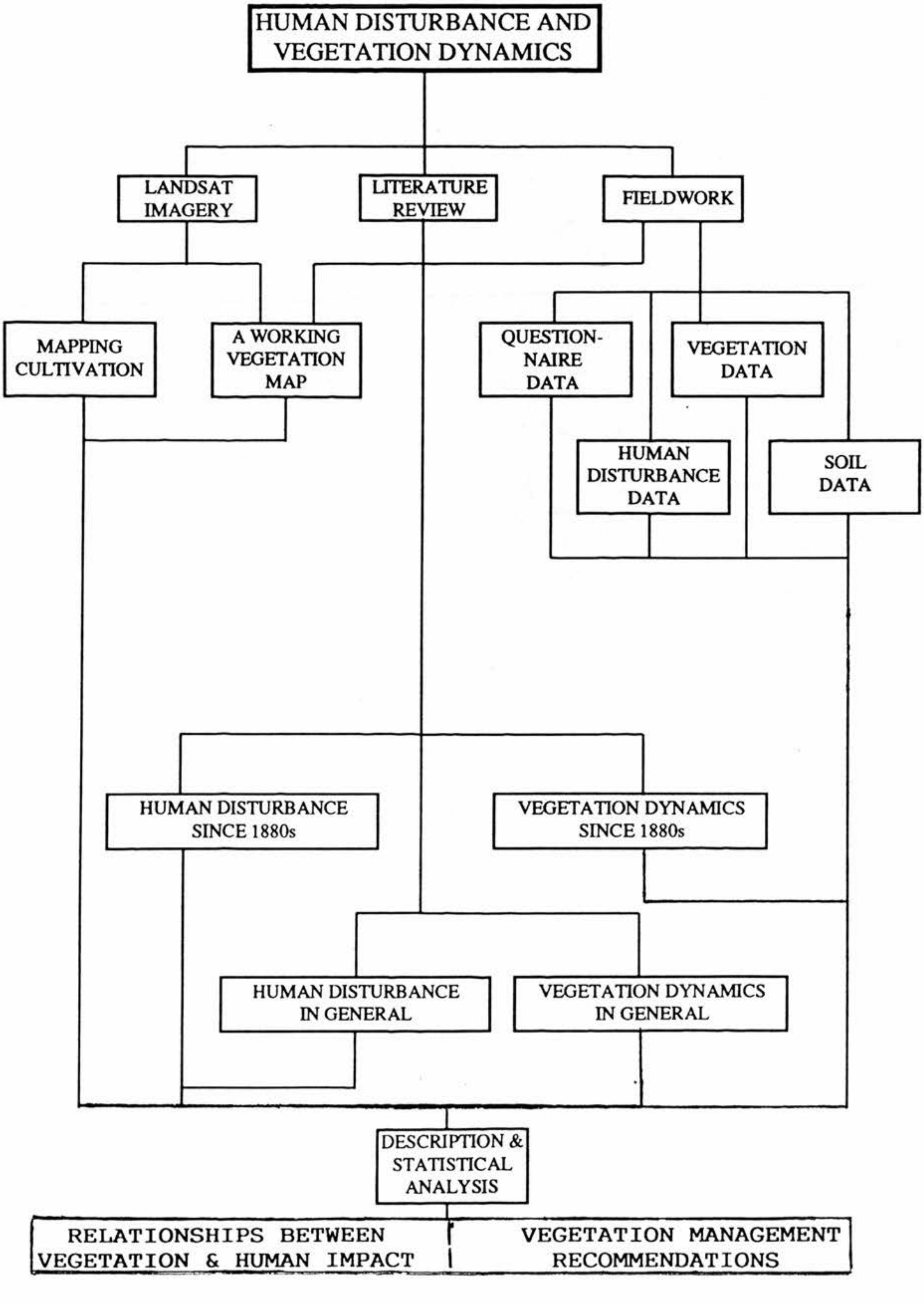
4. To use the results of this study to make relevant management recommendations for Narok's vegetation.

1.5 METHOD OF DATA COLLECTION AND ANALYSIS

The research was structured into two parts (Fig. 1.1). These are (1) data collection and (2) data analysis.

1.5.1 Three phases of data collection. Phase one was an evaluation of published and unpublished work on the vegetation of the study area, on tropical vegetation and on the nature of successional processes, human disturbances in the study area and the nature of human disturbance in general. This review helped to build up a picture of disturbance types in the different plant communities since the turn of this century. It also provided the theoretical basis necessary in understanding human disturbance and vegetation dynamics. The review answered question 1 and met objective 1 and helped to examine hypotheses

Fig 1.1 : A STEP-WISE SUMMARY OF THE RESEARCH APPROACH FOR THIS STUDY



1 and 3 of this study.

Phase two was fieldwork. Its purpose was to identify human disturbance characteristics, and vegetation composition and structure in selected sample sites. Both disturbance types and size were examined. Vegetation sampling centred on type and number of plant species and morphological parameters, mainly the diameter at breast height (dbh) and height. To supplement these data, a questionnaire was devised to obtain information about vegetation history and human activities. Soil samples were also collected from each site and analysed to determine fertility conditions. Data obtained from this phase were used to answer questions 1 and 2, to meet objective 3, and helped to examine hypotheses 2 and 3 of this study.

Phase three was a laboratory analysis of satellite images. A MSS hard copy of 1976 was used to produce a working vegetation map of the study area. Landsat Thematic mapper scenes 181/61 of 4th February 1984 and 169/61 of 13th January 1989 were used to map the expansion of cultivation in a specific part of the study area. Different maps also offered unique data which supplemented and/or helped to interpret image data. These data further helped to examine hypothesis 1 and objective 1 of this study.

1.5.2 Data Analysis and Interpretation. Different descriptive and statistical methods were used to analyse soil data. Both floristic and physiognomic approaches were used to describe fieldwork data. Different indices of similarity were used to compare sample association while *alpha* diversity was used to assess sample heterogeneity. Multi-variate analyses, mainly classification and ordination, were used to identify membership among samples and help relate field data to environmental and historical factors, respectively. Non-parametric Spearman correlation, isolines of environmental data and subjective evaluation were used to interpret the results of ordination.

Therefore, the overall study approach constituted a step-wise consideration of vegetation change due to human activities at a macro-level assessment, based on satellite images, and at micro-level, based on sample sites (Fig.1.1).

1.6 STRUCTURE OF THESIS

Chapter 2 presents an overview of qualitative and quantitative documentation on human disturbance and vegetation change in Narok District. These findings are significant in re-constructing vegetation history over the last 100 years. Historical aspects such as intervention of pastoralism are critically reviewed in an attempt to elucidate the roots of human disturbance. A description of the study area and fieldwork design is provided in chapter 3. Chapter 4 discusses the findings of questionnaire data. Data on the types and size of disturbances are covered in chapter 5, whilst details of soil chemistry are reported in chapter 6. Description and statistical analysis of vegetation composition and structure are presented in chapter 7. The findings in the preceding chapters, are used to recommend management practices valuable for the exploitation and maintenance of Narok's vegetation resources (Chapter 8). A summary of the study findings is presented in chapter 9.

CHAPTER 2 : HUMAN DISTURBANCE AND VEGETATION CHANGE - An Overview

2.1 INTRODUCTION

Several studies (e.g., Lamprey 1984; Karime 1990; Dublin 1986; Odenyo 1979; Olang 1985) have recognised the role of human disturbance in Narok District. This chapter examines the origin of the disturbances and their impacts on vegetation since the turn of this century. This information was derived from indirect or qualitative sources such as Narok District reports, accounts of writers retrieved from archives in Nairobi and Edinburgh and from published and unpublished reports. Two hypotheses are examined. These are that

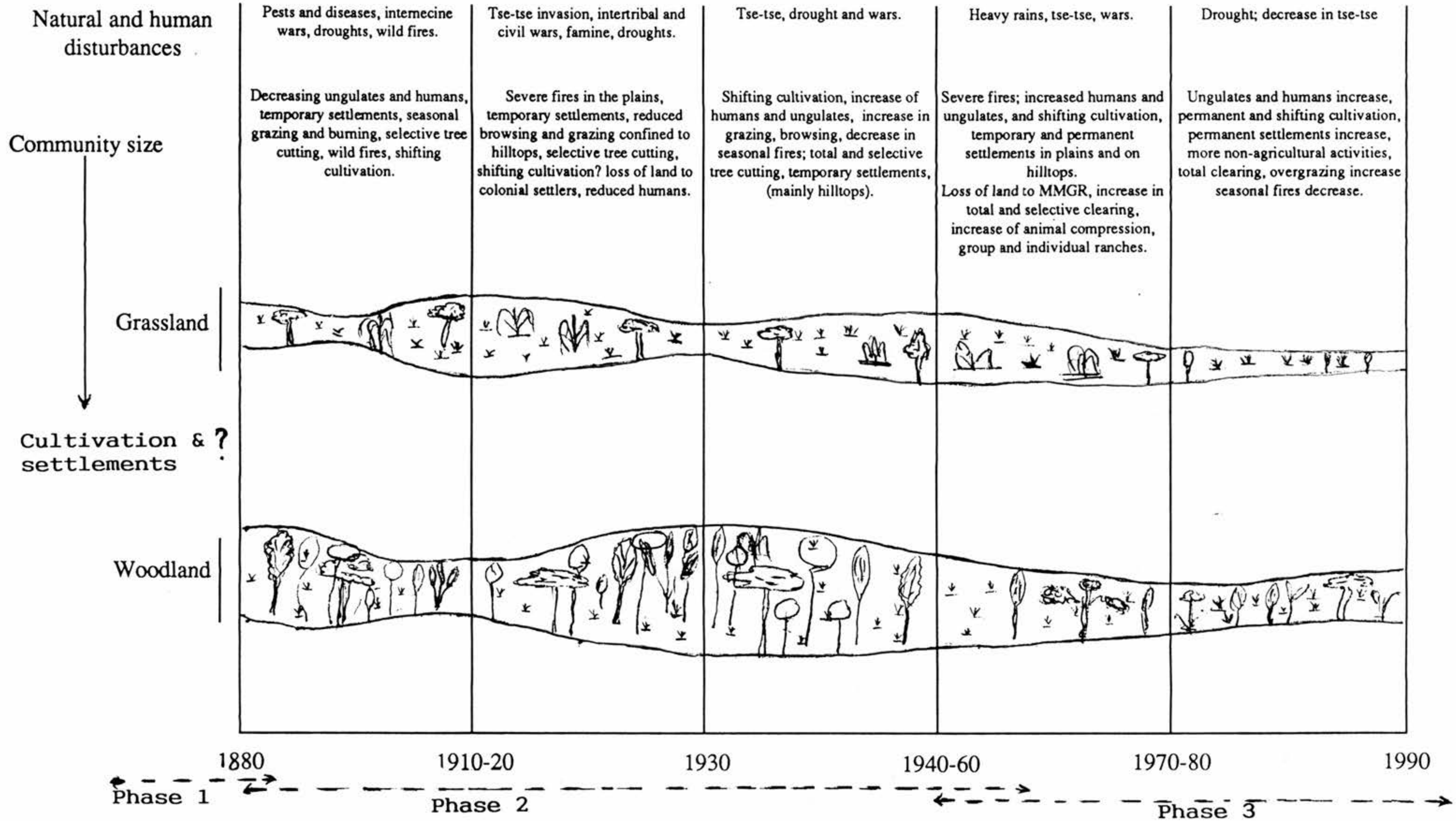
1. 'vegetation changes in Narok District for the last 100 years vary according to different human activities' and
2. 'the disturbance regime in each plant community has changed since the turn of this century'.

Two major phases of human activity and vegetation change have been identified: (i) a long pastoral phase and (ii) a relatively short phase of cultivation with pastoralism. As will be seen, the latter is unique in its rate of expansion and tremendous modification of the environment, through the increase in the exchange of material and technology within the District, and between the District and outside areas. These phases can be split into a time scale of 3 phases-: human activity and vegetation change before the colonial era, during the colonial era, and after independence (see Fig. 2.1).

2.2 HUMAN ACTIVITIES AND VEGETATION CHANGE BEFORE 1880

During this phase, Narok District was occupied mainly by the

Fig 2.1 A STEP-WISE CHRONOLOGICAL SUMMARY OF HUMAN ACTIVITIES AND VEGETATION CHANGE BETWEEN THE PRE-COLONIAL PERIOD AND 1990



Maasai. In order to understand their influence on vegetation, it is necessary to know who the Maasai are and the nature of their ecological impact. Therefore, this section starts with a brief account on the political and social history of the Maasai. This is followed by an account of the activities of the pre-colonial Maasai, and how these activities have, it is believed, contributed to vegetation change.

The Maasai are tribal groups who speak the 'Maa' language. Attempts to separate them on the basis of their differing degrees of relatedness has strongly been criticised by Sindiga (1986). Lamprey (1984) divides the Maasai into Il-Maasai, true pastoralists such as Il-Purko and Il-Kisongo and Il-Oikop, and the more agricultural Maa speakers such as the Njemps, Samburu and the Arusha. Narok District is predominated by Il-Purko Maasai. Other groups include the Siria and Il-Uasin Gishu. Each group is characterized by different ceremonial procedures, dress and dialects (Lamprey 1984). In all groups, decisions are made by the elders and backed by the warriors. Occasionally, disputes have broken out between neighbouring sections due to competition over grazing rights and due to cattle thefts, but during periods of disasters the groups share grief (Kenya 1955; Sindiga 1986).

Archeological excavations reveal that pastoralists have inhabited the rift valley floor for thousands of years. Marshall and Robertshaw's (1982) excavation in the Lemek valley suggest that the Maasai inhabited this area about 2000-3000 years ago. These findings differ from other published work (Sindiga 1984;

Arhem 1985) which is based on hypothesized migration routes. Further research is, therefore, required to resolve this conflict. It can be assumed that present records concerning the origin of the Maasai in Narok District are perhaps on one of the many past phases of Maasai movement. Therefore, it is worthwhile assuming that the past environment of Narok District was used by the pre-historic inhabitants, and that the present environment owes its origin partly to their activities. Nothing with certainty can be said about the pre-colonial Maasai. Evidence (see Jacobs 1965; Sindiga 1984; Lamprey 1984), tends to suggest that the Maasai used temporary settlements called `Kraals' (also called *Manyatta*) built close to water sources. These consists of circular mud and dung huts, *in-Kajijik*, enclosed by a thorn fence, *e-sita*.

During this early phase natural disturbances were perhaps predominant. The Quarternary must have been accompanied by changes in vegetation composition and structure. It is possible, based on evidence from other areas (Moreau 1965; Hamilton 1982), to suggest that the forest-savanna boundary shifted as these communities expanded or contracted over geological time. Fires resulting from pre-historic man, lightning and volcanicity during mountain building were also prevalent. Seasonal burning and grazing, and the large ungulate populations further assisted the expansion and maintenance of the savanna grasslands. Although detailed evidence on human activities is lacking, it may be argued that the vegetation of Narok District over this period demonstrates multi-temporal stability, characterised by a fine grained mosaic of successional changes.

Historical records (e.g Manshand 1974; Waller 1988; Arhem 1985) suggest that the Maasai used to occupy a large part of East Africa. Hypothesized migration suggest that they first settled, along with other Nilo-hamites before their southward movement, in present northern Kenya from where they dispersed in the 17th century. In the pre-colonial era, the Maasai controlled a vast area ranging from the plains between Lake Turkana and the Dodos-Karamojong escarpment in the north, to the central parts of Tanzania (Fig. 2.2). The east-west occupation is not widely recorded, but Sindiga (1984) and Waller (1988) indicate that at some time in history the Maasai occupied the area between Lake Victoria shores and the Indian ocean. Sindiga (1984:26) writes

"they grazed their livestock from the Indian ocean to Lake Victoria at one time or another in the 19th century".

It is further speculated (Arhem 1985; Manshand 1974), that at their peak, the Maasai dominated the East African grasslands and the neighbouring highlands. Despite this dominance over wide areas, historical records (e.g., Jacobs 1963; Waller 1988) indicate that Maasai population was greatly reduced by the internecine wars of 1810, 1862 and 1873.

One can therefore suggest that in the pre-colonial period, the influence of man on Narok's vegetation was mainly seasonal. The nomadic pastoralists used the District extensively and seasonally as they moved between the rift valley floor and the highlands or during their south-north migrations in search of

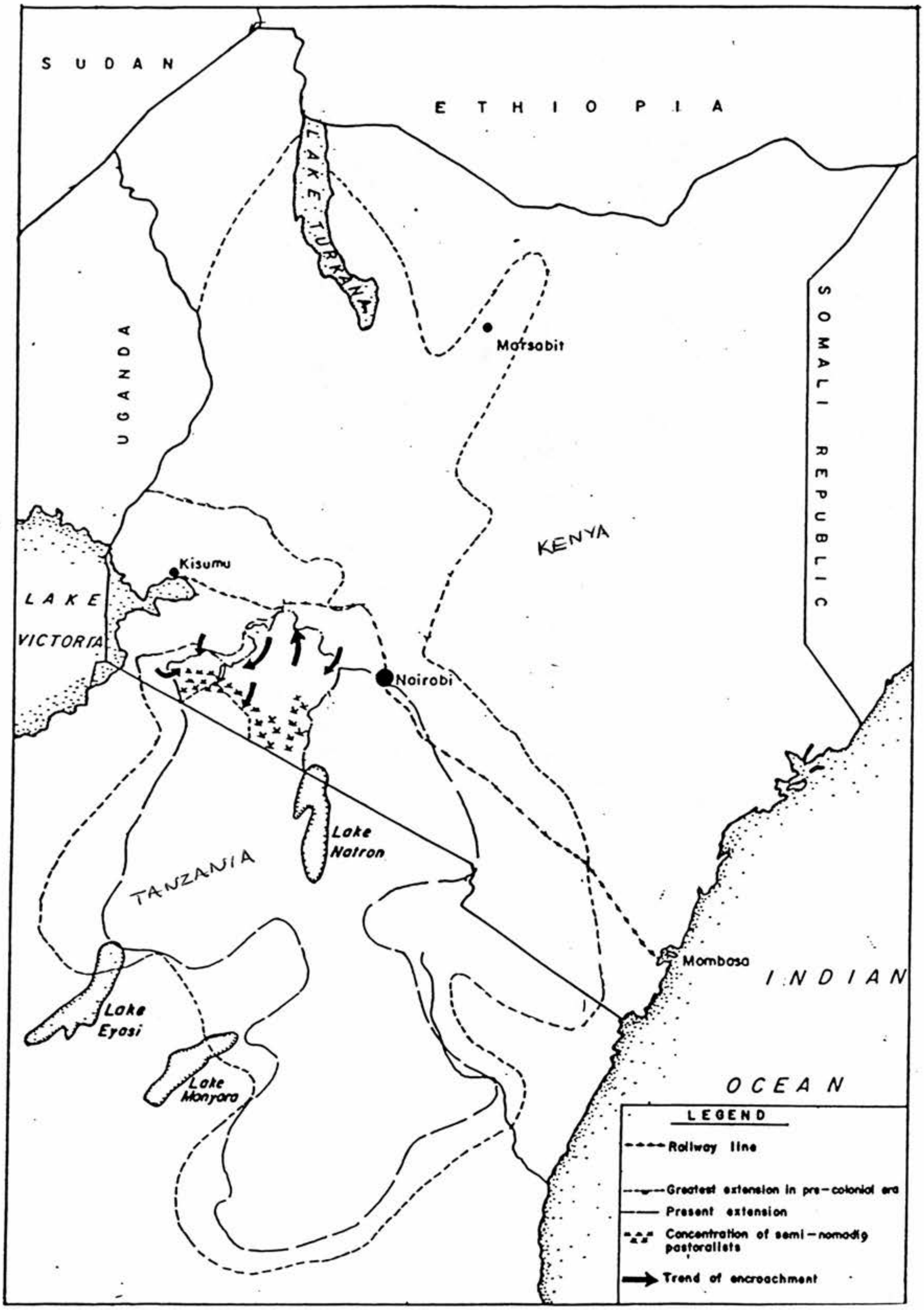


Fig. 2.2 The distribution of the pastoral Maasai

Source: Compiled from Jacobs (1963) and Arhem (1985).

pastures and water, and to avoid disease/pests and enemies. During the dry season they drove their herds up to the wet highlands which maintained pastures and contained water points and grazed them on the grasslands in the rift floor during the rainy season (Manshand 1974; Arhem 1985). Maasai nomadic pastoralism was therefore regulated by availability of grazing resources.

Since nomadic pastoralism was the predominant activity, human disturbances were limited and somewhat predictable; suggesting that plants were well adapted to them (see Bazzaz 1983; Reiners 1983). This view is shared by Ayuko (1980) and Jacobs (1980b) who argue that nomadic Maasai lived in harmony with their environment. A balance, occasionally interrupted by human and natural disasters (Fig. 2.1), may have been achieved between human activities and the vegetation. On the one hand, records made by the colonial government contradict this assumption by indicating that Maasai activities on the environment were detrimental. On the other hand, they tend to support it by pointing to the great discrepancies in human population and development between the Maasai and the neighbouring cultivator communities (Waller 1988; Sindiga 1984). These records therefore leave the effects of nomadic pastoralism on vegetation imprecise. At least one may conclude that nomadic pastoralism, like wildlife activities, temporarily modified the vegetation of Narok landscape. In so doing it assisted seed dispersal and the creation of predominantly small gaps such as animal hoof marks, patches of temporary settlements, and selective clearing for

Kraal construction. Some of these activities were significant in maintaining the development of plant communities. However, seasonal burning which was done to improve pastures and to eradicate pests, made long-term impacts on vegetation, many times keeping down the spread of woody communities.

2.3 HUMAN ACTIVITIES AND VEGETATION CHANGES BETWEEN 1880 AND 1963

This phase which begins with the colonial administration in Maasailand, has three remarkable events which have been associated with vegetation changes. These are :(a) epidemics of natural and human-induced disasters (b) about 2/3 loss of land by the Maasai to the *white* highland development and (c) ambitious development of the livestock industry.

Disease/pests, droughts, famine, and intertribal and civil wars predominated this phase (Sandford 1919; Sindiga 1984; Waller 1988; Lamprey 1984). These setbacks, which started in the early 1880s continued well into the 1960s. The outcome included reduced numbers and migration of domestic and wild animals, and people (Fig. 2.1).

In the 1880s, a series of droughts struck Maasailand. The most remarkable was the 1883 drought when people ate rats and livestock skins (Waller 1988). This was followed by rinderpest, an exotic viral ungulate disease, which is believed to have been introduced into East Africa through Ethiopia by Italians in 1889 (Ford 1971). Sweeping through East Africa, the disease virtually destroyed the entire livestock and ungulate wildlife populations. Sinclair (1977,1979) indicates that by 1900 buffaloes and wildebeest were heavily reduced, up to even 90%. The loss of cattle in great numbers ensured famine which inevitably left Maasailand almost free from human and ungulate disturbance (Sandford 1919; Arhem 1985; Lamprey 1984; Waller 1988). This was followed by drought and the great smallpox epidemic in 1891 and 1892, respectively, which wiped out a great proportion of humans and livestock who had survived earlier disasters. During these episodes, the elephant population was being reduced by the ivory trade; so that by 1900s, the Serengeti-Mara became known as an area without elephants (Buxton 1955). Between 1900 and 1930, human population was further reduced by a series of 'civil' wars among the Maasai which were exacerbated by the struggle for power, famine and stock thefts (see Waller 1988; Jacobs 1965; Sandford 1919).

Weakened by these disasters the Maasai lost their best grazing land first to European settlers and then to encroaching shifting cultivators. Between 1900 and the 1920s, following a series of agreements, the Maasai were eventually excluded by Europeans from the dry season grazing zone in the highlands north of the Kenya-Uganda railway. In 1904, Maasailand was split into the northern and southern reserves with the Kenya-Uganda rail line between them (Fig.2.2). The northern reserve consisted of Uasin Gishu, Laikipia and part of the Aberdares while the southern reserve extended from the Ewaso Nyiro river (in the west) across Ol Doinyo Orok in the east.

Following the 1911 agreement (see Sindiga 1984; Lamprey 1984; Kenya 1955), the Maasai were concentrated into the southern reserve. This was a remarkable change in the Maasai influence on vegetation as their grazing range was drastically reduced. Mau Narok had the first impact of this intervention. Kenya (1955) indicates that cattle and people were congested here during this displacement. As they came to settle, in 1913, the southern reserve was increased to include the area around Ewaso Nyiro and the Mara rivers (Sandford 1919). Later this reserve was extended to include the present west boundary of the District. The increase in land was insignificant compared to what had been lost to the *white* highland development. The influence of Maasai on vegetation, therefore, continued to mount. Cattle confinement within the reserve became a rule rather than the exception. Attempts to tackle the problems of denuded land became the colony's crucial issue. Holding to the idea that the Maasai had too many cattle, the colonial officials embarked on livestock programmes which lacked a comprehensive structure (Chapter 1), with destructive outcomes. These programmes are perceived as lacking comprehensibility because they failed to take into account traditional Maasai management of the environment.

In the 1920s reccurrent droughts swept away a great number of Maasai stock, whilst tse-tse infestation and bush encroachment became apparent. Narok District lost more than 30% of its original stock (Maasai Annual Report, 1922). The situation of grazing resources, however, did not improve as Narok lost 1617 km^2 of its land to the MMGR in 1945. In spite of disasters, the period 1930s to 1960s is characterized by the recovery of animals from preceding episodes, tse-tse eradication campaigns and an increase in shifting cultivation (Fig. 2.1).

Different vegetation changes are reported during the period 1880 and 1963. Early records (e.g., Buxton 1927) suggest that between 1900 and 1920, the Serengeti-Mara ecosystem looked much as it is today. Eastman (1927:57) describes part of the MMGR as

"a vast, level, mostly smooth plain, bordered with low rounded hills. The plain is sprinkled with trees of moderate size ... We can run our cars anywhere at any speed upto 30 or 40 M.P.H".

The vast grasslands in the Mara and the neighbouring areas at this time are attributed to seasonal burning by the Maasai at the end of the dry season which retarded woodland regeneration (Dublin 1986; Lamprey 1984). Hot fires were favoured by tall grasses following decimination of large herbivores by hunting and rinderpest, and decreasing impact of the Maasai because of famine and diseases by the 1890s. These fires led to the expansion of the grasslands as they spread from the plains to the neighbouring hilltops.

It should be recalled from above that between 1889 and the 1890s the plains became almost devoid of human and animal populations following the different episodes. Thus, the grasslands had enough combustible biomass to favour burning by the end of each dry season. The grassland communities expanded as woody communities on their margin were set to fire. Thus, penetrating fires pushed back the savanna-forest boundary. Fierce fires at the edges of forests were favoured by large wild herbivores and livestock activities. Lamprey (1984) and Werger (1983), for instance, indicate that elephants, by opening up patches within the woody communities, increase herbaceous species and litter thus enabling fires to penetrate further and further leading to the destruction of more and more trees. At this time, the influence of livestock on woody communities was however minimal because it was seasonal and coincided with the dry season, when tree regeneration and seed germination were minor.

The vegetation in the plains changed by 1920s with the outbreak of tse-tse flies, mainly *Glossina swynnerton* and *G. pallidipes* (Lewis 1934). These are vectors of *Trypanosoma,* a protozoan endoparasite which cause Trypanosomiasis in animals and sleeping sickness in humans. By 1913 when the Maasai had finally settled in the southern reserve, it was free of these flies (Sandford 1919) because the vegetation was inhospitable to tse-tse habitation. Increase in woody communities, in the formerly open grasslands following reduced human and animal activities, between 1910 through the 1940s allowed their proliferation. At this time Lewis (1934:445) refers to the vegetation at the grassy plains of the Mara as

"numerous intersecting and narrow belts of thorn-brush (Croton). In order to reach the Mara river, it was necessary to cut out a path for vehicles to pass through densely-growing *Acacia seyal* and another species known (to the Maasai) as 'Ol-jerai'...".

A sudden fly invasion which occurred in the period 1915-1920 led cattle grazing to be confined to the highlands. This was followed by reduced burning and re-invasion of the plains by woody communities. The process was facilitated by further withdrawal of human influence. Lewis (1934:447) writes "there is evidence (Sandford 1919) that a large number of Maasai including Purko, moved into the Trans-mara country in September 1913 after Woosman's discovery of *Glossina fulscipleuris* and his suspicion of the existence of another species.

Unlike most occasions, this time the Maasai abandoned their Manyatta (traditional Maasai settlements) without burning them, a situation which accelerated woodland regeneration. Lewis (1934:447) writes

"perhaps in their hurry to move, they did not burn their settlements and shrubs were able to recolonize leading to increase in woodland".

Lamprey (1984) and Dublin (1986) using photographs taken by hunters demonstrate that between 1930s and 1940s, the open grasslands of the MMGR were clothed with *Acacia-commiphora* bushland.

Between the 1930s and the 1950s, in their new settlements on the higher areas, the Maasai continued with 'burn and advance' practice of grazing. Except for a few areas such as Enkikwe which lost its woody vegetation to construction of Manyattas, human impact on vegetation was minimal. Tree harvesting for construction and woodfuel was selective such that the regeneration of most woody species was high (Lamprey 1984). However, reduced cattle movements led to isolated cases of bush encroachment on the hill and lowland areas in Trans-mara. At Lemek, concentration of cattle reduced the herb layer leading to losses in top soil (Lamprey 1984). During this time, the smallstock, sheep and goats, which are resistant to trypanosomiasis, were using the tse-tse infested plains as dry season grazing zone. Lamprey (1984) reports that during the dry season tse-tse fly densities were lower and cases of trypanosomiasis less prevalent.

In the 1940s, a few woody and herbaceous communities were tse-tse free as eradication campaigns intensified. Tse-tse eradication used 'floral approach'. This method involves the removal of the plants associated with the fly. In the late 1950s and the early 1960s woodlands and bushlands in the MMGR experienced fast decline following severe fires, and clearing and uprooting of woody communities, particularly in the areas where tse-tse fly concentrated (Langridge *et al.*,1970). Total clearing converted the riverine vegetation and clumped bushes of Trans-mara into open grasslands as this was believed to stop the spread of the fly up-stream the river Migori (Olompala pers. comm.). Fires burnt freely, taking up to one week to move between Nyangusu and Nyamaiya.

Total clearing involved immense tree-cutting across the cis-Mara to arrest northward spread of the fly. The upper Migori river was cleared and settlements established (Kenya 1955). A corridor of open grassland was created from Njibish valley through Abossi (Posee plains) to the confluence of Nyangores and Amala rivers. In the process, trees and shrubs were destroyed by uprooting and burning of stumps (Kenya 1955), with the intention to replace woodlands and bushlands with a treeless grassland. The most affected community was *Acacia-Commiphora* which is preferred by tse-tse (Lamprey 1984). In the MMGR, the most affected constituents of this community were *Grewia* species and *Cordia ovalis.* The use of selective or partial clearing to destroy tse-tse infested areas is also described by Langridge *et al.*, (1970).

The influence of tse-tse on vegetation, which has received little attention, has been two fold. First is relief of vegetation, from human disturbance, as man avoids or withdraws from tse-tse infested areas (Sindiga 1987; Lewis 1934; Sandford 1914). Second is by the destruction of vegetation cover through burning and clearing (Lewis 1934; Gamassa 1986), during tse-tse eradication campaign. Lewis (1934), for instance, recounts that the Maasai and their animals migrated in the face of the advancing fly.

In sum, the effects of tse-tse campaign on vegetation are yet to be understood. They are likely to be more than may be thought given that it involved no botanical experience (Ford 1984; Gamassa 1986). Gamassa (1986) describes the floral approach to tse-tse eradication as ruthless and ecologically destructive. What is clear however, for Narok District, is that the absence of sound landuse practice in cleared areas, means cessation of control which has resulted in woodland regeneration and tse-tse re-infestation (Lamprey 1984, see also below). The settlements and development projects established as part of the tse-tse eradication campaign were soon abandoned (Kenya 1955).

During this phase, human disturbance on the forest community was becoming noticeable as the pastoralists concentrated along its edges. By the late 1950s, Narok District was beginning to recover from previous losses of livestock and wildlife (Pennycuick 1975). Subsequent pressure in the plains from domestic and wild animals exacerbated by isolated cases of tse-tse fly forced the Maasai to move their livestock to the highlands where they had not lived before. In doing so, destruction of forested areas started. Glover and Gwynne (1961:451) write

"even the dense, almost impenetrable forest on the high Mau is being grazed throughout, and large glades are being burned in its centre".

Shifting cultivation had also started encroaching the forests of Trans-mara and Mau region (section 2.4).

Heavy rainfalls between 1961 and 1967 favoured grass production which in turn later supported severe fires which reduced woody communities (see Lamprey 1984; Dublin 1984; Langridge *et al.*,1970). Burning was deliberately concentrated in the tse-tse occupied areas. As the tse-tse population decreased, the re-utilization of the plains by the Maasai started. Introduction of livestock on the heels of smallstock to formerly tse-tse infested areas was, however, gradual. Ole Saiyelel (pers. comm.) recalled that Talek-Aitong which was once avoided, came into use temporarily in 1961 and 'permanently' in 1969. More burning was necessitated to push back the fly; allowing humans and their livestock to settle in the plains (Grimwood 1960; Lamprey 1984).

Lamprey (1984:168) writes

"over the period 1961 to 1974, declines in the tse-tse infested Acacia-Commiphora belt, which had previously shielded the southern areas from the Maasai, allowed this sward shift of the Maasai and their livestock".

Accordingly, the upland woody communities were partly relieved of livestock and settlement impact.

This section has highlighted the beginning of the intervention of Maasai pastoralism. Four factors associated with vegetation change are : reduced grazing range, fluctuations in human and animal populations, rainfall patterns and increased tse-tse fly eradication campaign. The following section examines the advancement of this intervention and its impact on vegetation.

2.4 HUMAN ACTIVITIES AND VEGETATION CHANGES BETWEEN 1963 AND 1990

Since 1963 three major events that are of significance to this study have occurred in Narok District. These are : increasing human population and cultivation, increasing impact on vegetation of livestock and wildlife and the introduction of non-agricultural activities.

Narok's population has generally had low growth rates recorded until 1960s (Sindiga 1984). Intercensal data between 1948 and 1979 (Table 2.1) show an increase in growth rate of population of the Narok District. Much of this increase is as a result of immigration of non-Maasai Kenyans. In 1979 alone, immigrants formed 44% of the District's population. This increase is also due to increasing fertility paralleled with decreasing mortality (Kenya 1981; Sindiga 1984). Population change has been associated with increasing cultivation and settlements, and a change in Maasai lifestyle (i.e., eating and cooking habits), with consequent effects on vegetation (Chapter 4).

Year	Intercensal	Percentage increase	Immigrants(%)
1948	37648		
		192.0	
1962	110100		
1963	-------	---	21.3
		13.5	
1969	125129		23.5
		68.0	
1979	210306		44

Table 2.1: Maasai population estimates 1948 to 1979.

Source: Modified from East African High Commission(1953) and Kenya (1964,1970,1981)

Cultivation is a recent phenomenon in the Narok District. Early allocation of the District to pastoralism as tribal trust land (Lamprey 1984) and the hostility of the Maasai, precluded cultivation. Several attempts by the Kikuyu, a highly mobile tribe (Gordon 1986), early this century to cross the Aberdares into the rift valley were rebuffed by the Maasai.

Unlike other areas in Kenya, both small- and large-scale cultivation in Narok District are expanding at a very fast rate. Between 1880 and 1963, only shifting cultivation was in practice (Kenya 1955; Waller 1988; Huntingford 1953). Areas such as Narosura and Ndasekera were under small patches of cultivation by 1882. Kenya (1955) indicates that in the middle of this century shifting cultivation was being carried out by Mau Mau detainees in the Mau region and by the Il-Uasin Gishu in the upper Migori. In the late 1950s, these groups were joined by agricultural Kipsigis and the Kikuyu, following land pressure in their homeland, generally referred to as 'acceptees'. The latter in turn invited their relatives. In spite of disputes between the immigrants and the Il-Uasin Gishu Maasai, the number of cultivators kept on rising such that by 1974, the upper Migori forest had been reduced from its original 200 Km^2 to less than 55 Km^2 (Lamprey 1984, Kenya 1955). Also, the Maasai who had been forced to school by the late 1940s, acquired farming skills which enabled them to cultivate small farms near their homesteads. Mr. Olompala of Nkararo (pers. comm.), recounted that he cultivated maize which he sold to prisoners in Narok town in the late 1940s.

In Trans-mara, cultivator immigrants were conducting shifting cultivation by the early 1960s. The Abagusii and Luos started to experience land shortage following population explosion and land adjudication by the late 1950s and the early 1960s in their home Districts. Gradually, they moved to the border areas in Narok District growing cereals such as maize and finger millet. Skirmishes between these cultivators and the pastoral Maasai following cattle theft (Chapter 4), interrupted the growth of cultivation. In the 1970s following the boom of the cultivation of pyrethrum in Kenya, a lot of small-scale farmers forced their way into Narok's 'idle' land. Since then, in spite of frequent intertribal wars, cultivation has increasingly gained momentum spreading steadily across Trans-mara, Olkurto and Osupuko

Divisions.

The expansion of cultivation has been exacerbated by mechanised farming which followed a 'confidential' report written by a Canadian team on Narok's agricultural potential in 1968. Therefore, present cultivators include resettled Mau Mau detainees mainly of the Kikuyu origin, a few Maasai, resettled immigrants who have purchased land from the Maasai, and the small- and large-scale, short-term, immigrants. Land leasing systems are the principal factors behind the rapid expansion of cultivation in the District. For instance, the small-scale farmers have been attracted by free leasing and crop sharing systems (Chapter 4).

Tables 2.2a and 2.2b confirm the expansion of cropland in the Narok District over a six and five year period, respectively. From these Tables, cropped land rose steadily while the crop types remained predominantly the same. For instance, the area under maize increased steadily from just under 7,000ha in 1982 to 40,000ha in 1988, with a sudden drop in 1984. This drop is associated with the 1984 drought (Buigutt 1989; NDDP 1984,1989). The area under the remaining crops show no consistent trends. Cropland fluctuations may, however, be attributed to changes in the requirements of food products and the land user (Chapter 4). The sharp fall in total hectarage under cultivation in 1979 followed the tightening up of the requirements for loan facilities (NDDP 1984).

Consequently, vegetation has been transformed and/or reduced into croplands. In Trans-mara, the extension of the South Nyanza (SONY) sugarbelt is destroying the woodlands and bushlands of Oyani. The present wave of agricultural development, which is characterized by the expansion of cultivation, has increased movement into and within the District; on the heels of the pastoralist are cultivators (Ogutu 1990). The trend of migration is from the borders into the interior and from the highlands to the plains and *vice versa* (Fig. 2.2, see also Chapters 3 and 5). The 'front line' is threatening the Maasai pastoralist, the MMGR and the different plant communities. This is the pattern of frontier development in the tropics, the local people are continuously displaced by the expanding agro-industries in their wake (Ogutu 1990). Extension of large-scale farms into the grasslands has promoted bush encroachment (Chapter 4).

Year Crop	**1977**	**1978**	**1979**	**1980**	**1981**	**1982**	**1983**
Wheat	22900	13124	3823	12800	17494	18182	17000
Barley	9185	18612	11680	13150	16500	8000	8000
Maize	6780	8890	9750	13000	17422	20143	20000
Potatoes	1750	1440	1000	1200	2645	415	2000
Beans	305	305	-	1025	1075	831	1200
Rapeseed	700	706	26	8	12	1000	2000
Pyrethrum	140	169	20	50	378	347	389
Others	30	54	160	-	235	-	200
Totals	**41790**	**43300**	**26459**	**41233**	**55761**	**48918**	**50789**

Table 2.2a : Estimated Hectarage of various crops in Narok District, 1977-1983.

Source: Narok District Annual Reports, NDDP (1984:8)

Crop	Year 1984	1985	1986	1987	1988
Wheat	22746	29300	39500	43871	48000
Barley	5218	8000	6000	10000	10000
Maize	13244	16600	24676	30740	40000
Irish potatoes	1855	2950	2900	4600	5000
Beans	1179	1950	1900	6420	8000
Cabbage/Kale	551	551	700	200	2500
Pyrethrum	____	____	____	390	420
Others	28	43	____	1140	1950
Total	**44821**	**59443**	**75676**	**97361**	**115870**

Table 2.2b: Approximate Hectarage of various Crop Land over the past four years, and the 1988 estimates.

Source: District Annual Reports, NDDP (1989:54)

Replacement of wood resources by bush encroachment is not keeping pace with the loss to cultivation, domestic use and to animal activities, mainly elephants and wildebeest (Chapter 7). The elephant population include those displaced from Tanzania. In the 1960s, following agricultural expansion in the areas bordering Serengeti National Park, a lot of elephants were forced to move northwards into the MMGR (Norton-Griffiths 1979; Dublin 1986). This population added to elephants which had been displaced from settled and cultivated woody communities in the foothills of Mau Narok and riverine communities in Siyabei and Trans-Mara rivers (Dublin 1986). Although the influence of wildebeest in Narok District is predominantly seasonal, their large number is also associated with destruction of vegetation (Lamprey 1984; Dublin 1986). The offtake of wildebeest followed their recovery from rinderpest and increase in dry season grass production in the 1970s (Pennycuick 1975). Successful and extensive programmes of immunization against rinderpest launched

since pre-independence, is the primary factor behind massive increases in wildebeest population both in Kenya and Tanzania.

The present period has also been accompanied by non-agricultural activities which have direct and indirect effects on vegetation. For instance, there have been losses of vegetation to roads, settlements and urban construction. The average road density by 1982 was 0.102 Km/km^2 of the District area (18,513 km^2). Although this figure appears small relative to the size of the District, indirect consequences that are associated with road construction are extensive. First, are the array of human activities such as cultivation and increasing wood harvesting which have followed increased accessibility. Second, is the destruction of plants *in situ* and in the neighbouring areas, particularly trampling due to off road driving in tourist centres (Chapter 5). Also, permanent settlements including urban centres have converted and/or replaced natural vegetation (Chapter 3).

2.5 CONCLUDING REMARKS

This chapter has confirmed that human influence between the pre-colonial and post independence eras gradually, then drastically, changed from small-scale and seasonal to large-scale and continuous disturbances. In the pre-colonial and much of the colonial era, vegetation was affected by nomadic pastoralism. Associated disturbances were seasonal and, predominantly, of small-scale. On the contrary, the present situation is characterised predominantly by continuous and large-scale disturbances with a number of new ones. These changes are associated with decreasing grazing resources and, the increase in cultivation. Human influence on vegetation has also greatly been influenced by external factors, mainly administration, climate, disease and pests and accessibility, which have influenced temporal and spatial distribution of human and animal numbers.

For the last 100 years, the grassland and woody communities in the plains have existed as components of a system. Predominance of one over the other has resulted due to changes in productivity following changes in disturbance regime. Implicit in these events is disturbance selectivity and differences in resilience of plant community components. As will be seen in chapter 4, the latter are important in determining the invasion or exclusion of a particular community.

CHAPTER 3 THE STUDY AREA AND FIELDWORK METHODOLOGY

3.1 INTRODUCTION

Figure 3.1 shows the location of Narok District on the Kenya map. The District, which lies in the Rift Valley Province, has an area of 18,315 km^2. It extends from the Kenya-Tanzania border in the south, and borders with Kisii and South Nyanza Districts in the west, Kajiado District in the east, and Kericho and Nakuru Districts in the north.

The first part of this chapter is a description of the District's physical environment, mainly topography, drainage, geology, soils, climate and vegetation. Information on these aspects is used to interpret fieldwork data (Chapters 5, 6 and 7). The second part is a detailed discussion of fieldwork methodology. The theory involved and the practical problems encountered in selection of appropriate methods are elucidated.

3.2 THE PHYSICAL ASPECTS

3.2.1 Topography and Drainage

Narok's diverse topography, classified broadly into highlands and plains (Wright 1967; Jaetzold and Schmidt 1983; Mbuvi and Njeru 1977), is attributed to faulting and vulcanicity. In this thesis, the contour 2100m is used as a practical boundary between the highlands and the plains. Accordingly (see Fig. 3.2), most of the District lies within the plains. The highlands include the Loita hills (2670m) and the Mau escarpment (3030m) while the plains include the Loita, Siana and Lorogoti plains which lie between 1500m and 2100m. The latter are interrupted by

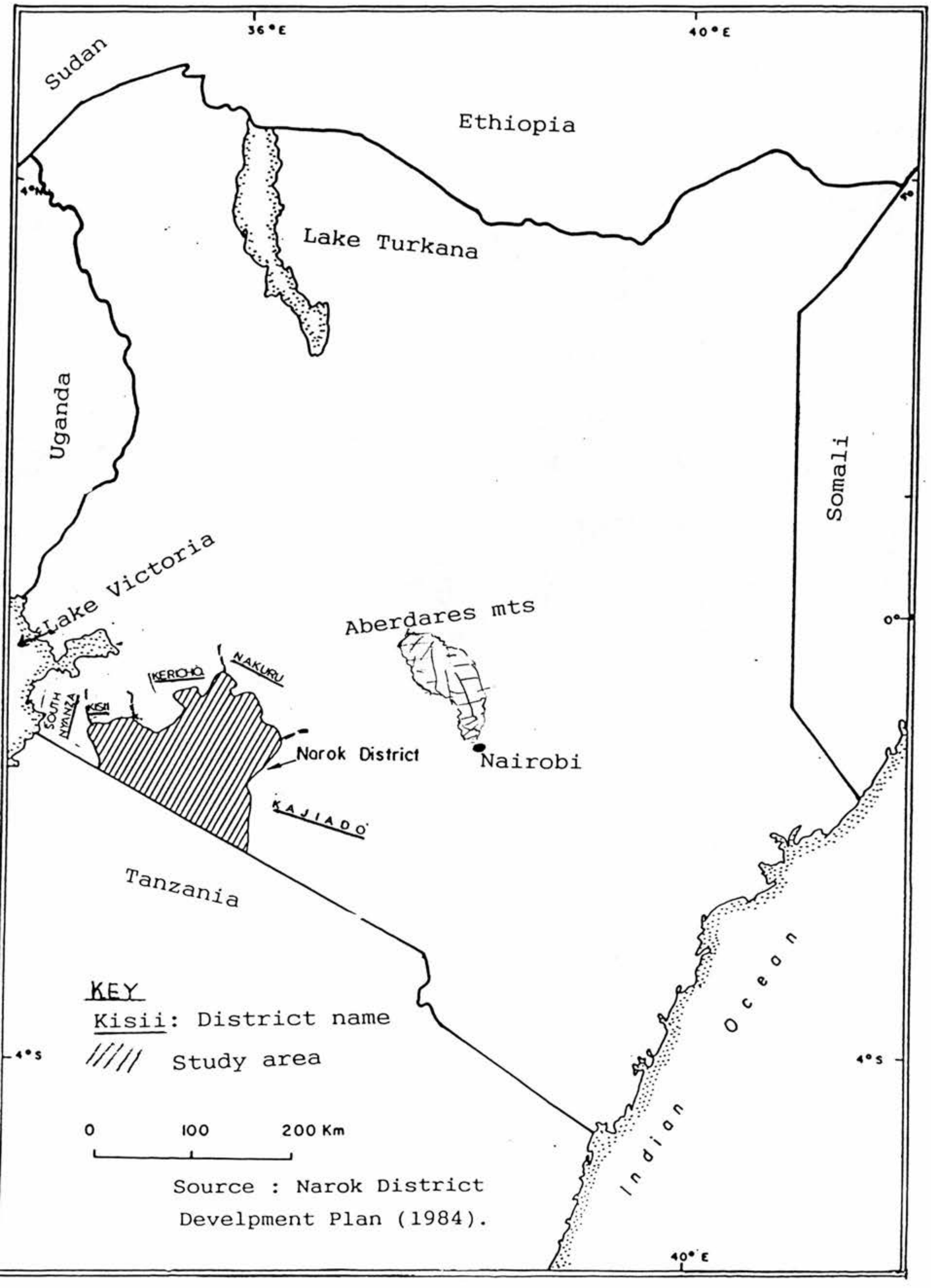


Fig. 3.1 Map showing the location of Narok District in Kenya

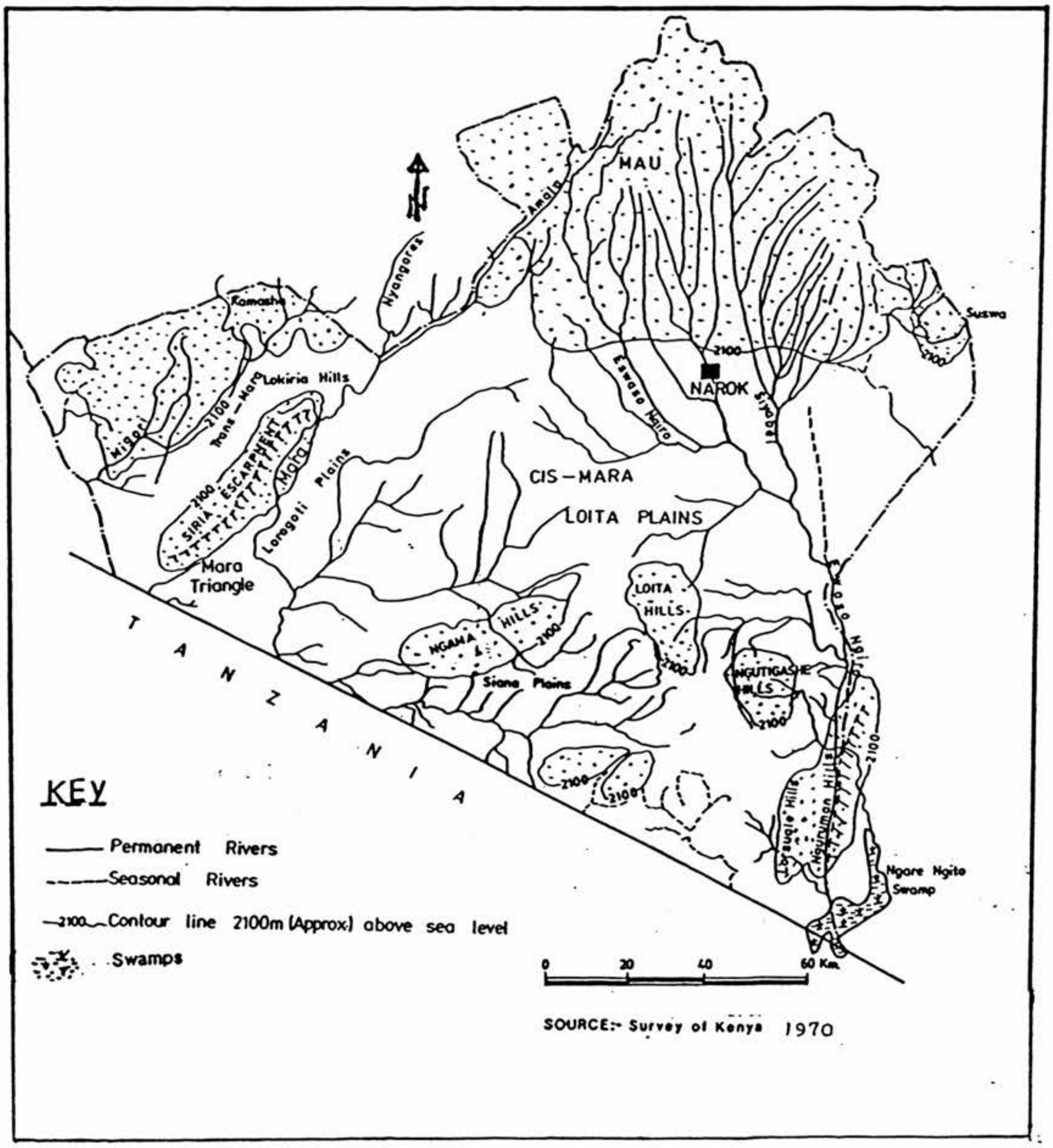


Figure 3.2: Topography and Drainage, Narok District

scattered rounded and stony hills.

From figure 3.2, we can see a general rise in topography from the south to the north and north west. On the foothills of the Mau escarpment are hills such as Ol Kinyie (2270m), Bardamat (2120m) and Ol Doinyo Lalangelesho (2220m) which give rise to undulating topography. Other major topographical features include the Siria escarpment and the Trans-mara plateau in the west, and the Nguruman escarpment in the south east.

A description of Narok's drainage system has been provided by Glover (1966) and Wright (1967), see also Figure 3.2. Both perennial and temporary rivers drain either into Lake Victoria (e.g., rivers Mara and Migori) or Lake Natron (e.g., river Ewaso Nyiro). The Mara river system, which forms the easternmost river in the Lake Victoria basin, originates from the Mau escarpment and Kericho District as the Amala and Nyangores rivers, respectively. Within the plains it is joined by tributaries such as Talek and a number of ephemeral springs. The Ewaso Nyiro is the largest river in the eastern half of the District. Generally, except for a few ephemeral springs which rise from the hills within the plains, most rivers originate from the Mau escarpment (Fig. 3.2).

3.2.2 Geology and Soils

The geology of Narok District has been mapped by Odenyo (1979), Wright (1967), Jaetzold and Schmidt (1983). Like topography, it varies greatly over the District (Fig. 3.3). Two broad geological regions can be identified. A great part of the

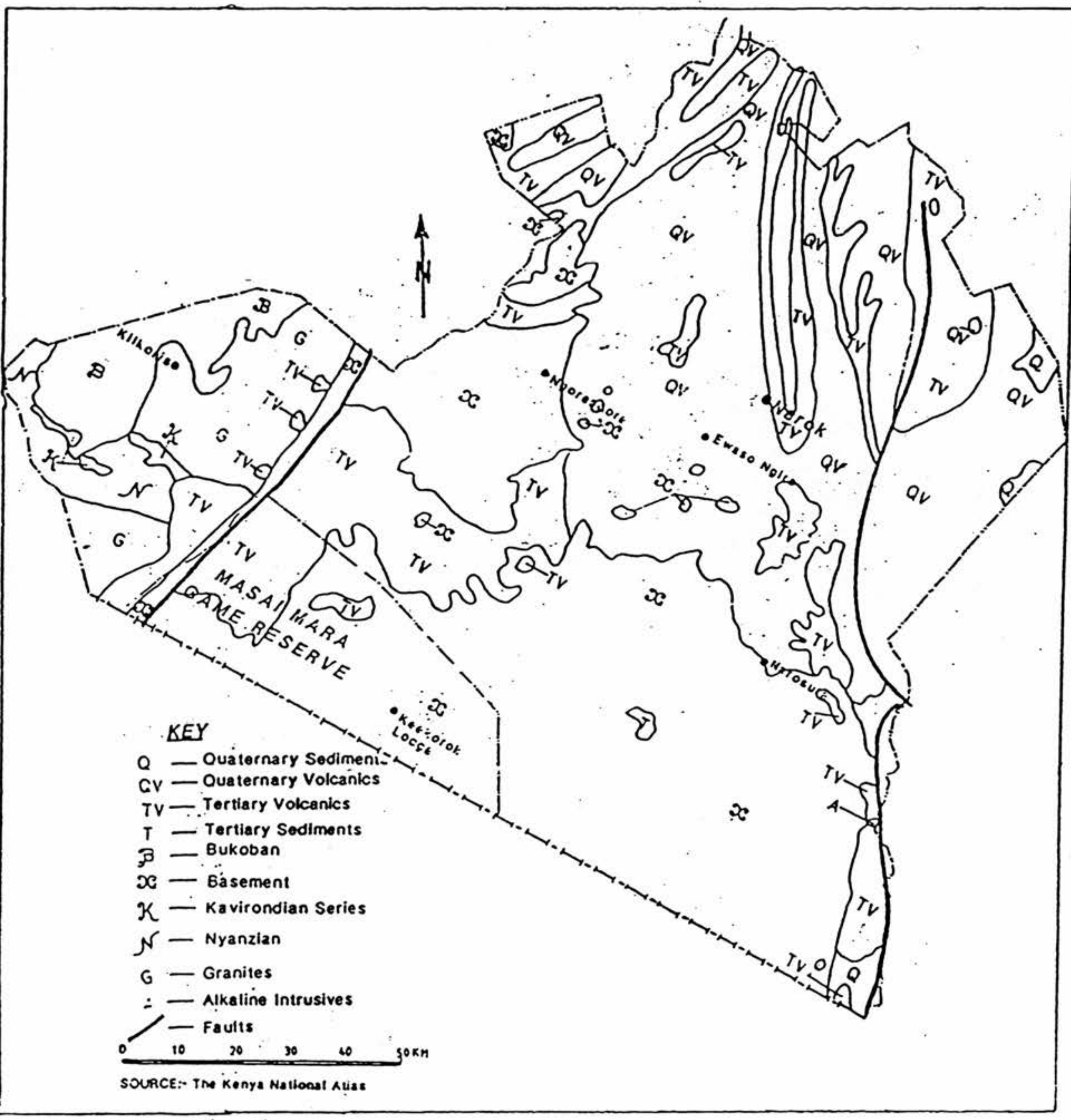


Figure 3.3 : Geological Units, Narok District

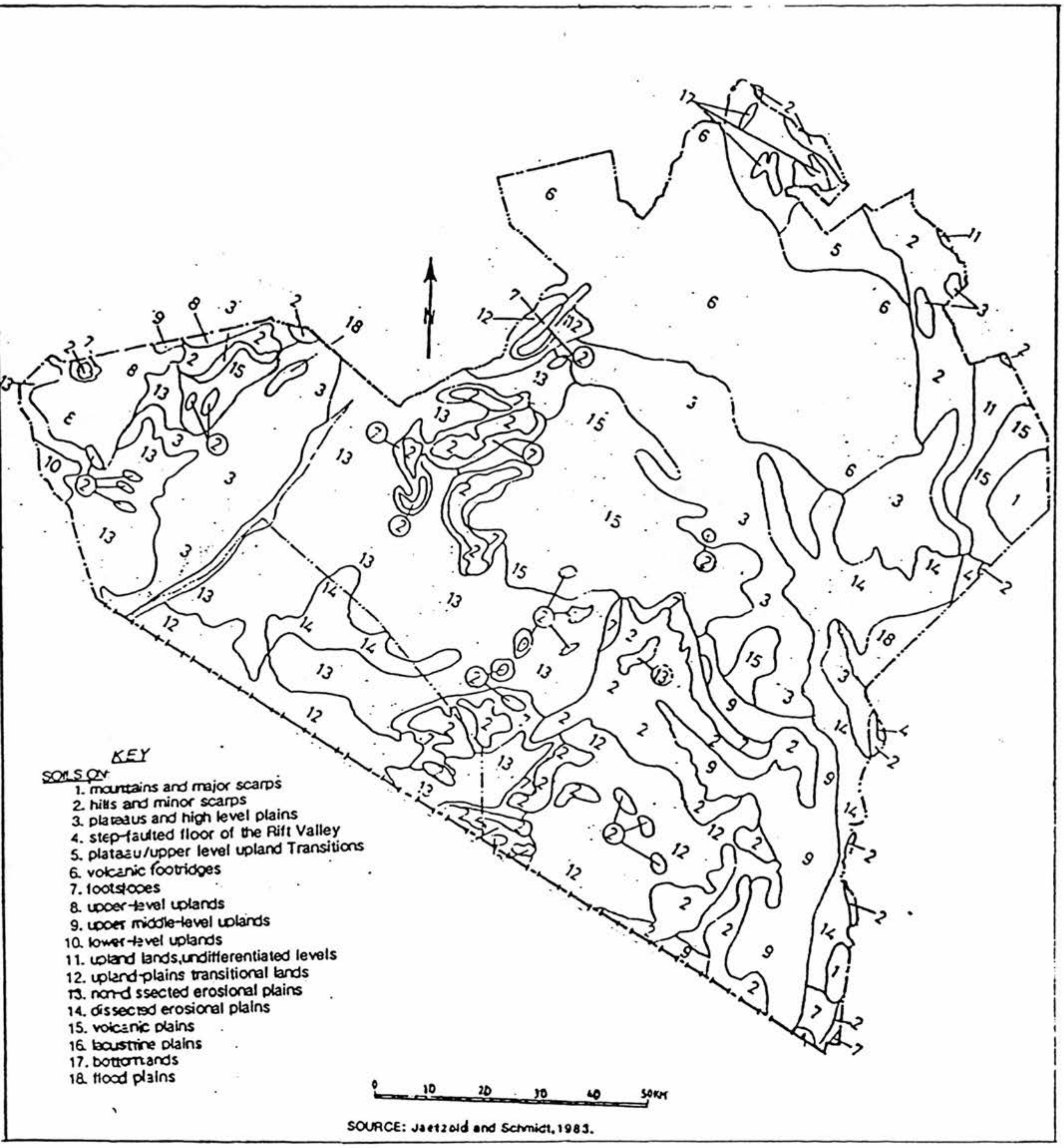


Figure 3.4: Soil Types characterised on the basis of physiography

District - the Mau escarpment, the Loita and Olorokoti plains and the rift valley bottomland - which are of Tertiary and Quarternary volcanic origin dominated by volcanic tuffs and volcanic ashes (Jaetzold and Schmidt 1983). The remaining portion - mainly the Loita hills and Trans-mara Division is composed of Pre-Cambrian rocks of the Basement complex (Survey of Kenya 1970). According to Jaetzold and Schmidt (1983), the latter includes Kavirondian series, Nyanzian, Granites, Bukoban and Basement geological units (Fig. 3.3). Running linearly in a north-south direction in the eastern part are a series of rift valley faults. Occasionally, Quaternary volcanic ashes overlie tuffs which are widespread in coverage and are frequently altered into clay in the humid zone. The ash layer which thins out westwards consists of subaerially deposits and waterlain sediments.

The soils of Narok District have been described in detail by Jaetzold and Schmidt (1983), see also Appendix C. Soil variations are attributed mainly to differences in geology, topography and climate (Fig. 3.4). This description agrees with Mbuvi and Njeru's (1977) study which also describes the soils of Mau Narok as polygenetic. The major soil types include brown loams and red friable clays, in the highlands, and red friable clays and sandy loams, in the plains. Except for areas with impeded drainage, most soils are deep, and well developed. Patches of shallow soils are not uncommon (Jaetzold and Schmidt 1983; Chapter 6). Soils in the plains are highly alkaline as a result of their recent volcanic origin.

3.2.3 Climate

Climatic conditions of the study area have been described by Glover (1966), Sombroek *et.al.*,(1982), East African Meteorological Department (1972) and Woodhead (1968). The significance of climate in the District is implicit in its use for land classification systems (Sombroek *et.al.*,1982; Jaetzold and Schmidt 1983).

Narok's climate, which varies considerably, is attributed to altitude, the Intertropical Convergence Zone (ITCZ), and the presence of Lake Victoria (Lamprey 1984; Sinclair 1979). Long-term meteorological observations in the District suggest that the rainfall pattern is a more important climatic variable than temperature. Except for parts of the Mau uplands which experience frost, temperatures are normally high enough not to interrupt plant growth. Differential distribution of rainfall, and especially its seasonal variation, is significant in determining vegetation cover, agricultural potential and the migration of wildlife in the Serengeti-Mara ecosystem (Sinclair 1979; Norton-Griffiths *et al.*,1975; Karime 1990; Boutton *et al.*,1988). Isohyet maps for this ecosystem (Fig. 3.5, see also Sinclair 1979; Epp and Agatsiva 1980) reveal rainfall gradients, with rainfall increasing from the southeast to the north and northwest directions.

Rainfall amount is greatly influenced by topography and altitude, compare Figures 3.2 and 3.5. The strong topographic effect of the Siria escarpment on rainfall has been suggested by

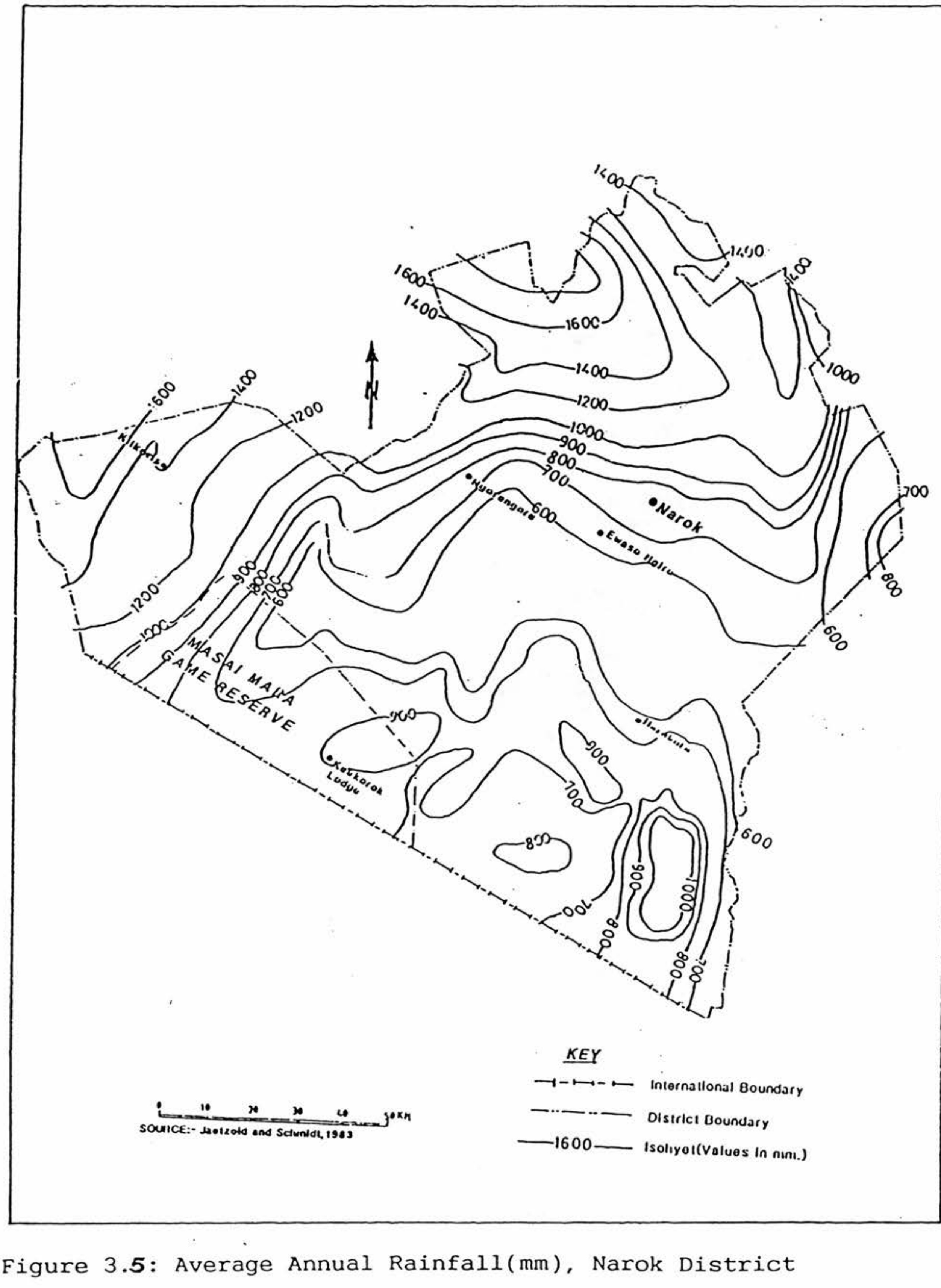


Figure 3.5: Average Annual Rainfall(mm), Narok District

different authors (Sinclair 1979; Lamprey 1984). Also, annual rainfall decreases from about 1600mm on the top of the Mau uplands (in the north) to approximately 508mm on the plains (in the south). Variations in temperature, topography and altitude affect rainfall effectiveness (Jaetzold and Schmidt 1983). Reduced evaporation due to low temperatures in the highlands, for instance, increases rainfall effectiveness.

The descriptions by Sinclair (1979) and Norton-Griffiths *et.al.,*(1975) of seasonal climatic change in the Serengeti-Mara ecosystem fit the climatic pattern for the study area. As in many parts of East Africa, Narok's climate is broadly associated with the movement of the sun and the ITCZ. The movement of the ITCZ leads to rainfall variation in the District. Its southward movement brings north-easterly, drier, winds which are associated with the first (short) rains while its northward movement brings the second (long) rains following the south-westerly, wetter, winds. Accordingly, the north is advantaged over the south by having cool conditions, earlier rains and a late dry sequence.

Rainfall seasonality and predictability also follow this pattern. The onset date for rainfall, for instance, is less predictable in the semi-arid part of the plains than for the upland areas. While most of the study area has a bimodal rainfall pattern with approximately 85% occurring during the months of March-May, 'long rains', and July-September, 'short rains', the semi-arid zone is characterized by a monomodal pattern with rainfall occurring between November and January.

Further modification of rainfall pattern is associated with Lake Victoria. Moist winds from Lake Victoria, markedly increase the wet and dry season precipitation, particularly in the higher south-western half of the District.

3.2.4 Vegetation

3.2.4.1 Introduction

The vegetation types discussed in this section were derived from Landsat imagery, existing maps of landuse, vegetation and topography, and fieldwork. Three steps were involved. First was a macro-level investigation of vegetation based on maps and satellite imagery. The objective was to obtain a broad view of the vegetation in the study area. Second was a micro-level stage which involved visual identification of the plant communities on the basis of structure and dominant species. The objective was to identify relatively homogeneous vegetation groups for sampling. This was followed by the examination of specific sample sites so as to obtain details on species type and number.

In order to decide on the classification approach to use, the methods used by previous studies (e.g Trump 1972; Taiti 1973; Darling 1960; Trapnell *et al.*, 1969; Pratt and Gwynne 1977; Lamprey 1984) had to been considered. These studies generated classification of Narok's vegetation from community to sub-community level using physiognomically-dominant species. This approach which may be called 'modifiers approach' could not be used in the present study, as it is excessively time-consuming. Instead, vegetation is examined at plant community level. The term 'plant community' is used to refer to an assemblage of plants, in which the species are more or less uniform/similar in composition and structure (see Whittaker 1973; Pratt *et al.*,1966; Pratt and Gwynne 1977; Odenyo 1979; Olang 1983). This approach is in line with the Level 1 lifeform classification of Grunblatt *et.al.,*'s (1988), and the Braun-Blanquet's (1932) phytosociological approach to vegetation studies. The approach of Grunblatt *et.al.,* (1988) recommends assigning plant assemblages into different groups according to the dominant lifeform of the canopy cover.

3.2.4.2 Methods and Materials

In order to establish the spatial pattern of plant communities, vegetation was mapped and visually interpreted from an unpublished 1976 MSS colour composite hard copy image (Fig. 3.6), obtained from the Regional Remote Sensing Centre, Nairobi. The scene containing the study area was at 1:500,000 scale.

Transparent paper was overlayed onto a light table over the hard copy and areas of tonal differences delineated. Vegetation types were then identified on the basis that different plant communities register different tones because of differences in plant density and/or composition (Griffiths 1985; Odenyo 1979; Lillesand and Kiefer 1979). The traced copy was enlarged for ease of adding details and making changes. Vegetation units and boundaries were checked using existing maps (Karime 1990;

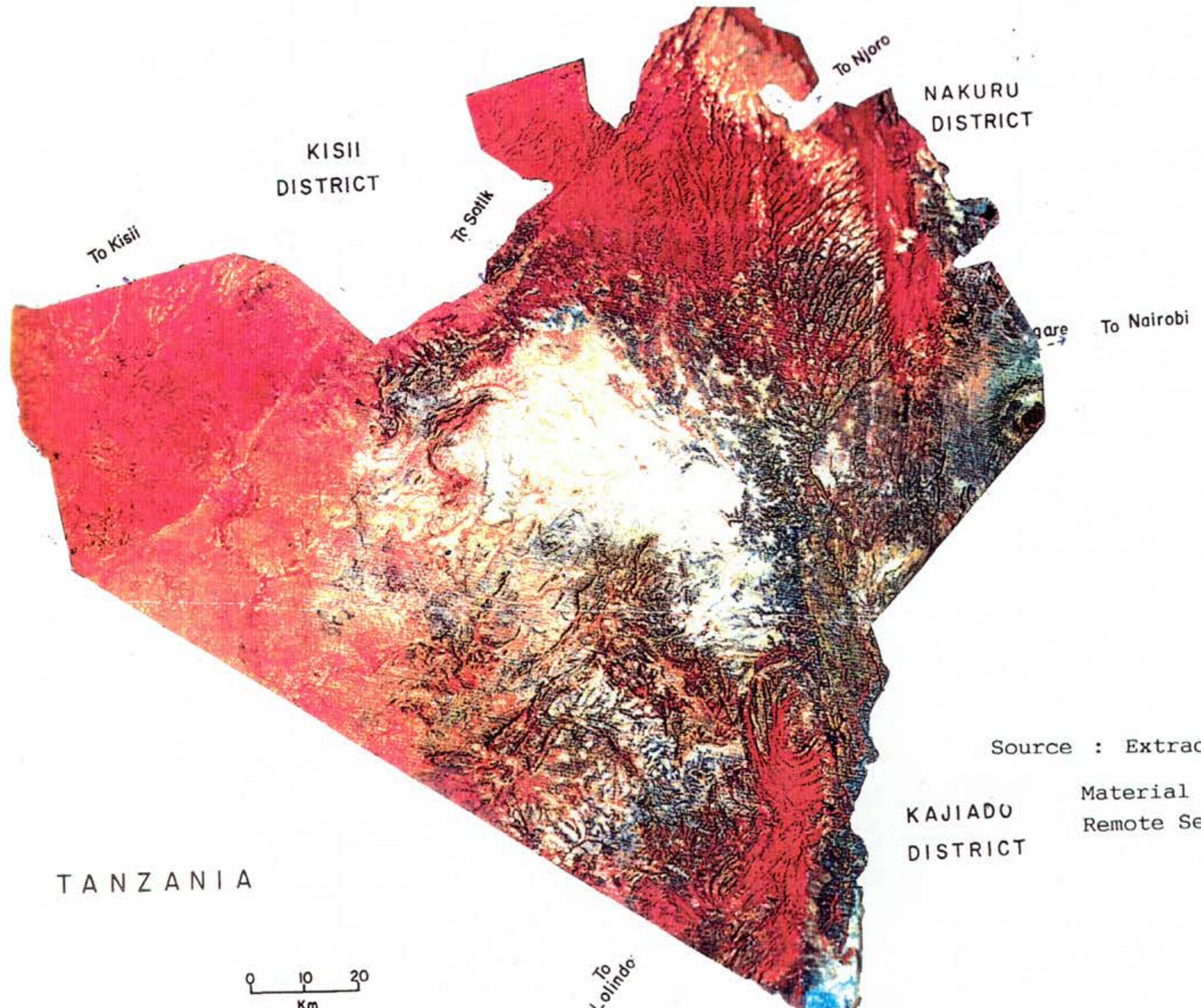
Msafiri 1985; Mbuvi and Njeru 1977; Mwichabe 1986), and during reconnaisance in the field. Landsat Thematic Mapper images of 4th Feb. 1984 and 13th Jan. 1989 were also used to update the information on vegetation types. For descriptive purpose, details such as structural and floristic composition, which could not be interpreted from satellite images were added during fieldwork.

3.2.4.2 Results

Narok's plant communities span an entire spectrum from grassland to shrubland, bushland and woodland to patches of forests (Fig. 3.7). Between and within the different communities are ecotones which have been subjectively allocated to those communities, it was considered, they best belong. Agricultural areas are also categorized as vegetation units, referred to by the plant community which they have replaced.

On the composite imagery (Fig. 3.6), the forest community registers as dark-red patches. This community refers to closed vegetation dominated by trees (woody, single-stemmed) of at least one storey with an interlocked crown. Tree heights range between 7m and 40m or more. The ground cover has herbs and shrubs, and climbers such as lianas and epipytes.

Two types of forests, the lowland and upland, are identified. The former appears as a network of richer red dendritic linings along rivers such as the Mara and Migori. The upland forests occupy the south-east and north-west parts of the District.



Source : Extracted from unpublished
Material obtained from the
Remote Sensing centre, Nairobi.

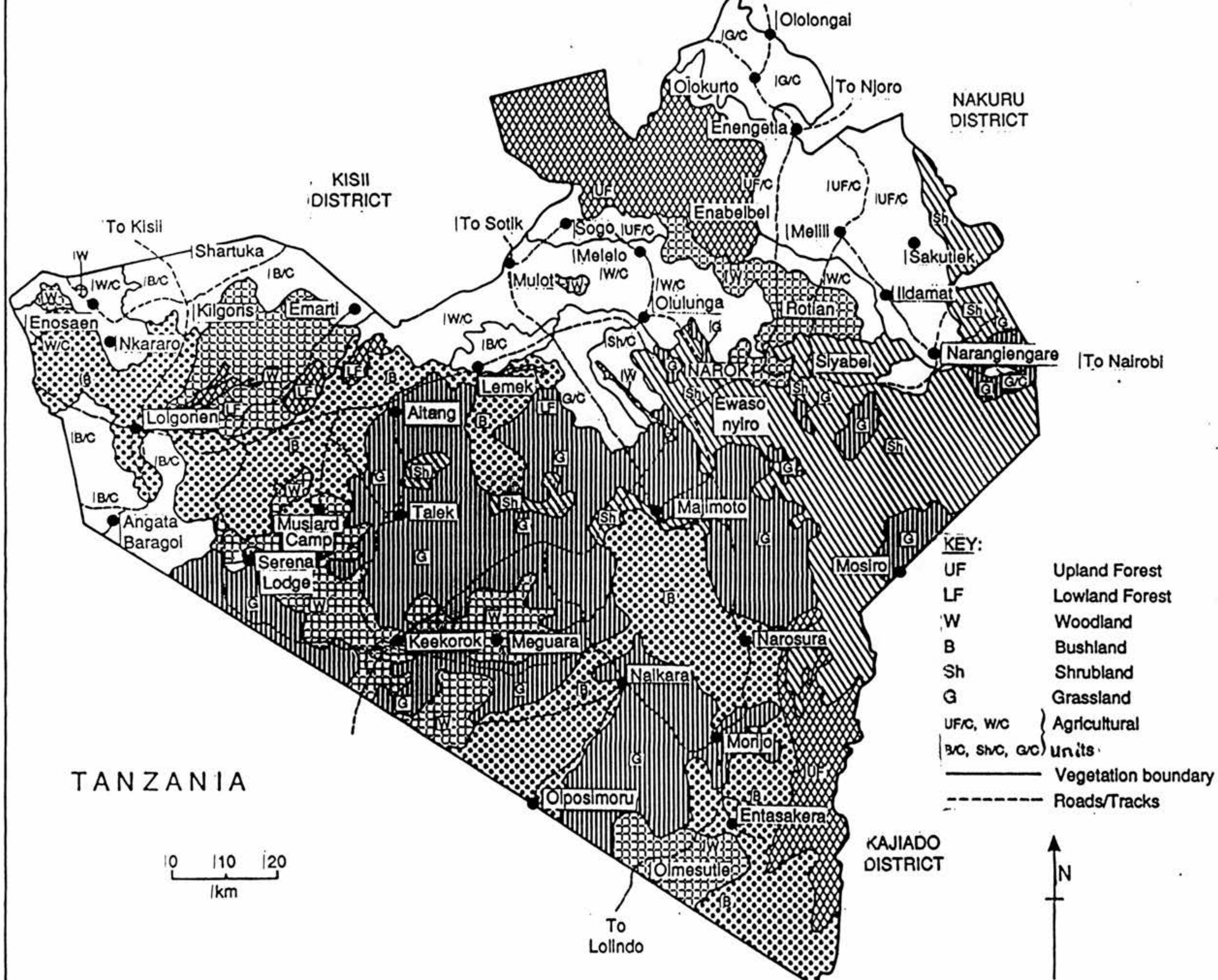
Fig. 3.6 Vegetation types of the Narok District. A 1976 Mss colour composite hard copy. See print details in text and Fig 3.7

However, they are difficult to identify especially where terrain is rugged. Shadows imposed on the landscape, obscure their identification.

The woodland community refers to vegetation stands characterised by more trees than shrubs, woody and single-stemmed, of at least 7 to 10m high with an open or continuous, and a light interlaced canopy. The field layer usually consists of grasses. This community which appears as light red/whit ish-brown on the imagery (Fig. 3.6) is difficulty to isolate from the forest and bushland communities. Although woodlands are widely scattered, distinguishable stands are common in the MMGR and parts of Trans-mara. Also, they cover the foothills of the Mau, north-west of Ololunga.

The bushlands which register more or less the same colour as woodlands, are confined to Loita and Trans-mara (Figs. 3.6 and 3.7). This is a community with thick impenetrable stands characterised by thorny shrubs and a few trees of average heights less than 10m. In the plains, this community consists of low stands with tall scattered grasses within clumps of trees/shrubs.

The shrubland is either an open or a closed landcover dominated by shrubs (woody, multi-stemmed) with height less than 6m. It appears whit ish-blue on the composite imagery, occupying the area surrounding the central grasslands (Figs. 3.6 and 3.7). Lastly, the grassland community refers to vegetation dominated by grasses and other herbaceous components. This community is,



Source: Compiled from MSS hard copy 1976 along with TM 1984 and 1989 images, topographic, landuse and vegetation maps.

Fig. 3.7 Vegetation types, Narok District.

occasionally, intercepted with widely scattered or grouped stands of trees and shrubs of average height less than 6m. On the satellite imagery (Fig. 3.6) the grassland community is the most readily identifiable. Since grasslands are often scorched during the dry season, they appear as ash-white tones. Although the distribution of this community is difficult to isolate particularly in cropped areas, and especially on TM images, field observations confirmed the existence of vast areas of intact and disturbed grasslands in the south and mid-south western parts of the District, and a number of patches in the Mau, south west and central parts of the District (Fig. 3.7).

Agricultural community refers to vegetation in settled and cultivated land. On the imagery, it appears blueish-white/brown and it is concentrated along the borders and on the margin of the central plains (Figs. 3.6 and 3.7). There are also linear portions of this community along the roads, particularly the Narok-Njoro road. The community consists of remnants of indigenous vegetation or predominantly man-made vegetation and/or bare ground. Bare ground which is faintly visible on the imagery, became evident in the field.

3.2.4.3 Discussion

Before proceeding to the discussion of plant community distribution, some limitations associated with the approach used in this study in mapping vegetation should be noted. Successful mapping, requires supplementing satellite data with air photo interpretation and ground checks (Gwynne and Croze 1975;

Griffiths 1985). Lack of funds to purchase air photos limited interpretation to ground truthing while delays to purchase TM images, meant that they had to be used after fieldwork, omitting ground truthing. Vegetation mapping is therefore, predominantly, confined to interpretation of the hard copy.

Also, existing maps which are obsolete and of different scales made vegetation comparisons difficult. Lastly, since not all areas were visited during fieldwork, limiting ground verification, this study has avoided including any statistics on the size-distribution of the different plant communities. The communities are, therefore, described qualitatively.

In spite of these limitations, field observation revealed that the communities identified for this study are highly diverse (Chapter 7). This diversity is a result of differences in the physical environment (see above) and vegetation history (Chapter 2).

3.2.4.2.2 Forest Community

The bamboo and montane forests plus other upland forests occur on the Mau and Nguruman escarpments at 2400m altitude. The bamboo forest is confined to an altitude where agricultural land use is limited by low temperature. The dominant species include *Dombeya goetzenii*, *Arundinaria alpina* and pockets of *Erica arborea* and *Stoebe kilimandscharica.*

Lowland forests cover the river valleys which interrupt the plains. Also, scattered here and there on the hilltops are patches of evergreen and deciduous forests. These forests, which now exist in a drier climate, are floristically related to montane forest on the Mau uplands (Mwichabe 1986). They may be assumed to be relicts of formerly extensive forests which retreated following increased aridity in the Quarternary and have further been reduced by human activities. Examples include the forests on the Loita Hills and wetter parts of Trans-mara which have characteristic species such as *Juniperus procera, Olea usambarensis, O. hochStetteri* and *Podocarpus milanjianus.*

The forest community has been disturbed differently. Even the Nguruman forest, once described as the only forest in Kenya that had remained untouched (Doute *et al.*,1981), is gradually being harvested for charcoal burning. The distribution and diversity of this community is subsequently changing. Using Figures 3.6 and 3.7, the total area under forest has greatly decreased, an impression contrary to recent records. Doute *et. al.*,(1981) and the NDDP (1984) estimated the forest community in Narok District to be 1037km^2 (228,115ha) and 1302km^2 (270,553ha), respectively. The increase in forest coverage is not an indication of forest recovery, but it is due to methodological differences associated mainly with interpretation and the definition of a forest community. The NDDP statistics are misleading, particularly because the early 1980s was the time when agricultural encroachment into forest land was greatest (Chapter 2). The total forest area was obviously reduced. For instance, between the period late 1970s and the early 1980s more than 30% of the forest on the Mau escarpment was removed (ERD

1984). This significant change is not reflected in NDDP's statistics because non-forest woody communities are included. This anomaly is expected, particularly, when vegetation mapping considers communities as they should be and not as they are.

While most of east Mau has been cleared following recent encroachment (Figs. 3.6 and 3.7), pockets of thick forests cover west Mau. At Enoosupukia, expansion of small-scale farming is responsible for forest loss while at Sakutiek, the loss is due to both small- and large-scale farms. Other than being thinned out through selective wood cutting and tree destruction by domestic and wild animals (Chapter 4), relict and riverine forests are also being lost to cultivation. At Kanunga and Narosura gravity water irrigation has attracted horticultural activities. About 500ha of riverine forest has been lost to cultivation over the last 4 years (Ototo G. pers. comm.). It needs, however, to be clarified that much of forest destruction is not from the Maasai people, because their activities have been less damaging. Fast destruction of upland forests is attributed to encroachment by non-Maasai Kenyans (Chapter 2) and lack of a landuse policy (Chapter 1, see also NDER 1986; NDDP 1984).

3.2.4.2.3 The Grassland Community

The origin and development of this community is yet to be established. The world types of grasslands, grouped as anthropogenic, climatic and edaphic (Cole 1986, Werger 1983), are represented in Narok District. The significance of the grassland community in supporting pastoral populations and large numbers of ungulates in the Serengeti-Mara ecosystem, and in other parts of East Africa is unquestionable (Chapter 5). On the whole, this community is decreasing (Figs. 3.6 and 3.7) following wheat cultivation in the plains (Chapter 5), overgrazing and therefore bush encroachment (Chapter 4).

Climatically determined grasslands occur on the Mau and in the semi-arid plains. The Mau has montane grassland which is dominated by the moorland flora such as *Erica arborea* and *Artemisia afra,* and weed grasses such as *Pennisetum clandestinum, P. schimperi* and *Digitaria scalarum.* Human activities have greatly influenced this grassland through burning, grazing and cultivation (Chapter 2). The drier plains are characterised by drought resistant grasses such as *Digitaria macroblephara* and *Sporobolus marginatus.*

Edaphically determined grasslands on the plains, are confined to areas with impeded drainage, and partly, to soils low in fertility. The characteristic soils in the plains, the vertisols (Chapter 6), which are of volcanic origin support grasses such as *Echinochloa pyramidalis* and *Eragrostis haploclada, Hyparrhenia dissoluta* and *Pennisetum mezianum. Panicum maximum* is common in areas flooded for long periods. Sometimes, edaphic grasslands are difficult to isolate from those which are climatically determined. This is because climatic stress, for instance, affects plants through the modification of soil conditions.

Anthropogenic grasslands cover the MMGR, Aitong and Loita plains. Frequent human activities are undoubtedly responsible for the expansion and maintenance of this community (Chapter 2, see also Dublin 1986; Vesey-Fitzgerald 1970,1973). Vesey-Fitzgerald (1973) describes burning as a cheap and quick way by which grasslands have been increased at the expense of woody communities. The dominant species include *Digitaria*, *Cynodon*, *Themeda* and associated grasses which according to Vesey-Fitzgerald (1970) are fire-tolerant species. Abandoned cultivated farms in the uplands and in the lowland woody communities have attracted *P. clandestinum* and *P. schimperi*, and *Eragrostis spp*, respectively (Chapter 4). However, this re-invasion, which appears as an expansion of the grassland community, is short-lived as the areas involved would be recalled for farming.

4.2.4.2.4 The Woodland Community

This community is a derivative of the forest community. Cultivation, settlements, fire, tree felling by large herbivores and trampling are the forces behind the conversion. For instance, shifting cultivation and settlements at the foothills of Maasai Mau is associated with the conversion of Engare Engito, Ngulut, Maasai Mau and Masandara forests into woodlands. Woodlands are also widely distributed in Trans-mara, scattered hills in the plains and on the foothills of the Nguruman escarpment. Differentiated on the basis of relict species of the original forest type, they include *Cassine buchananii* of the Buffalo area, the *Balanites aegyptica* of Aitong-Koyage area, *Acacia* woodland along watercourses and evergreen woodlands on the lower ridges of the Maasai Mau forest.

The distribution of woodlands is the most difficult to map, given that the community exists in various stages of regrowth or destruction of the original forest land. In settled areas of Trans-mara and the footslopes of the Mau uplands, clear-cutting and selective tree harvesting are destabilising and reducing this community into a lower vegetation category. In the MMGR the woodland community is being thinned out or reduced in size or both by animal activities and seasonal burning (Dublin 1986).

3.2.4.2.4 The Bushland Community

This is a succesional community which exists either as degraded forest and woodland, or as a transitional community succeeding the grassland through bush encroachment (Chapter 4). Like the woodland, the bushland community must be maintained by some ecological force. Overgrazing and reduced burning, for instance, are responsible for its re-invasion.

A unique type of bushland generally called clumped bush forms a community which occupies much of Trans-mara Division. This community is associated with patches of deep and shallow soils. However, it is being reduced by the expansion of SONY sugar belt and small-scale farms (Chapter 2). Characteristic woody species include *Rhus natalensis, Teclea nobilis, Olea hochstetterii* and *O. africana*. The ground layer is dominated by the herb *Ocimum basilicum* and *Loudetia kegerensis*. In much of the semi-arid areas, the bushland community is characterized by genera such as *Combretum, Croton, Acacia, Albizia* and *Terminalia and a grass cover dominated by Hyparrhenia, Digitaria* and *Themeda* species. On the plains, evergreen and semi-deciduous bushlands cover a large part of the Loita hills (Fig. 3.7).

3.2.4.5 The Shrubland Community

This is a successional community which is extensive in Ndulele-Eurokule and the Ewaso Nyiro-Ololunga, west of Narok town (Fig. 3.7). The characteristic woody species include *Tarchonanthus camphoratus, Acacia drepanolobium, Teclea simplifolia, Rhus natalensis* and *Olea africana* whilst the herbaceous layer consists of *Eragrostis tenuifolia, Themeda triandra and Digitaria abyssinica.* The shrubland community appear to have originated from cedar forests, due to overgrazing, and it is expanding at the expense of the latter. At Ndulele-Eurokule, the vegetation is characterized by relic (charred stumps) and aging cedar trees with grass cover confined to open spaces.

Only a small part of this community has been lost to wheat farming (Fig. 3.7; Chapter 5), and permanent non-Maasai settlements. This is ascribed to its low agricultural potential, particularly at Ndulele-Ewaso Nyiro, associated with low rainfall amount and relatively poor soils (Jaetzold and Schimdt 1983, Chapter 6). The community which has existed through burning and animal activities, appears to have acquired resistance and tolerance towards these disturbances. The high frequency of different disturbances has favoured the dominance of weedy plants, mainly *Solanum incanum, Acacia drepanolobium* and *Tarchonanthus camphoratus.*

3.2.4.6 The Agricultural community

This community is expanding steadily following high influxes of immigrant cultivators. Its expansion involves the displacement of pastoral Maasai which started early this century (Chapter 2). Encroachment of agricultural community is most evident in Lolgorein in the south west, Nkararo-Nyangusu-Kilgoris-Mulot along the west border and Mau-Sakutiek-Suswa in the north and north east (Fig. 3.7). Here, it exists as a floristic continuum ranging from bare ground through totally converted indigeneous vegetation to vegetation with remnants of indigeneous species. Therefore, floristic composition of the agricultural community consists of a combination of indigeneous valuable, weedy and exotic species (see Appendix A).

This study has shown that the agricultural community occupies a larger area than is shown on Figure 3.7. This is because small areas not identifiable on the hard copy and not covered during field-checks are excluded. These include settlements and farms less than 1/4ha, too small to be identified on a satellite imagery.

3.2.4.7 Concluding remarks

This section has provided a description of Narok's vegetation at the community level. Fluctuations, characterized by decrease in size have been indicated in all communities, supporting the instability of vegetation (Chapter 2). The following section, is a detailed description of the fieldwork methods used to collect questionnaire, disturbance, vegetation and soil data at the micro-level, that is in each sample.

3.3 FIELDWORK METHODS AND MATERIALS

3.3.1 Introduction

Fieldwork was carried out with an assistant during the periods September 1989 to April 1990, and June 1990 to August 1990. Field investigations are described under the following subheadings : reconnaissance, preliminary classification of vegetation and sampling procedures.

3.3.2 Reconnaissance

In order to decide on the best methods for studying vegetation and investigate accessibility within the study area, we spent one and half months in going through the District. Some areas were extremely difficult to visit because of poor roads or for fear of wildlife or were accessible only during the dry season. During this survey, it became evident that Narok's vegetation exists at different levels of recovery. The assemblages range from those without dominant species, suggesting some gradation of vegetation, through to distinct ones.

During this time, the District Officers and Locational Chiefs were visited to explain the purpose of the study and to obtain assistance related to questionnaire administration (section 3.3.4.1). A research permit had also to be obtained from the Office of the President.

3.3.3 **Preliminary Classification of Vegetation**

Section 3.2.4 discussed details about drafting a working vegetation map. The purpose was to update the distribution of vegetation types so as to decide on the location of sample sites. It was very difficult, however, to design a satisfactory classification (see section 3.2.4.3), but it was equally difficult to sample vegetation without one, especially because random sampling was not to be employed (see below).

3.3.4 **Sampling Procedures**

After establishing vegetation boundaries, sample sites were chosen on the basis of accessibility, homogeneity and representativeness of the specific community. The working map (section 3.2.4), questionnaire data and direct observation were used when considering these factors.

Sample sites were chosen subjectively so as to represent the full range of vegetation in the study area. Subjective sampling is used more often by plant ecologists than regular and random sampling (Gauch 1982; Muller-Dombois and Ellenberg 1974; Greig-Smith 1983; Goldsmith *et al.*,1986) because it is more rapid. Also, it allows sampling of floristically and/or environmentally homogeneous areas and may produce satisfactory results with fewer samples (Gauch 1982). The disadvantages are that the observer's perceptions and biases may cause errors such that statistical procedures are limited to descriptive purposes rather than hypothesis testing, since the assumption of random sampling is violated (Gauch 1982; Kershaw and Looney 1985;

Greig-Smith 1983; Goldsmith *et al.*, 1986).

Therefore, the reasons for using subjective sampling design are that it allowed plots to be chosen within easily accessible areas, according to known vegetation history, and it enabled detailed description of floristic composition and structural characteristics of all plant communities (see section 3.4.5). It was the best procedure given the high level of variability of vegetation in Narok District. Using random sampling would be difficult and time-consuming in such conditions (Gauch 1982).

A total of 42 sample sites or plots was chosen for uniformity in plant characteristics. A deliberate effort was made to sample homogeneous assemblages. Replicate sample sites for undisturbed vegetation, from different localities, were examined in order to place replicate samples of disturbed stands into perspective. Thus, investigation of vegetation dynamics centred on spatial sampling of floristic and structural data, a 'static' as opposed to temporal approach (Richards 1952; Purata 1987). Undisturbed vegetation included assemblages that had been influenced by man and those, it was assumed, that were affected predominantly by natural disturbances.

Sites were classified as disturbed depending on whether they had been subjected to severe burning or cultivation or total clearing or overgrazing or a combination of these within the last 10 to 30 years. These disturbances were considered to have the potential to destroy vegetation and severely decrease re-establishment. It must be admitted that it is difficult at times to differentiate between disturbed and undisturbed sites. Broadly, this study assumes that disturbed and undisturbed communities are components in a disturbance continuum, so that the boundary between them is arbitrary. However, it will be noticed in chapter 7, that disturbed sites are characterised by weedy species which are associated with human activities. Having undisturbed vegetation for comparison was a rare advantage for this study. Thus, the need to reconstruct the potential natural vegetation, so as to understand human impact, was unnecessary.

In terms of distribution among communities, 14 plots were placed in the forest community, 6 in the woodland, 8 in the bushland, 4 in the shrubland and 10 in the grassland communities. The number of plots per community was determined by the community's relative size, and how much it had been exposed to human influence. Consequently, the grassland and forest communities have the highest number of samples because of their largest size and greatest subjection to human disturbance.

The plot shape remained square while plot size was varied on the basis of the physiognomy of the characteristic species in each plant community (Gauch 1982; Greig-Smith 1983; Goldsmith *et. al.*,1986; Olang 1983). Time constraints limited the use of the 'minimum area', in deciding on the size of quadrats, to be attempted only for the grassland communities. This is the smallest area assumed to provide information representative of a particular community type (Gauch 1982; Greig-smith 1983; Kershaw and Looney 1985). The woody communities were examined in 50m by

50m plots while 25m by 25m plots were used to study the grassland communities. These plot sizes are within the limits recommended for sampling plant communities in the tropics (Gauch 1982; Westholf and Maarel 1978). Accurate positioning of plots into square form and demarcation of boundaries was difficult, especially where there was thick undergrowth or thorny shrubs.

Table 3.1 is a summary of the variables collected in each plot and the method used.

Variable	**Method**
Qualitative data	A structured questionnaire.
Disturbance type	Identified on the basis of soil surface and plant evidence, at a randomly chosen sub-plot.
Disturbance size	Measured by a tape measure or estimated, in case of large-scale.
Type of species	Identified in the field or at the herbarium in Nairobi.
Number of individuals per species	Woody species counted, herbaceous species coded 1.
Plant height	Measured using a tape measure or estimated, for tall trees.
Plant diameter for woody species	Measured at 1.3m above the ground.
Soil	Three samples taken within the profile for each site.

Table 3.1 A summary of variables collected in each plot and the method(s) used.

For re-location, the plots were photographed and their positions on the map indicated (see Fig. 3.8).

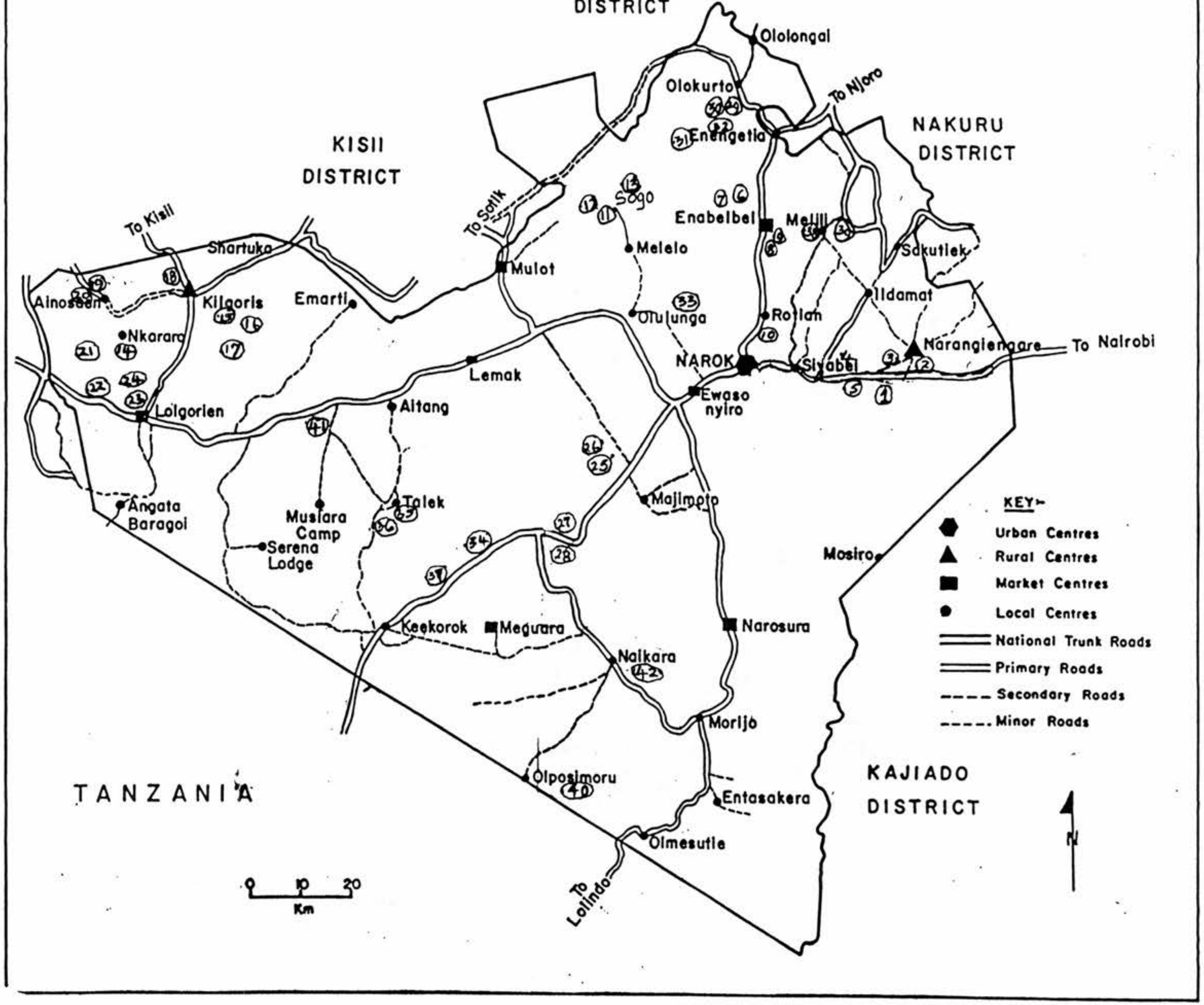


Fig.3.8. The location of Sample Sites.

3.3.4.1 Questionnaire Administration

3.3.4.1.1 Rationale

This study realised that field sampling, and the use of satellite images (Chapter 5) could leave certain aspects of the study unattended. For instance, both approaches could not provide an adequate picture on human activities, vegetation history and suggestions needed for recommending the type of management of vegetation (Chapter 8). Administration of questionnares was therefore necessary. Questionnaire data were most useful because of the static approach used to study vegetation. The objectives of administering a questionnaire were :

a. To establish landuse and vegetation history so as to decide on the location of sample sites and make inferences on the human impact on vegetation.

b. To establish people's attitudes towards different landuse types so as to be able to make recommendations on pertinent management of vegetation.

3.3.4.1.2 Methods and Materials

Questionnaire administration preceded the selection of sample sites. This was important in deciding on representative sites for the different plant communities. Relevant information was obtained during sampling at each site so as to account for the observations made.

Having established which human and vegetation variables would be useful for this study, a questionnaire was formulated. The format of the questionnaire (Appendix D) took into account time contraints, the respondents' culture and the scope of the study.

Two drafts were constructed during the design procedure. At each stage, both the questions and the complete schedule were piloted on a small number of respondents. Minor modifications and major changes were then incorporated in what later became the first version of the questionnaire. This version had to be reformated after learning that some questions were inconsistent and likely to raise misunderstanding and confusion between us and the respondents.

In particular, the problem of whether to use open or closed questions was investigated. Both question formats had to be used as it is believed (see Oppenheim 1968; Moser and Kalton 1971) that open-ended questions offer as many problems of ensuring accuracy and reducing bias as do closed questions. Questions assumed to be maximumly informative, were used. Written closed questions were used to get quantitative information relatively quickly while open questions were used to elicit qualitative information. Double questions were also used to build up evidence on certain assumptions made by the respondents. Questions which obliged the respondent to think over a wide range of issues were split up. My assistant was required to explain them thoroughly and patiently. This was necessary only if the respondent could not speak Kiswahili or English or Ekegusii.

A household survey which aimed at two heads[1] of households, a woman and two middle aged Maasai men, and an office survey which involved a government or a NGO official was conducted for each sample site to be selected. The households and the relevent officials were originally chosen, selectively, during reconnaissance with the help of the village headmen and Locational and Divisional administration officers. In Maasai homes, except for a few, only household heads offered to be questioned. Maasai women are not allowed to interact with strangers. Young Maasai men had to seek consent from elders in order to be questioned. In non-Maasai occupied areas, women were questioned mainly on the situation of wood resources. However, it was very difficult to find many people at home even when prior arrangement was made. Occasionally some of the respondents could not or would not co-operate with the study. To this effect, some questionnaires were incomplete and have been omitted in the discussion.

Out of a total of 160 questionnares, thought to provide sufficient information within the time period, only 132 are considered, at least two from each sample site. Out of these, 16 are from government officials, 8 from NGO officials, 23 from men immigrants 12 from women immigrants, 3 from Maasai women, 24 from middle-aged Maasai and 46 from Maasai elders. While conducting this survey, it was assumed that each respondent had

[1] A head of a household refers to men elders, at least 35 years of age in a Manyatta or in any immigrant's house while middle-men refer to men of the age between 25 and 35.

good knowledge of the vegetation history and landuse type(s) of the respective area. Based on the responses, except with some immigrants, this assumption proved to be reasonably correct.

Questionnaire design focused on landuse type, land tenure and local use of vegetation (see Appendix D for details). The respondents were questioned on potentials and limitations of landuse types, status of woody and grassland communities over the last three decades and the ways of dealing with weed plants. The ways of coping with pasture and wood shortages were also queried. The respondents were questioned on the occurrence of fire, soil erosion and animal influence on vegetation. The questionnaire also covered the frequency and the amount of wood collected and the different ways through which wood is extracted.

3.3.4.2 **Human Disturbance Characteristics**

3.3.4.2.1 Types of Human Disturbance

Data on disturbance types in each plot and within a 2km radius, were collected by observation. Disturbances in proximity were sampled because they were believed to be influencing biotic activities in sample sites. The activities causing disturbance were restructured from evidence *in situ* and historical records, supplemented with questionnaire data. The cause of disturbance was determined by observation of plant remains and the soil surface. Disturbed sites were identified as openings in the vegetation with injured and/or destroyed plants or with low plant cover and disrupted soil crust. Table 3.2 shows *in situ* evidence used to identify disturbance types. The use of indicator species proved most useful in inferring long-term human impact on vegetation (Chapter 7), but was limited by inadequate physioecological knowledge of plants in the study area.

For sampling purposes, each plot was divided into 5m by 5m sub-plots, and the disturbances were recorded in five of randomly chosen sub-plots. A table of random numbers was used to select the subplots. A similar exercise was conducted to establish disturbance type for the area around each plot, but by walking a 2km distance in three randomly chosen directions and recording the disturbances at every 500m. The directions were decided from the centre of each plot, using 'bearing' cards.

Thus, a total of 17 points was sampled for disturbance characteristics at each site. Disturbances associated with natural forces such as termite mounds were ignored.

3.3.4.2.2 Human Disturbance Size

To understand the status of the vegetation the size of the disturbances (hereafter, called gaps) observed in the 17 points, was measured or estimated. For small gaps (<1/4ha), both length and width were measured using a tape measure while the size of large gaps (>1/4ha) was estimated.

Disturbance type	Evidence
Burning	ash on the ground, soot/burned scars on plants presence of indicator species e.g., *Acacia spp, Themeda triandra* and *Digitaria spp.*
Browsing	cut/clipped shoots, stripped stems and branches animal dung and foot prints.
Trampling	bare ground or destroyed vegetation cover, animal foot prints and dung, indicator species e.g., *Solanum incanum, Croton spp* and *Tachonathus camphoratus.*
Light grazing	selectively cut/clipped grass, grass height more than 20cm, presence of ground cover, animal dung and foot prints.
Overgrazing	total removal of grass, some grass but no selective grazing, trampled ground, animal dung and foot prints grass height less 20cm, indicator species e.g., *S. incanum, T. camphoratus, Microchloa kunthii* and *Aristida adoensis.*
Animal droppings	animal foot prints and pellets.
Selective wood cutting	stumps and/or logs, some standing trees/shrubs of different species.
Total clearing	all trees/shrubs removed, stumps and/or logs cultivated fields, settlements current/abandoned.
Mining	presence of a mine, rock/soil deposits, animal licks.
Quarrying	presence of a quarry, rock/soil deposits.
Cultivation	presence of farms current or abandoned, crop remains, indicator species eg., *Pennisetum clandestinum, P. schimperi* and *Eragrostis spp.*
Soil erosion	exposed plant roots, gullies, trampled or bare ground, indicator species e.g., *M. kunthii, S. incanum, Croton spp* and *Acacia spp.*

Table 3.2 ***In situ*** **field evidence used to identify disturbances. The evidence is supplemented with questionnaire and existing literature.**

A disturbance gap has been defined variously, as a breach in the canopy (Bazzaz 1984) and as an opening (even) within tree canopies above undergrowth (Brokaw 1985; Belsky 1987). The difficulty with gap definition centres on its depth within a stand of plants. Brokaw (1985) suggests that the 'hole' should extend to about 2m above the ground, a definition which is limited to woody communities, and could not be applied to the grassland communities in the study area. Therefore, the present study uses the term gap to refer to an opening created by the death of a single plant or a branch to an hectare created by total clearing. Occasionally, small gaps were observed within large disturbed areas some under regeneration, in which case, both small and large gaps were recorded and their relative frequencies indicated (Chapter 5). This was true of abandoned farms and settled areas.

3.3.4.3 **Vegetation Characteristics**

For this study, to decide on the status and trend of change of the vegetation in both disturbed and undisturbed sites, both floristic and structural aspects were recorded.

3.3.4.3.1 Type and Number of Species

To establish the response of plants to disturbances, individual plants 'rooted' in each sample site were counted by species type. For identification and accurate counting of species and individuals per woody species, respectively, each plot was subdivided into 5m wide sections. To overcome the difficulty of defining an individual, herbaceous, creeping and climbing plants, which are not amenable to recording by density (Greig-smith 1983), were coded 1 if present. Only plants that could be identified in the field were listed. Otherwise, plants whose identities were uncertain, were collected, pressed and later identified at the herbarium at the University of Nairobi for completion of plot vegetation inventories. Local names have been used (see Appendix A) for specimens which could not be identified. A total of 610 plant species was collected.

3.3.4.3.2 Plant Height and Diameter

Tree/shrub height, and diameter at breast height (dbh) were estimated or measured using a tape measure. The objective was to obtain insights into the trend of succession of plant assemblages and the amount of wood available in each site. The ground level, as for basal diameter, was ignored because of the convoluted outline of some individuals due to buttresses or multi-stems. Consequently, an arbitrary height (1.3m called breast height) was used. To get some idea about the selectivity of human disturbances, the species frequently harvested for wood products, the plants somewhat endangered and to estimate the intensity of wood cutting (Chapter 7), trees/shrubs cut were counted. Because of the difficulty in identifying the cause(s) of tree stumps, the number obtained for totally cleared sites under cultivation (on-going or abandoned more than two years prior to fieldwork), are treated as estimates.

Grass height was measured for estimating the intensity of trampling and grazing, and in accounting for fluctuations in fire occurrence (Chapter 5).

Also, at each site, notes were made on the presence of seedlings and saplings. This was necessary in understanding changes within vegetation assemblages. The number of seedlings browsed was also recorded by species type in an attempt to estimate the intensity of browsing on vegetation and to predict regeneration trends. Seedlings were considered browsed if any of their parts (e.g., leaves, branches) was clipped (Table 3.2). Since some plant species reproduce vegetatively, in that they resprout from rootstocks, it was difficult to readily isolate seedlings from saplings. Therefore, this study uses the term seedling to refer to all trees/shrubs less than 1m tall, irrespective of, whether they were rootstock resprouts, suppressed plants or newly germinated seedlings. Due to tree/shrub coppicing, studies focusing on successional trends in eastern Africa (e.g., Kigomo *et al.*,1990; Belsky 1985; Vesey-Fitzgerald 1973; Glover 1966) have had to be based on height and diameter classes rather than age distributions.

3.3.4.4 **Soil Sampling**

3.3.4.4.1 Background and Rationale

The interdependence between soil and vegetation may allow inferences to be made on vegetation change based on soil properties. This section starts with a brief background which develops the argument that soil and vegetation are related. With reference to different human disturbances in the study area (Chapter 5) and existing literature, an attempt is made to demonstrates how this relationship may change.

The relationship between plants and soils in the tropics, is well established (Jordan 1985; Bazzaz 1984; Grubb 1977; Longman and Jenik 1987; Adu and Oedes 1978; Rovira and Greace 1957; Brady 1990; Sanchez *et al.*,1983; Went and Starke 1968). These authors, support the idea that vegetation plays a crucial role in the nutrient cycle of the humid tropics. Firstly, this is because of the high levels of leaching which produces large losses of nutrients, eventually, leading to impoverished soils characteristic of the moist tropics. Plants intercept and take up nutrients released from organic matter or from the atmosphere or from bedrocks before they percolate down to the mineral soil. In undisturbed ecosystems, most of the minerals captured by plants are eventually returned to the soil.

Secondly, plants protect the soil against losses of organic matter, and physical forces such as raindrops and the scorching sun. Undisturbed vegetation has profoundly favourable effects on soil properties, particularly through its moderating impact on the micro-environment (Lal 1987; Bazzaz 1984; Balesdent *et al.*,1990). This influence is remarkable in surface and to a lesser extent sub-surface soils.

Other than storing and supplying water and nutrients to plants, soils also support the root system. Therefore if vegetation has to recover successfully following disturbance, soils must have, among other things, an adequate supply of nutrients, water and enough space for root development.

On the assumption therefore, that soils and plants are significantly interdependent in many if not most situations, we need to establish how the removal of vegetation and/or its conversion to farmland, following human disturbance, disrupts this relationship resulting in loss of nutrients shallow and degraded profiles.

In the Narok District, human activities - mainly cultivation, overgrazing and burning (Chapter 5) are interrupting the role of vegetation in the recycling of nutrients. Until the middle of the 1960s, shifting cultivation and seasonal fires were the common disturbances. As was indicated in chapter 2, their impacts on vegetation are short-lived and many times less destructive. Shifting cultivation is approved for its nutrient conserving, accumulating and recycling mechanisms (Brady 1990; Watters 1971; Jordan 1985; Longman and Jenik 1987). The system, because of the small size of the cropped area, allows rapid recovery of vegetation. Furthermore, the vegetation close-by supplies propagules for recolonization, protects the soil from severe erosion, devastating impact of erratic rains and the scorching sun. Since the late 1970s socio-economic factors (Chapters 2 and 4) have forced in extensive commercial farming at the expense of shifting cultivation. The small-scale farmers who are practicing shifting cultivation are being forced to recrop an area in less than 2 years; thus, reducing replenishment between cropping periods which is the backbone for the success of this system.

Cultivation exposes the soil to different forces. For instance, it affects the nutrient source through the removal of vegetation. Although the impact cannot be generalised with certainity, one may say that cultivation affects soil fertility by altering soil organic matter input and the way in which this input is incorporated. Once virgin land is put into cultivation the above ground component of the nutrient cycles is either reduced or lost. However, the impact of this on soil nutrients is gradual. At first, the amount of nutrients in the soil rises as mineralization increases, due to increases in organic matter and improved aeration and temperature, in the exposed land (Wadsworth *et al.*,1988; Brady 1990; Jordan 1985; Grubb 1977). Under shifting cultivation, the amount of calcium, magnesium and potassium in the soil increases due to their mobilization in the organic matter and burnt ash from original vegetation (Nye 1961; Nye and Greenland 1960; Lugo *et al.*,1974; Jordan 1985). An immediate effect of the accumulation of these nutrients in the soil is an increase in pH and a decrease in aluminium and manganese toxicity. Another effect is the increase in phosphorus making agriculture possible for a few months or years. Gradually the nutrients start to decline as organic matter in stock decreases following reduction of its source, and increased mineralisation. Loss of nutrient sources is a loss of nutrients in stock.

In cleared areas, greater nutrient loss will occur through leaching since there are few or no plants to retain them. Consequently, the nutrients will decline to a level where the soil cannot adequately support plants. Nitrogen and phosphorus are nutrients that are likely to be most affected, because of the elimination of the whole living complex of vegetation and micro-organisms which fixes and conserves them (Jordan 1985). This situation will also be characterized by reduced basic cations, increased soil acidity, a range of deficiencies and a decline in crop productivity (Olson and Engelstad 1972; Nye and Greenland 1960). Under commercial farming, the farmer resorts to fertilization while for shifting cultivation, abandoning the land for a better one is the alternative (Chapter 4).

In view of the preceding arguments, the elapsed time since natural vegetation is converted or removed, plays a crucial role in determining human impact in deflecting soil fertility status from equilibrium. Generally, the longer land is under human influence the more the nutrient cycle, and particularly the nutrient conserving mechanisms will be disturbed or changed. In chapter 6, it will be clear that climate and parent material are playing a significant role in determining the time factor influence on nutrient change.

In Narok District, the removal of vegetation is undoubtedly reducing soil fertility through soil erosion (Chapter 5). The removal of vegetation reduces soil aggregation leading to the loss of nutrients along with soil particles (Jacobs 1963; Mbuvi and Njeru 1977; Jaetzold and Schmidt 1983). Also, the actual process of soil tilling leads to soil erosion (Kumada *et al.*,1985). By improving soil aeration, tillage increases organic matter decomposition rendering the soils more vulnerable to removal. Soil organic matter helps to maintain soil aggregation. Also, compaction by tractors and ploughs, by destroying the soil structure, creates a compacted layer even hardpan, leading to accelerated runoff and the loss of nutrients.

Human activities, through animals, are also affecting the soil differently. In grazing lands, animal dung and urine are a source of soil nutrients. Animals accelerate mineralisation by trampling on biomass (Chapter 5). The situation is different where animal activities are leading to overgrazing in which case there will be short-term increases of nutrients (Chapter 4). Unless the overgrazed site is invaded, usually by woody species, nutrient loss will occur through leaching and soil erosion. Also, the physical impact associated with overgrazing hardens the soil leading to edaphic drought and soil erosion.

Seasonal burning, necessary for the improvement of pastures, is associated with a sudden influx of nutrients (Boutton *et al.*,1988). Unlike burning in woody communities during which minerals are normally lost through leaching and soil erosion (Uhl 1987; Lal and Cummings 1979), most of the minerals released during grassland burning are readily trapped by rapid regrowths of herbaceous plants following rainfall. Immediately after burning, potassium and phosphorus increase while volatile nutrients such as nitrogen and sulphur decrease, as they are lost. Loss of volatile nutrients is likely to be highest in Narok's plains where both seasonal burning and wind erosion are commnon (NDER 1986; Jacobs 1963; Chapter 5). The amount of nitrogen in the soil should, however, be stable due to high microbiological activities.

Having established the impact of vegetation change on soil nutrients, the following section discusses the methods used to collect soil samples. The results of analysis of these samples are reported in chapter 6. They are then used to infer human impact on vegetation in chapter 7.

3.3.4.4.2 Collection of Soil Samples

Three soil samples were collected from a pit beneath each site where the vegetation was sampled. Time, misunderstanding between myself and the landowners and financial constraints, limited sampling to only 30 sites (Appendix B). Thus, a total of 90 samples was collected. For instance, Maasai elders are sceptical about sampling soils and grasses. This is firstly, because they feel that the exercise may lead to the death of livestock. Secondly, because of the fear that the government may end up taking their land for non-pastoral activities.

Soil sampling was carried out in one of the subplots where disturbances were investigated. A *jembe* (an indigenous hoe) was used to dig a soil pit up to between 1/2m and 1m deep. Using a ruler and a *panga* (a traditional slash), soils were collected at 0-10cm, 10-20cm and 20-30cm depths. This exercise was made difficult where the soil profile was either excessively friable or hard. This was true in dry sandy and clayey soils or in soils with hardpans.

The initial plan to inspect and sample by means of soil augering was abandoned because of the difficulty of penetrating to any depths, particularly where the soils had been trampled and/or contained crusts. The use of a *jembe* to excavate soil pits was therefore necessary. Indeed, this allowed viewing of profiles from which, when necessary, sampling was adjusted to different horizons. The use of a soil auger would also be problematic for the wet, sticky clays such as those of Olkurto.

For each sample site, brief notes were made on soil conditions (see Appendix C). Chapter 6 has detailed description and statistical anlaysis of soil chemistry whilst chapter 7 uses the results to describe human impact on vegetation.

CHAPTER 4 QUALITATIVE ANALYSIS OF HUMAN ACTIVITIES AND THEIR IMPACT ON THE VEGETATION OF NAROK DISTRICT

4.1 INTRODUCTION

The philosophy, structure and limitations of questionnaire administration were highlighted in chapter 3. This chapter reports the findings of the survey, supplemented with field observation, on human activities and their impact on the vegetation. Although some respondents provided information as far back as the middle of this century, this chapter is confined to the period from 1960 to August 1990.

Organisation of data involved a numerical summary of the responses of the principal factors (Table 4.1).

4.2 RESULTS

4.2.1 Introduction

This section will report qualitative data under the following subheadings : human activities and vegetation changes. Table 4.1 is a summary of the primary findings.

4.2.2 Human Activities

Questionnaire data showed that there has been a drastic change in human activities over the last 10 to 30 years. This change has resulted from transformations in the lifestyles of the Maasai with growing emphasis on cultivation and conversely less dependence on pure pastoralism, together with increasing human population. Both pastoralism and cultivation were reported to have been valuable over the last two decades, but their priority differs from one area to another.

Human/Vegetation item	Findings
Cultivation	35% reported it is becoming significant.
Mixed economy	82% supported a shift to mixed economy. 8% supported that both cultivation & pastoralism are significant.
Land adjudication	44% said it is undesirable. 56% supported it.
Livestock	57% said livestock was the mainstay of the Maasai people. 8% was undecided 80% said cattle movement is getting increasingly restricted. 12% supported destocking; 68% opposed it.
Wildlife	20% said its conservation is beneficial. 80% suggested that wildlife be done away with. 82% reported a decrease in wildlife numbers. 18% reported an increase in wildlife numbers.
Overgrazing	10% associated it with increase in livestock. 60% denied that it is associated with increase in livestock numbers. 30% were undecided.
Destocking	87% said it is not the best way to deal with land degradation. 13% were undecided.
Vegetation	23% reported an increase in woody communities. 64% reported a decrease in woody communities. 93% said weed grasses were increasing. 52% reported a general decrease in grasses. 16% reported an increase in grasses. 92% reported scarcity of valuable plants.

Table 4.1: A summary of the Principal Findings of Questionnaire Administration. See questionnaire details in Appendix D.

All Maasai respondents confirmed that livestock was their ancestral way of life. However, only 57% of the respondents said that livestock was still the mainstay of the Maasai people, while 35% reported that cultivation was becoming more significant. The remaining 8% said both livestock and cultivation were important. Only 12% of the respondents expressed the desire to destock; otherwise about 68% wanted livestock increased. About 82% of the respondents supported that there has been a shift to mixed farming. With regard to the general trend of agriculture, most respondents appeared confused on the impact of land privatisation. About 44% said that the exercise was undesirable because it was attracting cultivation, while the remaining supported land adjudication.

The respondents complained that development of the livestock industry was being threatened by shortages of water and pastures (e.g., at Masurura-Sikawa and Talek), diseases and pests (e.g., at Nkararo-Moita hills and Olopito) and wildlife (mainly in the semi-arid area). All respondents reported inadequate transportation and marketing facilities as a major hinderance to the development of both cultivation and livestock industry. Inaccessibility to common resources, mainly salt licks and water was reported to be a recent problem facing livestock industry, and was attributed to land privatization and inadequate water development projects. More than 80% of the respondents reported increasing restrictions on cattle movements. This was attributed to reduced grazing land, land privatisation and fear of wildlife. Sending a few cattle to relatives, in areas with pastures, was reported as a successful strategy in dealing with drought.

Only 20% of the respondents, mainly from non-cultivated areas in the plains, reported wildlife conservation as beneficial; the rest recommended that it should be done away with. 82% of the respondents supported tremendous decrease in wildlife numbers and distribution in settled areas while the rest, mainly from the plains, reported wildlife increase. All respondents reckoned that there is little seasonal change in wildlife numbers. Only 10% of the respondents acknowledged the contribution of large livestock numbers to overgrazing and soil erosion. Most people perceived these phenomena as normal, noticeable during drought years, and would not be associated with overstocking. 87% of the respondents suggested that destocking had not been the best way to reduce environmental deterioration; yet they didn't recognise it existed.

The area under cultivation was reported to be increasing. However, cases of abandoned farms had become prevalent in both cash crop and subsistence crop growing areas. In some areas cultivation had not been introduced or was in the inception. Out of the 132 people questioned, 46 (35%) respondents said that cultivation was becoming very significant. Most respondents supported that it was taking over from pastoralism. The questionnaire also confirmed that cultivation was becoming permanent due to scarcity of free land and the increasing use of fertilizers. The expansion of cultivation was, however, said to be hindered by the nature of the rainfall and soils (e.g., at Masurura and Suswa), inadequate capital (e.g., at Sikawa, Sogoo and Olopito), by the land tenural system (in communally owned land), intertribal wars (mainly in Trans-mara Division) and Wildlife (in all areas except the Mau uplands).

Land leasing for money was perceived as a source of income. 85% of the Maasai respondents said they treated tenants as members of their family with only 15%, mainly from Trans-mara, reporting that tenants were a threat to Maasai socio-economic lifestyle. Respondents in Trans-mara associated cattle theft with an increasing proportion of idle immigrants. Here, 87% of these respondents resented land leasing, the rest were undecided. The respondents from different parts of the District were undecided on what effect the withdrawal of tenant farmers would have on food situation.

The size of individual farms under cultivation varied from 0.25ha and 20ha for sedentary Maasai and small-scale immigrant farmers to 100ha or more for wealthy immigrants plus the Kenya Breweries Limited (KBL) and the East African Industries (EAI); and less than 0.25ha in the semi-nomadic communities.

4.2.3 Vegetation

Questionnaire data showed that there have been changes in different plant communities (Table 4.1). Out of 132 respondents, 30 (23%) reported an increase in woody communities, with 85 (64%) holding the contrary view, and the remaining 12 (13%) were undecided. Wood regeneration was reported mainly in abandoned settlements and farms, and in grazing land on the plains and the neighbouring hills.

The increase in grass height, during the wet season, in most settled areas was reported to be remarkably small. The spread of *Pennisetum clandestinum* and *Cynodon dactylon* was reported by 93%

of the respondents. 68 (52%) respondents reported a general decrease in grass type and height whilst 21 (16%) reported an increase in grass height and type. 42 (32%) respondents reported vegetation changes characterized by a decrease in grass height only. Sekenani-Fig Tree-Keekorok, in the MMGR, was reported to have a more or less dense carpet of biomass which was associated with lack of burning for the last two years. Elsewhere in the game reserve, the grasslands were open and were reported to have burned within the last 1 year. Reduced quantity of grass due to overgrazing was reported to be the cause of fewer fires and increasing soil erosion in the rangelands.

Questions on the frequency and the amount of wood collected as fuelwood and building poles, attracted the respondents' interest. In permanently settled areas, 76% of the respondents reported valuable building trees to have disappeared and could only be obtained from at least 10 km away at Ololunga, 4-10km at Nairagie-Ngare, 4-5km away at Enabelbel, 5-10km away at Kilgoris-Nyangusu and 5-8km away at Nkararo (Fig. 3.8), taking between 2hrs and 1 day for collection. This is true of tree species such as *Teclea, Grewia, Euclea divinorium, Strychnos henningsii* and *Rhus natalensis*. The respondents suggested harvesting of less valuable species for domestic use as one way of coping with wood shortages. In non-Maasai occupied areas, and in the grassland plains, selective wood harvesting was less prevalent. In Maasai occupied areas such as Ogwedhi-Sikawa and Masurura, when both men and women were accompanied in their wood forays, wood harvesting was found to be selective. Here, although there were differences in the distance covered (ranged between 2-5km) during wood collection, relatively less time (1-3hrs) was spent. Trees were also selectively cut for charcoal burning which was reported to be a significant source of income. About 92% of the respondents confirmed that several medicinal plants had become scarce. Plant species such as *Warburgia ugandensis*, *Croton dichogamus* and *Euphorbia inaequilatera*, which 10 to 30 years ago used to be in plenty and within ease of reach were now absent.

As indicated in section 4.3.2, most respondents were reluctant to answer questions concerning the impact of livestock on vegetation. Only three out of 17 (13%) respondents, mainly from the plains, associated recent bush encroachment with overstocking. However, 80% of the respondents reported rapid regeneration of woody species from rootstocks, forming thickets, in overgrazed land, and abandoned settlements and farms. The respondents reported that most of the plants regenerating were less valuable, implying that they would not alleviate the increasing wood shortages.

4.3 DISCUSSION

4.3.1 Human Activities

The significance of livestock, reported during the survey, is associated with its long history in Maasailand as a source of food and a symbol of prestige. Livestock has been the cornerstone of traditional Maasai wealth and today it contributes significantly to the supply of food in Narok District, in particular and Kenya in general. About 95 per cent of Narok's total population rely on livestock (NDDP 1989; NDER 1986; Buruchara 1986). Livestock products such as milk, meat and blood form the main diet for the Maasai, who constitute 56 per cent of the population (Ssennyonga 1986). Cattle hides are used to make skin bags and ceremonial cloaks. They are also used as beds. Besides providing livelihood for the family, livestock, and especially cattle are also considered a source of social prestige. One is better placed socially if you have a bigger herd.

The significance of livestock in the Maasai ecology is well reflected among the local people at Ndulele-Nairagie-Ngare and Sikawa-Masurura who prefer cattle-keeping to cultivation even where rainfall is high enough, about 1000mm per annum, to support cropping. The common breed of cattle is the indigenous small African zebu, commonly described as a 'hardy animal', which, however, has low growth rate and low milk production. In the high potential areas of Mau, Osupuko and Trans-mara Divisions, and in livestock improvement centres run by religious sectors, both traditional and exotic breeds such as Friesian and Ayshire are kept. A variety of smallstock, donkeys and pigs are also reared. While exotic livestock is supplemented with fodder such as napier grass, extensive grazing and in some areas controlled grazing on natural pastures is the most extensive landuse which covers an array of vegetation types (Chapter 5).

Factors such as poor management, shortages of pasture, diseases and pests, and the influence from outside cultivators have enforced the adoption of mixed farming enterprises, particularly, in the high potential areas. The high risk attached to monoculture practices and to reliance on livestock due to frequent droughts and disease outbreak, are also contributing to a diversified economy. For instance, respondents associated the growing of crops in addition to keeping livestock with the effects of the 1984 drought. In the semi-arid plains, transformation from pure pastoralism has been necessary because of increasing grazing pressure due to increasing settlements and cultivation. At Ol Choro Orogwa cattle ranch, one of the oldest cattle ranches, livestock are being phased out due to poor management, declining land under grazing and higher tse-tse fly risk. Despite the present transformation from pure pastoralism to mixed economy, destocking has not been approved among the Maasai.

Destocking has been a conflicting issue of livestock development between the Maasai and the government. Problems of livestock industry have been attributed to Maasai reluctance to destock (Chapter 1). The present study observes that, although this allegation is somewhat contrary to Maasai response to livestock development of veterinary and water services in the middle of this century, reluctance to destock is crucial to the growth of the livestock industry and the state of the environment. Suffice it to say that the generation of contradicting views on Maasai response to livestock development is a reflection of the complexity inherent in the issue. On the one hand, the Maasai have strong attachment to cattle numbers, a factor which principally contradicts the goals of destocking. As a routine, Maasai sell their animals due to necessity and not by plan. For instance, animals are sold to meet school funds for their children's education and for *Harambee*[1] contributions or to purchase food items, mainly cereals. On the other hand, livestock development has often been faced with recurrent problems, particularly those associated with droughts, diseases/pests and marketing (Chapter 1). The Maasai feel that large cattle numbers are a security against these disasters, a stand which contradicts the need to destock.

The greatest problem facing the livestock industry is the loss of grazing land due to expanding cultivation and tension among individual pastoralist due to the scarcity of grazing resources. As free range grazing is dying out, particularly in demarcated areas, accessibility to common resources such as water and salt licks is becoming more complicated. Traditional Maasai ways of coping with seasonal shortages of water and pastures are being disrupted or dying out. They include moving animals to areas endowed with these resources (Chapter 2). A herd of strong cattle may be moved seasonally to distant or neighbouring wetter

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[1] Harambee refers to self-help approach to development in which the members of a community pull together their meagre resources for the welfare of community or individual projects. This movement, which is the backbone of Kenya's development, was introduced by Kenya's first President, Mzee Jomo Kenyatta. It is being advanced by President Moi.

areas under reciprocal agreement with the people who stay there. This involves construction of temporary settlements by young and middle aged men who look after them. Alternatively, some livestock are transferred to relatives where grazing resources are abundant. With the return of the rains, the animals are recalled or they are left to stay, with calves collected in the case of cows. Both strategies are being limited because of changes such as the raising of fences associated with land privatisation. It needs, however, to be clarified that threats to traditional ways of dealing with fluctuations in grazing resources are not a recent issue. They started with the loss of land to the colonial government (Chapter 2). They were further advanced by the Swynnerton plan of 1958, which limited free range grazing to group ranches. The situation is now being compounded by the expansion of cultivation and land privatisation.

The expansion of cultivation is associated with the increasing influence of sedentary ethnic immigrants mainly the Kikuyu, Abagusii and Kalenjin. The influence is in two forms, through immigrant cultivators and through intermarriages between the Maasai and immigrants. Accordingly, despite the traditional attachment to livestock, a few Maasai in Trans-mara and North Osupuko are responding positively to ox-cultivation. Here, small farms about 1/4ha, are cultivated involving subsistence crops such as maize and beans. These farms are confined around homesteads, preferably on abandoned *Manyattas*. Otherwise, cultivation is predominantly done by immigrants. Irrigation potentials at Narosura and Kanunga has attracted horticultural crops. These are marginal areas where pastoralism is still the primary activity. Farms ranging between 1/2 and 2ha are cultivated by immigrants and a few local people. In the Mau and Olkurto Divisions, cultivation involves leased large farms of size between 20 and 4,000ha. Here, commercial companies and wealthy individuals practice mechanisation growing wheat, barley, maize and rapeseed. The size of these farms compare with those provided by NDER (1986) - 0.4ha and 10ha, and more than 20ha for small- and large-scale farms, respectively.

In spite of the increase in cultivation, some land previously cultivated is being abandoned. These include farms in forest reserves from which illegal settlers were evicted. Early in the 1980s, parts of southern Mau and Olposumoru forests were destroyed by clearing for cultivation. These areas were erroneously declared an adjudicated land and people illegally settled there (Chapter 2). With the realisation of subsequent environmental impacts, between 1984 and 1986, the government evicted the settlers and gave the land to the forest department for development. Elsewhere, farms are being abandoned for various reasons.

Large-scale farms are being abandoned because of the invasion of weeds such as ray grass or wild oats (e.g., at Enabelbel-Olkirikiria and Olkurto), lack of capital (e.g., at Ngorengore-Loita and Mau Narok) and decline in soil fertility (e.g., at Olkurto and Ngorengore). For small-scale farms, mainly in Trans-mara Division, cultivated land is being abandoned because of a fall in soil fertility and misunderstanding between the tenants and landlords. Although shifting cultivation is becoming less common in Trans-mara, where land is abundant, farmers often prefer switching to virgin land where higher yields are expected. Otherwise, land is abandoned largely because of border skirmishes. For instance, intertribal wars between the Maasai and Luos in 1973 and 1988, and the Maasai and Abagusii in 1989 and in mid 1990, forced immigrant cultivators to abandon their farms. These farms are being used as grazing lands.

At Enengetia-Olkurto, abandonment of cultivation is characterized by a shift from barley and wheat growing to sheep rearing. This option is necessitated on account of decreasing crop yields, and inadequate capital required to improve crop production. Losses are incurred following costly cropping inputs such as fertilizers and herbicides because of the declining fertility and spreading weeds. Invasion of wild oats, for instance, has lowered the quality of cereals making it difficult for farmers to repay loans, and even to sell the produce. Elsewhere in the uplands, the expansion of cultivation is being restricted by inadequate capital required to maintain tractor-mechanized farms or to pay for human labour for clearing the thick woody vegetation and for weeding. Environmental constraints such as low rainfall and poor soils are partly contributing to the abandonment of farms mainly in the plains. A second factor is the pressure from the local community against the expansion, and even introduction, of cultivation to grazing land.

Other than abandoning land, further ways of dealing with weeds include direct uprooting and burning of the weeds. Cultivation of grazing land is being used in Nyangusu-Kilgoris to reduce the expansion of unpalatable grasses such as *Pennisetum schimperi*. The approach is replacing seasonal burning which, it is believed (Pratt and Gwynne 1977; Ivens 1967), favours the expansion of most weeds in grazing land. A move to mixed crop farming in formerly monoculture systems in large-scale farming areas of Olkurto-Sakutiek in the Mau uplands, and crop rotation in Ngorengore-Loita plains have proved effective in improving soil fertility.

Two crucial issues with regard to immigrant cultivators emerged from the survey. The first is their leading role in cultivation, given that a majority of the Maasai are pastoralists. For instance, in Trans-mara over 80% of cultivation is done by immigrants (Baraza W. pers. comm.). Despite this role, they are being subjected to harassments by the Maasai. This study ascribes this situation to the lack of defined hiring/leasing terms, such that tenants are at the mercy of landlords. Tenant harassment is usually associated with border clashes that are not necessarily stirred by tenants, to start with. However, they become easier targets to Maasai anger. Border clashes which lead to immigrant harassment are associated with cattle rustling and land disputes. The second issue with regard to immigrants is their predominance in cultivation even in marginal areas, interfering with the development of livestock industry and the biota in these communities. Here, not only are the immigrants coming into direct conflict with traditional Maasai landuse thus increasing competition for the meagre resources, but they are also transfering unwanted technology to a fragile environment. The crucial issue is that this encroachment lacks a conservation philosophy. Horticulture, for instance, could be encouraged with an understanding both of its significance to the Maasai people and its contribution to good management of the physical environment. Accordingly, the Maasai should be given priority as a way of encouraging destocking.

In conclusion, one may say that whereas lack of a landuse policy is not providing immigrant cultivators with long-term security, it provides them with short-term benefits such as the ease of access to land through different types of leasing. However, as already indicated, there are risks with these benefits to the people involved and the welfare of the environment.

In different parts of the District, land is leased for free or for crop sharing or for money. Where cultivation is being introduced, for instance at Sogoo and Sikawa-Olenkasorai, land is leased for free for at least two growing seasons. Thus, landlords (the Maasai) lease land to tenants (cultivator immigrants) who do not remit anything in return. This type of leasing involves small-scale farmers. The thick vegetation characteristic of areas which are being transformed to farms provides a challenge to the cultivators who are, usually, financially poor. It is to this effect that the land is leased for free, as a means of opening it up. With the expiry of the agreement period, the land is either leased for crop sharing or money. Under crop sharing, the tenants remit part of the crop harvested to the landlords. Crop sharing may involve a single farm or the leasee may cultivate his piece of land and another one for the landlord. Leasing land for money by individual wealthy farmers and Companies is confined to Nairagie-Ngare-Meleli, Ngorengore-Loita and Keyan-Kilgoris-Mulot. These are areas which are accessible by road. The period of lease varies from one growing season to tens of years. This type of land leasing is becoming popular, even replacing the other two. The Maasai see it as a quick source of income. The price of a piece of land is negotiable. In Trans-mara and Mau uplands, the price per hectare has increased by more than ten fold since early 1980s.

Other than providing both the tenants and the landlords with short-term benefits, lack of a landuse policy has more implications on the development of cultivation. For instance, cultivation is predominantly determined by the agreement between the leasees and the local people. The leasees' interest on land which, inevitably, is short-lived is leading to different environmental problems. The seriousness of this situation is underscored by the NDDP (1984:11), which writes

"many of them (leasees) have not made improvements. This has caused serious soil erosion and may at worst remove the fertility of the land within only a few years".

Although mixed views were offered with regard to the effect of the withdrawal of immigrant cultivators on food situation, the present study observes that areas where cultivation is being introduced are more vulnerable to food shortages if tenants withdraw. This is because the immigrant farmers are controlling cultivation, gradually, transferring farming skills to the Maasai. The transfer of these skills is a very slow process because of the historical attachment of the Maasai to pastoral economy.

The presence of wildlife is another major factor affecting the development of cultivation. Animals such as wild pigs, monkeys, elephants and buffaloes are a threat to crops, especially in the area bordering the MMGR. At Ndulele-Eorekule, the expansion of cultivation has been retarded by wildlife. Here, residents recall bitterly the crop losses they encounter from elephant invasion and migrating buffaloes in search of pastures. The low response (20% of the respondents) on the need to preserve the integrity of game may therefore be ascribed to wildlife damaging of crops and livestock. These respondents, who are mainly from the plains, include those who had benefitted from renting of camps on their land to tourists and those who had been compensated following loss of their crops or livestock. Therefore the majority's view, to do away with wildlife, is partly attributed to the lack of or delays in compensating damages. Compensation by the Ministry of Tourism and Wildlife (MWT) is too lengthy. Cases are known to have taken up to five years (NDER 1986).

The conflict between livestock and wildlife industries, and cultivation observed during this study, is not a new issue. The control of wildlife by fencing to avoid competition for water and grazing resources is first mentioned in the NDDP (1948). In an attempt to control Maasai use of pastures, the colonial government erected a game fence to achieve control over wildlife incursions onto pastures for livestock, a suggestion which, however, was rejected by the Maasai. Attempts since then to erect the fence, have indicated that the exercise could be a failure. Lamprey (1984) reports of the construction of a fence in the Ngorengore wheat farms which was to prevent game invasion from the Loita plains. Unfortunately, this fence did not stay because of the expansion of wheat farms to the south while part of it was destroyed by hungry wildebeest.

Lastly, the development of cultivation is characterized by limited expansion. As with the abandonment of formerly cultivated farms, the factors behind this include natural constraints, wildlife crop damages, capital and pressure from the local community. In the plains, the expansion of cultivation is restricted mainly by low agricultural potential due to poor soil (Chapter 6) and low rainfall (Chapter 3). Resistance from the local pastoralists is constraining the expansion of cultivation in both the semi-nomadic and settled areas. Expansion of cultivation to the margins of the MMGR is discouraged by the establishment of a non-compensation scheme, by the NCC, for wildlife damage to crops cultivated in the neighbourhood of the reserve (NDER 1986).

In spite of all the limitations, cultivation is expanding at the expense of pastoralism, stressing the carrying capacity of rangelands which sustain the largely semi-nomadic pastoralists and wildlife. The following section discusses vegetation aspects which are associated with human activities, already covered.

4.3.2 Vegetation

Questionnaire data suggested that vegetation has been unstable since the 1960s. The small amount of woody components reported over the plains in the past (10 to 30 years), than is found today, may be associated with the 1960s and 1970s severe fires (Chapter 2). This suggested increase in woody communities agrees with recent bush encroachment reported by Lamprey (1984), in high cattle density Maasai occupied areas.

Reported recovery of woody resources through bush encroachment involves a few plants such as *Acacia drepanolobium, Solanum incanum, Tachonanthus camphoratus* and *Croton dichogamus* (see also below). Except for *C. dichogamus,* the rest are less valuable species commonly referred to as weeds (Ivens 1967; Pratt and Gwynne 1977). *T. camphoratus* is a shrub whose rapid expansion is favoured by its high growth vigour, high regenerative capacity and unpalatability to livestock. Although *T. camphoratus* is consumed by black rhino (Mukinya 1973), its relative unpalatability to livestock and other wildlife favours its spread in overgrazed land. Like *A. drepanolobium*, it is spreading in the grasslands of Kiloriti and Kipleleo hills due to overgrazing (see also Lamprey 1984). *S. incanum* is common in settled areas, along paths/roads and cattle tracks; thus, eventually taking over open fields and grasslands that are chronically grazed. Its massive colonization is attributed to its unpalatability. For instance, its ripe fruits are poisonous to livestock.

Although only 10% of the respondents ascribed overgrazing and bush encroachment to overstocking, the concentration of these phenomena in the plains and on hilltops frequented by cattle and wildlife is contradictory. Overgrazing is common at water holes, villages or enclosures where the animals spend most of their time (Chapter 5). It progresses in a circular pattern, its impact waning radially from the centre. The latter which is most heavily disturbed is usually bare or it supports short-lived plants, mainly annuals, and rootstocks. The presence of species such as *Microchloa kunthii* and *Aristida adoensis* reported in the Loita plains is, further, an indication of overgrazing.

Abandoned farms and abandoned settlements have a different pattern of bush encroachment in which both herbaceous and woody species are represented. The common herbaceous species include *C. dactylon, P. clandestinum* and *D. scalarum.* Woody regeneration in abandoned small-scale farms consists of coppicing rootstocks and regrowths from stems which are cut considerably above the ground level. The dominant species include *Leucas calostachyus,* *Dombeya goetzii*, *Combretum molle* and *Rhus natalensis* most of which appear as earlier successors. Resprouting woody species from rootstocks in formerly herbaceous communities is also evident in different parts of the plains. It appears that the combined effect of reduced fires and competition from herbaceous layers is the force behind this invasion. The dominant species in abandoned settlements, especially in Maasai occupied areas include *S. incanum* (for most areas) *Lantana camara* (e.g., at Ogwedhi-Sikawa-Masurura) which is spreading from the lake region and *C. dactylon* (in most pastoralist landuse). Where animals have been withdrawn, *L. camara* is forming dense and impenetrable bushes.

Despite the rich literature (e.g., Huntley and Walker 1982; Walker and Noy-Meir 1982; Werger 1983; Lamprey 1984) on bush encroachment, the forces behind it are still not clear. This is partly because of the lack of quantitative data (Werger 1983). However, it has been hypothesized (see van Vegten 1981,1983; Ivens 1967; Skarpe 1990; Lamprey 1984) that human activities, primarily overgrazing by livestock, set the scene for bush encroachment. Ecologically, low temperature fires which cannot kill woody plants, the absence of browsers and perhaps allelopathic effect of shrubs on grass growth, are complementary factors to soil moisture and nutrient fluxes in explaining bush encroachment.

A modest theory of bush encroachment of overgrazed savanna is one presented by Noy-Meir (1982) and advanced by Walker and

Noy-Meir (1982), among others. This model which is based on competitive exclusion (Grime 1979, see also Fig 4.1), describes savanna as a two layered soil system with two plant lifeforms, woody and herbaceous species. Both lifeforms have access to water in the surface soil, although a healthy grass may outcompete woody species in this layer. Water which penetrates deeper in the soil is exclusively available for woody growth. A decrease in herbaceous cover following overgrazing or low fires late in the dry season results in more water available in both layers which is used by woody species to outcompete herbaceous species leading to bush encroachment. Main plant encroachers must, however, be advantaged by the shallow roots which access them to nutrient change and scarce water resulting from the rains which are sometimes only enough to wet the soil surface.

The preceding model may be used to explain bush encroachment in the plains, and the woodland-grassland 'cycle' reported in chapter 2. The main encroachers include *Acacia gerrardii, A. hockii, A. drepanolobium, Grewia spp, C. dichogamus* and *T. camphoratus*. Present human activities are disrupting the woodland-grassland cycle by holding it at the bush encroachment stage (Fig. 4.1). These include reduced burning and animal compression. Although overgrazing and the absence of severe fires appear the straight forward cases for bush encroachment in the Narok plains and the surrounding hills, the present research suggests that a different dimension must be added to the preceding model so as to explain bush encroachment due to reduced disturbance and not reduced competition by herbaceous species *per se*. The 'disturbance subsidence model', as it may be called, explains increasing bush encroachment in abandoned settlements, animal tracks and farms.

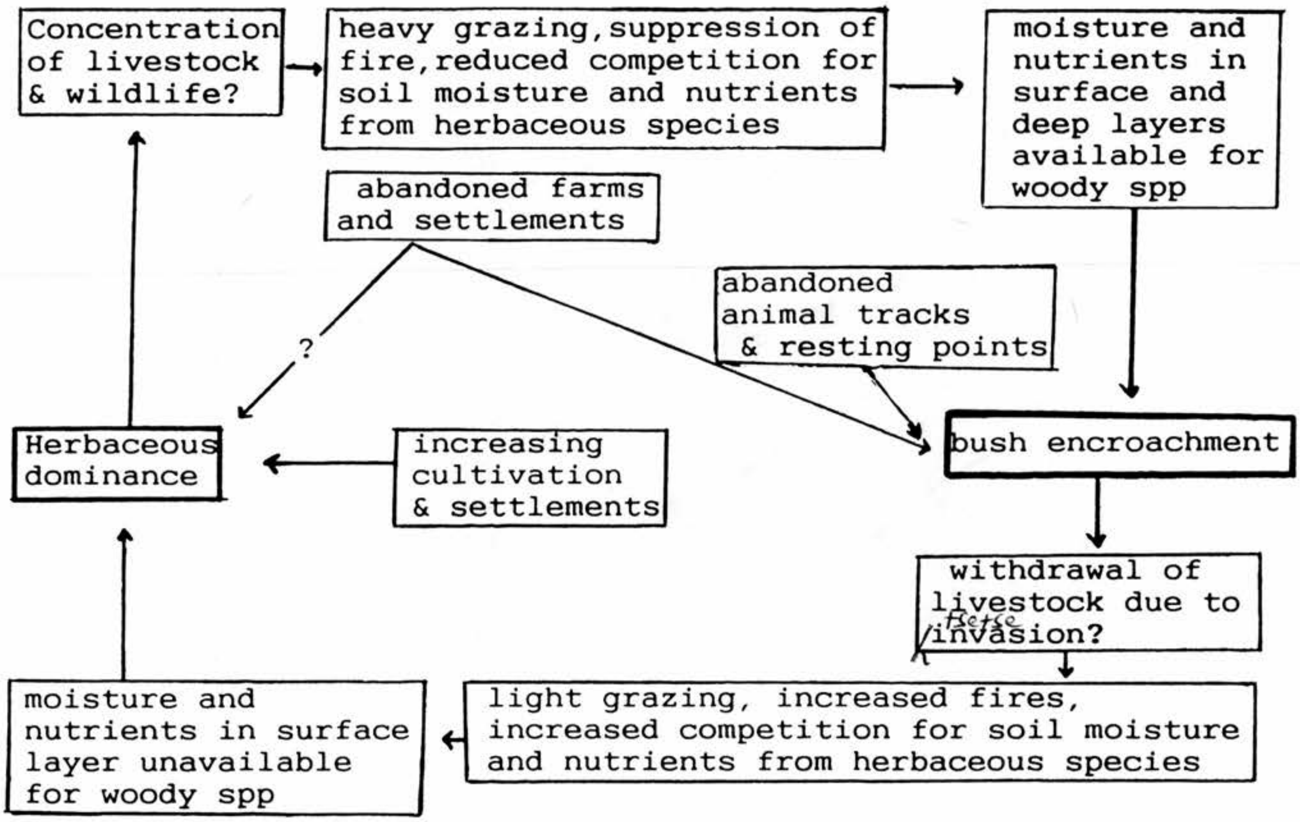

Fig. 4.1 'Resource availability' bush encroachment model in a Narok savanna landscape.

Other than bush encroachment, vegetation changes in the plains include a general decrease in grass height and/or changes in the distribution of the grassland community. These changes are primarily due to cultivation, and combined effects of overgrazing and reduced burning following compression of animals (Chapter 5). Grass invasion in abandoned farms is, also, becoming significant. In the Mau uplands, abandoned wheat and barley farms have been invaded by grass species such as *P. clandestinum, Eragrostis spp* and *D. scalarum.* This invasion is helping to regain upland grasslands lost to cultivation and it is expanding the herbaceous community in originally forested land. The community is maintained by continuous cattle and sheep grazing.

In spite of reported wood increase, over-exploitation of woody resources is associated with the decline and/or disappearance of a number of valuable plants. The latter include medicinal plants such as *Warburgia ugandensis* which treats stomach ailment, *Croton dichogamus* which is used for stomach-ache and a number of trees which provide shade. In the list, are trees/shrubs used for making tea and soup such as *Rhus natalensis* and *Euphorbia ugandensis.* These findings agree with the NDER (1986) which identifies excessive harvesting of indigeneous plants for specific use, overgrazing and browsing as forces behind the disappearance of valuable plants.

The reduction and/or disappearance of shade trees has different implications. For example, this survey established that, with the exception of thorny species, people use trees on hilltops and in the homesteads for shade. Humans, livestock, and even wildlife spend most of their time during the day sheltering from the scorching sun in the shade of trees. *Barazas* (local meetings) are also held under trees.

While the fast expansion of settlements and cultivation and wood cutting for domestic use are reducing woody communities, ecological changes due to exposure of vegetation following selective clearing and/or burning of upland forests is endangering specific trees. *Juniperus procera* (Cedar trees), for instance, are ringed for bark hives for bee keeping or bark for thatching houses. In the Mau uplands, tree ringing for bark, is confined to Olposumoru and Trans-mara forests where honey hunting by the Dorobo is common. Tree species such as *J. procera and Olea africana*, can easily be isolated from the rest by the rings on their poles.

The construction of bee hives by ringing trees is a potential threat to the woody communities of East Africa (Lind and Morrison 1974). Once the barks are removed, the trees are exposed to dehydration and bacterial infection and may eventually die. At Enengetia-Sasimua forest of Olposumoru, different timber trees are dying due to ecological change associated with burning, clearing and bark ringing. Also, reported decline in valuable trees for construction and fuelwood such as *Rhus natalensis, Olea africana, O. hochestetteri, Juniperus procera* and *Teclea simplifolia*, is attributed to increasing human use of wood resources. Increasing wood consumption is in response to increasing human population due to increased fertility among the Maasai and influxes of immigrants (Chapter 2). It will be seen in chapter 7 that wood shortages are becoming common in the densely populated parts of Trans-mara and Olkurto Divisions. Similarly, Lamprey (1984) reported a decimination of woody species at Talek-Ol Donyo

Orinka following an increase in Maasai settlements. He observed that tree species such as *Grewia species, Teclea species, E. divinorium* and *Strychnos henningsii*, preferred for hut construction, were obtained from bushlands distant from Manyattas.

Tree loss at Manyattas for construction, in the semi-nomadic areas, is increasing tremendously. Tree felling is concentrated near settlements. Away from such over-felled areas, trees/shrubs appear to be in good conditions as human influence decreases. A similar situation has been described for Marsabit District (Lamprey 1985:22), where

"The destruction of vegetation spreads outward from the village centres because people are obliged to travel further each year to obtain wood".

Mounting wood shortages are also associated with changes in Maasai modes of wood consumption. As indicated earlier, for the Maasai, trees and shrubs are useful materially and ritually. They are harvested for construction and building purposes, for medicine, for making tea and soup and for the preservation of food while tree leaves, flowers and barks are used for purification ceremonies. Due to increasing population, the construction of livestock enclosures called bomas and that of huts called enkangiti has increased, involving a variety of trees and shrubs. Except where wood is abundant, the trend of wood harvesting is moving away from specified trees/shrubs. Although some wood is used for fuel, these two are the major reasons for wood harvesting.

Changes in wood resources are associated with consumption of different forms of woodfuel. Both rural and urban population depend upon woodfuel as their chief source of fuel for cooking and warming. The demand for this resource has increased in the recent past, following changes in cooking/eating habit of the Maasai. Woodfuel was traditionally used for warming and cooking of meat. The shift of Maasai diet from a pure milk and meat to cooking two or three meals for some families per day which include vegetable products and *ugali* (maize meal), and maize and beans is contributing to wood shortages. Increasing use of *ugali* by the Maasai of Lemek area, is reported by Lamprey (1984). Similar findings of the impact of change in diet on vegetation resources are reported by Hughes (1986). She found, at the Hola scheme in the Tana River Flood Plain Forest (Kenya), that the quantity of consumption of wood depends on the number of people and the type of meals cooked. She also found that away from woody communities, women travelled 2 to 5 km, taking up to 5hrs for the round trip of collecting firewood. Hughes' (1986) findings are comparable to the findings of this study because both areas are ecologically similar and are undergoing similar disturbances associated with sedentarisation and cultivation. Lamprey's (1984) study also supports these findings. He observed that Talek women walked as far as 5 km from the Manyatta to obtain firewood. Increasing wood scarcity near settlements is therefore becoming very common. The distances and time spent, for wood collection, reported in this study, tend to vary with population density, the volume of wood originally available and the influence of immigrants on the Maasai.

The mounting pressure for firewood and poles in permanently settled areas is forcing additional wood to be collected from distances away. Also, it has resulted in the use of less valuable species. In densely populated parts of Kilgoris-Nkararo (see Kenya 1981), the use of low quality fuel and less valuable woody species for different domestic demands is evidence that wood is becoming scarce. The use of crop residues such as maize stalks, for cooking is becoming common. Fences around homesteads are also becoming a potential source of firewood. Here, common fuelwood species such as *Olea africana, T. camphoratus* and *Vernonia spp.* can only be obtained from distant woody reserves.

At Morijo and a few parts of the plains where wood is naturally scarce, woodfuel shortages have forced the people who neither have access to wood reserves nor the means to purchase it, to use dung as an alternative source of energy. At Ololunga-Mulot, the people are forced to extract wood from forest/woodland reserves. Also, uprooting of trunks for firewood and charcoal burning is becoming prevalent in Meleli-Enengetia. At Olopito and parts of Trans-mara bordering Kisii and South Nyanza Districts, increase in cut tree trunks of species such as *Teclea nobilis, Rhus natalensis, Grewia similis, Olea africana* and *Juniperus procera, and T. nobilis, Euclea divinorium* and *Markhamia platycalyx* near Manyattas and permanent settlements, respectively, is evidence of the high rate of tree harvesting. Attempts to deal with wood shortages involving agroforestry are at the initial stages. However, progress has been hampered by inadequate participation of the local people and inadequate social forest personnel. At Nyangusu-Kilgoris, the supply of seedlings is the major hinderance to agroforestry practices.

In the woodlands and bushlands of Trans-mara, and shrublands east of Narok town, trees are also cut for charcoal. Bags of charcoal and loads of firewood are placed at the roadside waiting to be transported to urban centres for sale. Increasing tree and shrub cutting for charcoal is a threat to wood resources, especially where it involves total clearing and sometimes uprooting of tree trunks. Heaps of wood laid for charcoal burning at Olenkasorai ranged between 130 and 136m^3, and there could be upto 8 heaps per km^2. Free access to woody reserves is the main factor contributing to drastic increase in charcoal burning, particularly in Trans-mara. The residents, who perceive deforestation as a way to create a better living environment, invite charcoal burners to clear up woody communities for cattle grazing and for cultivation. Despite its ban by the government, charcoal burning is prospering and has served as a source of income to immigrant population for over 20 years. Other than wood harvested for charcoal, the survey revealed that a lot of wood is illegally exported to neighbouring Districts in a form of firewood and building poles. At Olenkasorai, an individual transports upto 210 kg of wood per week into South Nyanza and Kisii Districts. The high population and the scanty wood reserves in these areas provide ready market for these resources. Indiscriminate tree cutting, for export, is highest in private forests, along routes and near settlements, especially in communally-owned land where the government finds it difficult to control.

Reported wood shortages have a direct link with recent influx of immigrants into Narok District. Both the Mau upland and parts of Trans-mara which have the highest influx of immigrants (Kenya 1981), have the vegetation endangered by vast agricultural encroachment (Msafiri 1985, Mwichabe 1986; Doute *et al.*,1981). While clear cutting in the Mau dates back to the 1940s (Chapter 2), massive clearing in Trans-mara took place in 1976 for wheat and barley trials, and pyrethrum and maize farms (Chapter 2). It involved uprooting of stumps and transformation of clumped bushes and riverine vegetation to farmlands in Nyangusu-Kilgoris. In spite of the abrupt abandonment of these trials, most areas are still under cultivation. Some of the abandoned farms have become grazing lands, having been invaded by herbaceous species such as *P. schimperi* and *Digitaria milanjian* with only a few regenerating to thickets.

In order to revert this sad situation, of increasing wood scarcity, it has become necessary that a permit is obtained from the Chief by those who need to cut trees for domestic use. This procedure is compulsory in privately owned forests of Enabelbel and Sogoo. However, a few people consider it to be an intervention of their properties. They feel that the restriction should be banned since it denies them the access to the trees they own.

Human activities are also associated with other forms of structural conversion of vegetation. On the hills and scarps of Ol Doinyo Orok, Ol Doinyo Olomisimis and Ol Doinyo Uasinon, the woodland/bushland communities are being thinned out and reduced to one storey following mild human disturbance. The vegetation north of Sikawa hills towards Keyan whose original community is probably "a lowland forest of the present Chepalungu forest" (Mwichabe 1986:9) has been reduced to *Vernonia* dominated bushland due to its subjection to shifting cultivation through clearing, burning and fallow. Although woody regeneration is taking place in these communities, continuous browsing is keeping seedlings to below 1m (Chapter 7). In different parts of the plains and in settled areas, the practice of debranching trees is contributing to tree destruction. Trees are debranched in order to provide wood and additional forage for livestock. Many of these trees die while those that survive are characterized by deformed structures.

4.4 CONCLUSION

This chapter has highlighted that agricultural development is characterized by different prospects and constraints. Inadequate transportation and marketing facilities and, pressure from the local people are limiting the expansion of cultivation. In spite of these constraints, cultivation is expanding and becoming permanent, involving the local Maasai. In the process, pastoralism and wildlife conservation are being threatened. Lack of marketing facilities, reduced grazing resources and the unwillingness by the Maasai to destock are affecting the growth of livestock industry.

It is also evident that vegetation changes centre on drastic decrease or disappearance of valuable plant species and reduced community coverage. Invasion of and/or the expansion of weedy species has become prevalent in settled areas and grazing lands. Cultivation, contraction of grazing land and the increasing wood consumption are the forces behind present vegetation changes in Narok District. Shortages of wood resources are being compounded by increasing dependency by neighbouring Districts on Narok District for wood products. The use of less valuable species is one way of dealing with wood shortages. The competitive exclusion model is suggested as being representative of present bush encroachment in the plains.

CHAPTER 5 HUMAN DISTURBANCE CHARACTERISTICS

5.1 INTRODUCTION

Human disturbances such as browsing, trampling, overgrazing, fire and wood cutting have played a significant role in vegetation change in Narok District (Chapter 2) and in many other parts of East Africa (see Belsky 1985,1987; Mwalyosia 1990; Tsingalia 1990; Sinclair 1979; Glover 1968; Ross 1985; Pellew 1983; Norton-Griffiths 1979). Glover (1968 :23), for instance, writes

"the savanna regions of Africa are made up of communities of plants ... which have been 'deflected' from their normal curve of ecological succession by the influence of cultivation, fire, grazing and browsing".

The role of these disturbances in Narok District is evident in the reduction of forest cover (Ochanda and Epp 1982; Lamprey 1984; Msafiri 1985) and the transition of grasslands to woodlands and back in less than 100 years (Chapter 2).

Despite the recognised role of human disturbances in Narok District, the present study realized that the available information on their spatial variations was inadequate. This chapter therefore examines different human disturbances recorded in the 42 sites, whilst chapter 7 discusses vegetation structure and composition in these sites. An attempt is made to examine the hypothesis that 'human disturbances in different parts of Narok District are similar'.

The methods and materials used to study human disturbances in the field were covered in chapter 3. The following section discusses the methods and materials used to map cultivation.

Data for both field and map studies are then organised for description (section 5.3). These data are supplemented with the questionnaire (Chapter 4) and animal data to highlight temporal changes of human disturbances.

Data on the number of animals was obtained from the Kenya Range Monitoring Unit (KREMU) reports (Wargute 1989) compiled by the Department of Resource Surveys and Remote Sensing (DRSRS) in Nairobi. The methods used to census animals is described by Norton-Griffiths (1978), therefore, no details are attempted here.

5.2 MAPPING CULTIVATION FROM SATELLITE IMAGES

5.2.1 Background

Improved understanding of the impact of man on vegetation, and particularly the implications of this impact, has become increasingly interesting in the recent past (Guppy 1984; Hall *et al.*,1991). Investigations of these implications require observations of human-vegetation interaction at different levels, local and regional. Long-term vegetation studies which require field observations are prohibitively expensive in terms of personnel and equipment, and they are inappropriate where human activities are occurring extremely rapidly and at a large-scale. Also, field sampling mainly provides site specific conditions, and on its own cannot therefore be used to characterize the spatial patterns of this interaction over large areas (Lieth and Whittaker 1975). The use of remote sensing is complementary.

Having learnt of the rapid expansion of cultivation (Chapter 2), the present research mapped its expansion using satellite images. The objective was to examine the impact of large-scale disturbance on vegetation (Chapter 7). An area considered most affected by recent expansion of cultivation, was chosen (see Figs. 5.3a and 5.3b).

The sample area lies west of Narok town, in the prime grazing Loita plains and the woody communities of Maasai Mau. It covers an area of 762.642 KM^2. Physiographically, the area is undulating and suitable for mechanization. The underlying rocks are mainly volcanic ash (Williams 1964; Mbuvi and Njeru 1977). The soils are predominantly moderately deep to shallow, sandy and rocky while average rainfall is moderate to low (Chapter 3).

5.2.2 Methods and Materials

Two Landsat images, TM of 4th February 1984 and 13th January 1989 scenes at the scale of 1:1,000,000 were used. Although the images were taken at close dates, differences in weather conditions and cover types led to different spectral colours (Figs. 5.4a and 5.4b). An 870 by 974 pixel extract taken was enlarged to the scale of 1:125,000 for viewing, ease of interpretation and mapping. Bands, 3, 4 and 5 were used as it is believed (Jensen 1986) that they contain most information on vegetation. For instance, band 3 is recommended for discriminating vegetation types, band 4 for determining the amount of vegetation biomass and band 5 for determining moisture condition (Erdas version 7.4, Jan. 1990).

Image processing was done using GEMSTONE version 4.1. The bands for the subscenes were, digitally enhanced both spectrally and spatially using arithmetic and enhancement options, respectively. Spectral enhancement involved band ratioing. The pixel values for band 4 were divided by those of band 3 to produce a synthetic band 3. This band plus bands 4 and 5 were filtered for edge enhancement using Laplacian filter size: X=3, Y=3, with a convolution matrix

$$\begin{pmatrix} 0 & -1 & 0 \\ -1 & 5 & -1 \\ 0 & -1 & 0 \end{pmatrix} /1+0.$$

Auto-equalise contrast stretch was then applied to the filtered bands to transform pixel values from skewed to rectangular histograms so as to improve visual quality. This was achieved by increasing contrast at the 'peak' of the histogram and lessening it at the 'tails'. The final image was then printed for delineating farms and calculating their area.

Cultivated land was easily identified from its characteristic shape and close colours. Delineated farms were firmly taped onto the data tablet, digitised and the total area obtained using a summagraphics MM1201. Identification of cropping details is not attempted since field-checks were not possible. Instead, for descriptive purpose, the chosen area is classified (broadly) into cultivated land and natural vegetation (Figs. 5.3a and 5.3b).

5.3 ORGANISATION OF FIELD DATA FOR DESCRIPTION

The disturbances observed in the 42 sample sites are recorded on the basis of presence-absence (Table 5.1). To obtain knowledge about the spatial distribution of the disturbances, their occurrence is ranked as common or rare (Table 5.3). Disturbances are considered common if they occurred at least 3 times in each plot or in the directions chosen (Chapter 3), otherwise they are considered rare. Because the small gaps had characteristically an ellipsoid shape, their area is calculated using the formular:

Length x Width x 1/4 (sq. units)

(Goldberg and Gross 1988).

To describe the impact of disturbances on vegetation (Chapter 7), the gaps created are grouped into either large (>1/4ha) or small (<1/4ha) (Table 5.3). This level is taken to be the cut point differentiating the rate at which a gap 'fills up', small gaps filling up faster than bigger gaps. Also, disturbances are characterized as high if they are predominantly large-scale, low if they are predominantly small-scale; otherwise they are arbitrary described as medium. This description of disturbance intensity is based on the fact that large-scale disturbances are predominantly long-lived and therefore more destructive while the converse is true for small-scale disturbances. The smallest and largest average area, and the number of occurrences are used as the lower and upper limits to describe the size and frequency distribution of the gaps in each site.

Questionnaire data (Chapter 4) is used to provide a picture of previous (10 to 30 years ago) human activities at each site. Accordingly, disturbances are categorized as recent if they are less than 10 years or historical if they are 10 to 30 years or more (Table 5.2).

The 10 to 30 years period is used to serve as a cut-off point because it marks the peak time of immigrant influxes and the introduction of large-scale farming into Narok District. The general objective is to establish both temporal and spatial distribution of disturbances.

For ease of description of the number and distribution of wildlife and livestock, data have been combined to make density distribution maps (Figs. 5.1 and 5.2). The results are used to explain animal impact on vegetation (see Chapter 7) that is believed to have been influenced by human activities. No attempt is made to isolate the contribution of wildlife and livestock to vegetation change. But when discussing the effects of browsing, trampling and overgrazing, reference is made to the distribution and to the contributions of each to vegetation change.

5.3 RESULTS

5.3.1 Types and Size of Disturbance

Different types of human disturbance (see Table 5.1) were recorded in the 42 plots. These are burning, browsing, trampling, light grazing, overgrazing, dung, wood cutting, mining and quarrying, cultivation and soil erosion. These disturbances vary in space and assume a wide range of size (Table 5.3). The shape of gaps varied considerably as well.

Based on frequency (Table 5.1), fire is among the least observed disturbances. Traditional grass burning by the Maasai was observed only in five plots, but none of these is from the forest and woodland communities. Out of these only one plot (site 26) had currently been burned, the rest consisted of charred plant remains ranging between at least 2 and 18 months old. Burning was confined to semi-nomadic pastoral areas in the grassland plains and the surrounding bushland and shrubland communities. However, grass burning around the MMGR and in the

Vegetation type/site No.		Cultivation	Overgrazing	S.c tree cutting	Tt tree cutting	Light grazing	Quarrying	Mining	Browsing	Fire	Charcoal	burning	Dung	Soil erosion	Trampling
Undisturbed forest	2	-	-	+	-	+	-	-	+	-	-		+	-	-
	3	-	-	+	-	+	-	-	+	-	-		-	-	-
	7	-	-	+	-	+	-	-	-	-	-		-	-	-
	9	-	-	+	-	+	-	-	-	-	-		-	-	-
	12	-	-	-	-	+	-	-	-	-	-		-	-	-
	31	-	-	+	-	+	-	-	+	-	-		-	-	-
	38	-	-	+	-	+	-	-	+	-	-		-	-	-
Disturbed forest	6	+	-	+	-	+	-	-	+	-	-		+	-	+
	8	-	-	-	-	+	-	-	-	-	+		-	-	-
	11	+	-	-	+	-	-	-	-	-	-		-	-	-
	13	+	-	+	+	+	-	-	-	-	-		-	-	-
	32	+	-	+	+	+	-	-	+	-	-		-	-	-
	33	+	-	+	+	+	-	-	+	-	-		-	-	-
	39	+	-	-	+	+	-	-	+	-	-		-	-	-
Undisturbed woodland	10	-	-	+	-	-	-	-	+	-	-		-	-	-
	19	-	-	+	-	+	-	-	+	-	-		+	-	-
	40	-	-	-	-	-	-	-	+	-	-		-	-	-
Disturbed woodland	14	+	+	-	-	-	-	-	-	-	-		-	-	+
	20	+	-	+	-	+	-	-	+	-	-		+	-	-
	41	+	-	+	-	+	-	-	+	-	-		-	-	-
Undisturbed bushland	16	-	-	+	-	-	-	-	+	-	-		-	+	+
	17	-	-	+	-	-	-	-	+	+	-		-	-	+
	21	-	-	+	-	+	-	-	-	-	+		-	-	-
	23	-	-	-	-	+	-	+	-	-	-		-	-	-
Disturbed bushland	15	+	-	+	-	-	-	-	+	-	-		-	-	-
	18	+	-	-	-	+	-	-	+	-	-		-	-	-
	22	+	-	+	-	+	-	-	+	-	-		-	+	+
	24	-	-	+	+	-	-	+	+	+	-		-	[illegible]	-
Undisturbed shrubland	5	-	-	+	-	-	-	-	+	-	-		-	-	+
	42	-	-	-	-	+	-	-	+	-	-		-	-	-
Disturbed shrubland	1	+	-	+	-	+	-	-	+	-	+		+	-	+
	4	-	+	+	-	-	+	-	+	-	-		-	+	+
Undisturbed grassland	27	-	-	-	-	-	-	-	+	-	-		-	-	-
	29	-	-	-	-	+	-	-	+	-	-		-	-	-
	34	-	+	-	-	+	-	-	-	+	-		-	+	+
	36	-	-	-	-	+	-	-	+	+	-		-	-	-
	37	-	-	-	-	+	-	-	-	-	-		-	-	-
Disturbed grassland	25	-	+	-	-	-	-	-	+	-	-		+	+	+
	26	-	+	-	-	-	-	-	+	+	-		+	+	+
	28	-	+	-	-	+	-	-	+	-	-		-	+	-
	30	+	-	-	-	+	-	-	+	-	-		-	-	-
	35	-	+	-	-	-	-	-	+	-	-		-	-	+
Total		14	7	23	6	28	1	2	31	5	3		7	7	12

Table 5.1: Spatial Distribution of Disturbances in the 42 sample sites. A total of 13 disturbance types recorded are represented by - if absent or + if present in the different sites. The abbreviation S.c stands for selective cutting whilst Tt stands for total clearing.

semi-pastoral areas of south-west Narok increased during the second part of this study. There was fire in almost every **4km** radius. Charcoal burning was observed in 3 plots, all from the woody community.

Small-scale disturbances mainly light grazing, browsing, and selective tree cutting are frequent. They range between 23 and 31 involving disturbed and undisturbed sites while large-scale disturbances, mainly overgrazing, soil erosion, quarrying and mining are least, ranging between 1 and 7 (Table 5.1). Cultivation, total clearing, trampling and dung have moderate frequencies. Light grazing occurs in 28 out of the 42 plots involving both disturbed and undisturbed communities. It is recent only in one of these plots. Browsing is recorded in 31 out of 42 plots. Out of these, only 14 plots are from the undisturbed category. Although it is characteristic of both disturbed and undisturbed sites, browsing is least in the forest community sites. Light grazing is recent only in one site whereas browsing is recent in 2 sites (Table 5.2), otherwise both disturbances are historical. Animal droppings occur in 9 plots, at least one from each plant community, except bushland.

Selective tree cutting occurs in 23 plots exceeding total clearing by 17. Although both disturbances are registered in both disturbed and undisturbed sites, limited mainly to woody communities, total clearing is predominant in disturbed forest communities which register in 5 out of the 6 plots. Also, total clearing is associated with cultivation. Cultivation (current or abandoned) *in situ* and/or within the 2km radius, registers in 13 plots (Tables 5.1 and 5.3) mainly in disturbed forest, woodland and bushland sites of Trans-mara and Mau uplands. Out of these, six sites are recent.

Disturbance Types ---->

Vegetation type/site	No.	Cultivation	Overgrazing	S.c tree cutting	Tt tree cutting	Light grazing	Quarrying	Mining	Browsing	Fire	Charcoal burning	Dung	Soil erosion	Trampling
Undisturbed forest	2	-	-	1	-	2	-	-	2	-	-	2	-	-
	3	-	-	1	-	2	-	-	2	-	-	-	-	-
	7	-	-	1	-	2	-	-	-	-	-	-	-	-
	9	-	-	1	-	2	-	-	-	-	-	-	-	-
	12	-	-	-	-	2	-	-	-	-	-	-	-	-
	31	-	-	2	-	2	-	-	2	-	-	-	-	-
	38	-	-	2	-	1	-	-	1	-	-	-	-	-
Disturbed forest	6	1	-	2	-	2	-	-	2	-	-	2	-	1
	8	-	-	-	-	1	-	-	-	-	1	-	-	-
	11	1	-	-	1	-	-	-	-	-	-	-	-	-
	13	2	-	2	2	2	-	-	-	-	-	-	-	-
	32	1	-	2	1	2	-	-	2	-	-	-	-	-
	33	1	-	2	1	2	-	-	2	-	-	-	-	-
	39	2	-	-	2	2	-	-	2	-	-	-	-	-
Undisturbed woodland	10	-	-	1	-	-	-	-	2	-	-	-	-	-
	19	-	-	2	-	2	-	-	2	-	-	2	-	-
	40	-	-	-	-	-	-	-	2	-	-	-	-	-
Disturbed woodland	14	2	1	-	-	-	-	-	-	-	-	-	-	1
	20	2	-	2	-	2	-	-	2	-	-	2	-	-
	41	1	-	2	-	2	-	-	2	-	-	-	-	-
Undisturbed bushland	16	-	-	2	-	-	-	-	2	-	-	-	1	1
	17	-	-	2	-	-	-	-	2	2	-	-	-	1
	21	-	-	2	-	2	-	-	-	-	1	-	-	-
	23	-	-	-	-	2	-	2	-	-	-	-	-	-
Disturbed bushland	15	2	-	2	-	-	-	-	2	-	-	-	-	-
	18	2	-	-	-	2	-	-	2	-	-	-	-	-
	22	1	-	2	-	2	-	-	2	-	-	-	1	1
	24	-	-	2	1	-	-	2	2	2	-	-	-	-
Undisturbed shrubland	5	-	-	2	-	-	-	-	2	-	-	-	-	1
	42	-	-	-	-	2	-	-	2	-	-	-	-	-
Disturbed shrubland	1	2	-	2	-	2	-	-	2	-	1	2	-	1
	4	-	2	2	-	-	1	-	2	-	-	-	2	2
Undisturbed grassland	27	-	-	-	-	-	-	-	2	-	-	-	-	-
	29	-	-	-	-	2	-	-	2	-	-	-	-	-
	34	-	1	-	-	2	-	-	-	2	-	-	1	1
	36	-	-	-	-	2	-	-	2	2	-	-	-	-
	37	-	-	-	-	2	-	-	-	-	-	-	-	-
Disturbed grassland	25	-	2	-	-	-	-	-	2	-	-	2	2	2
	26	-	2	-	-	-	-	-	2	2	-	2	2	2
	28	-	1	-	-	2	-	-	2	-	-	-	2	-
	30	2	-	-	-	2	-	-	2	-	-	-	-	-
	35	-	2	-	-	-	-	-	2	-	-	-	-	2

Table 5.2: Relative age of disturbance types in the 42 sites based on questionnaire data. A disturbance is denoted 1 if it is recent and 2 if it is historical. The abbreviation S.c stands for selective cutting whilst Tt stands for total clearing. - means that the disturbance type is not recorded.

Trampling, a disturbance which mechanically damages plants occurs in 12 out of the 42 plots, with only five of these from the undisturbed category. In eight of the sites trampling is historical. Soil erosion registers in seven out of the 42 plots. Trampling is associated with overgrazing while soil erosion is associated with cultivation and overgrazing. Mining and quarrying register only in one and two plots, respectively.

The size of gaps vary from community to community. From Table 5.3, undisturbed grassland sites 27, 36 and 37 in the semi-nomadic drier plains and sites 3, 7, 9, 12 and 31 in the low density areas of the forest community have gaps less than or equal to 1 m^2. Out of the 42 plots 20 (48%) have this gap size *in situ* and/or in the surrounding 2km radius. This gap category is common in forest communities, 14 out of the 20 plots. Seven of these plots, all from the forest community, register cultivation *in situ* and/or in the surrounding area. Seven out of the 42 plots have gap size more or equal to 1/4ha rare *in situ* and/or within the 2km radius. Also, out of the 42 plots 12 have gap size more or equal to 1/4ha *common in situ* and in proximity. Five of these, sites 2, 3, 16, 29 and 38 are from undisturbed communities, and the gap category occurs in proximity. In the grasslands, similar gaps were observed at water points, settlements and animal resting sites outside sample sites and the 2km radius.

5.3.2 Cultivation

The preceding section has reported the frequency distribution of cultivation recorded in the field. This section is, therefore, concerned with mapping cultivation from satellite imagery.

Vegetation type	Site No.	Gap size(s)	Remarks	Descriptive Level of Disturbance
	2	$.6\ m^2-3m^2$	rare within	Low
		1/2-100ha	common outside-cultivated	
Undisturbed	3	$.1\ m^2-0.3m^2$	common within	Low
forest		6ha-200ha	common outside	
	7	$.5\ m^2-9cm^2$	common within/outside	Low
	9	$.5\ m^2-9cm^2$	common within/outside	Low
	12	$<1m^2$	common within	Low
		$0.2m^2-1m^2$	common outside	
	31	$.2\ m^2-8cm^2$	rare within	Low
		<1/4ha	rare outside	
	38	$.5\ m^2-<1m^2$	rare within	Low
		<1/2-100ha	common outside	
Disturbed forest	6	$.5\ m^2-1m^2$	common within-abandoned farm	Medium
		1/2ha-2ha	rare outside	
	8	$<5cm^2$	common within/outside	Medium
	11	$.5\ m^2-10cm^2$	common within-abandoned farm	
		2ha-4ha	common outside	High
	13	$.5\ m^2-8cm^2$	common within-abandoned farm	
		1/4ha-4ha	common outside -cultivated	High
	32	$.2\ m^2-8cm^2$	common within	Medium
		<1/4ha	rare outside-cultivated	
	33	$.3\ m^2-1m^2$	rare within	Medium
		<1/4-10ha	common outside-cultivated	
	39	$.5\ m^2-20cm^2$	rare within-abandoned farm	
		1/2-1000ha	common outside -cultivated	High
Undisturbed	10	$6m^2-8m^2$	common within/outside	Medium
woodland	19	$.2\ m^2-6m^2$	common within	Medium
		1ha-50ha	rare outside-cultivated	
	40	$.5\ m^2-8m^2$	common within/outside	Low
Disturbed woodland	14	1/2ha-20ha	common within/outside -abandoned farms	High
	20	$.5\ m^2-1m^2$	common outside	High
		1ha-4ha	common outside-cultivated	
	41	$.10\ m^4-3m^4$	common within	Medium
		1/4-1000ha	rare outside-cultivated	
Undisturbed	16	$.4\ m^2-30^2\ cm$	common within	Medium
bushland		1/4ha-1ha	common outside	
	17	$.5\ m^2-1m^2$	common within	Low
		1/2ha-3ha	rare outside/cultivated	
	21	$.4\ m^2-1m^2$	rare within/outside	Low
	23	$.5\ m^2-4m^2$	rare within/outside	Low
Disturbed	15	$<5\ m^2-10m^2$	common within	High
bushland		2ha-6ha	rare outside-abandoned farm	
	18	$.4\ m^2-3m^2$	common within	High
		1/2ha-5ha	common outside-cultivated	
	22	$.4\ m^2-4m^2$	rare within	Medium
		1/4ha-2ha	common outside-cultivated	
	24	$.5\ m^2-20m^2$	common within	Medium
		<1/4ha	common outside	
Undisturbed	5	$.6\ m^2-5m^2$	common within	Medium
shrubland		$20m^2-300m^2$	common outside-resting points	
	42	$.6\ m^2-4m^2$	common within	Low
		1/4ha-1ha	rare outside	
Disturbed	1	$.5\ m^2-4m^2$	rare within	Medium
shrubland		1/2-1000ha	rare outside-cultivated	
	4	$2m^2-100m^2$	common within/outside	High
Undisturbed	27	$<1m^2$	common within/outside	Medium
grassland	29	$.5\ m^2-20cm^2$	rare within	Medium
		<4m-4ha	common outside	
	34	$.5\ m^2-10m^2$	common within	Medium
		<1/4ha	common outside-settlements	
	36	$.5\ m^2-10cm^2$	rare within/common outside-along tracks	Medium
	37	$<5\ m^2$	common within/outside	Low
Disturbed	25	$.4\ m^2-6m^2$	common within	High
Grassland		1ha-5ha	rare outside-resting points	
	26	$.5\ m^2-10m^2$	common within/outside-water and resting points	High
	28	$.5\ m^2-1m^2$	common within	High
		<1/4ha	common outside-settlements /resting points	
	30	$.5\ m^2-4m^2$	rare within	Medium
		1/4ha-10ha	common outside	
	35	$.4\ m^2-1m^2$	common within/outside	High

Table 5.3: A summary of gap sizes *in situ* and within a 2km radius based on field observations. The lower and upper limits of the average gap size are used.

Figures 5.3a and 5.3b, and Table 5.4 show that the number and size of farms increased for the period 1984 and 1989. Figures 5.4a and 5.4b are screen prints of the sample area. Within this period, the number of farms increased from about 53 to 72[1] for the period 1984 and 1989. The farm size rose from 299.4215 to 325.7792km2 between 1984 and 1989. This means that a total of 26.3 km2 of land was lost to cultivation. Within this period, 21 farms were introduced, five expanded and 3 abandoned.

Size of	Year 1984	1989
Farms(sq kms)	299.4215	325.7792
Natural vegetation	463.2205	436.8628

Table 5.4: Expansion of Cultivation in the Loita Plains for the period Feb.,1984 and March, 1989.

Source: Data derived from comparison of Landsat TM scenes

5.3.3 Density Distribution of Livestock and Wildlife Herbivores

Table 5.5 shows estimates of animal population for the period 1977-1987. The animals increased in number for this period except for 1985 when they fell to about half the preceding population. There is an overlap in livestock and wildlife distribution.

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[1] It should be noted that these figures are estimates. Differences in soil and cropping conditions could have imposed boundaries within a single farm to raise the number of farms. This study, therefore, considers total farm size as a reliable estimate of the expansion of cultivation. This assumption is justified given the lack of ground truth.

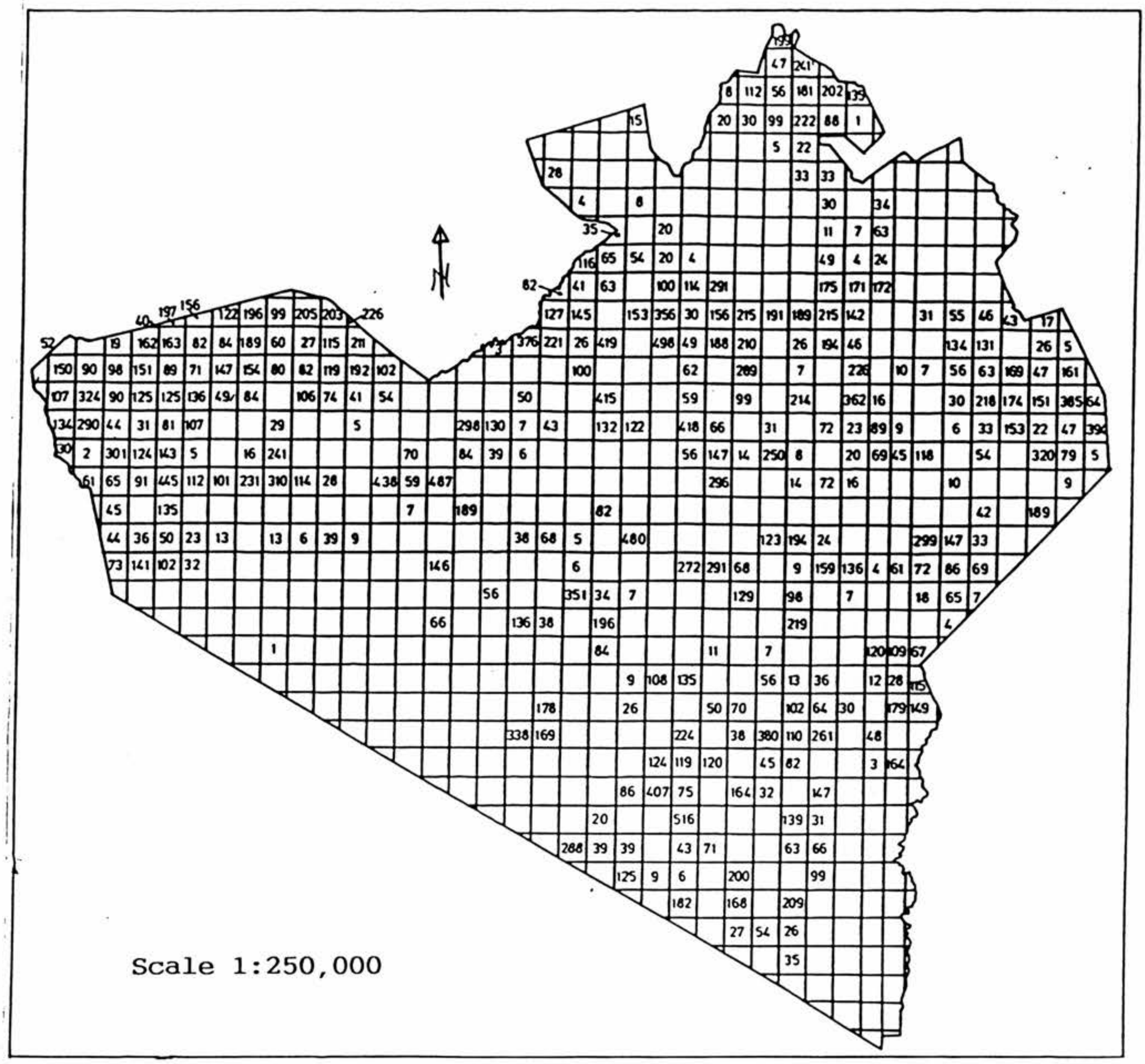


Fig. 5.1 Livestock (Cattle, Goats, Sheep & Donkeys) density per km^2. Lowest livestock densities are in woody communities and in the MMGR. Data for 1987, modified from Wargute (1989).

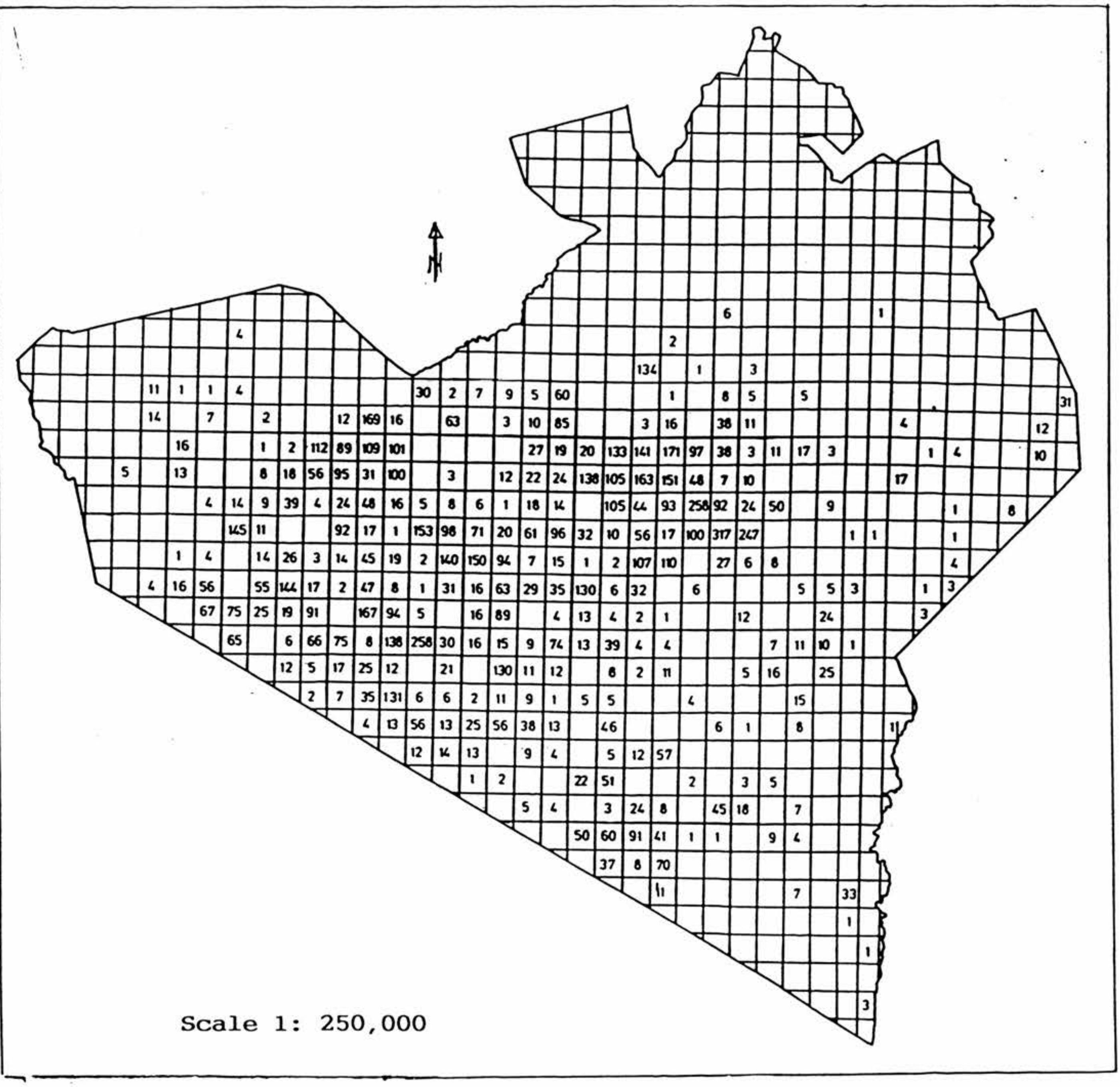
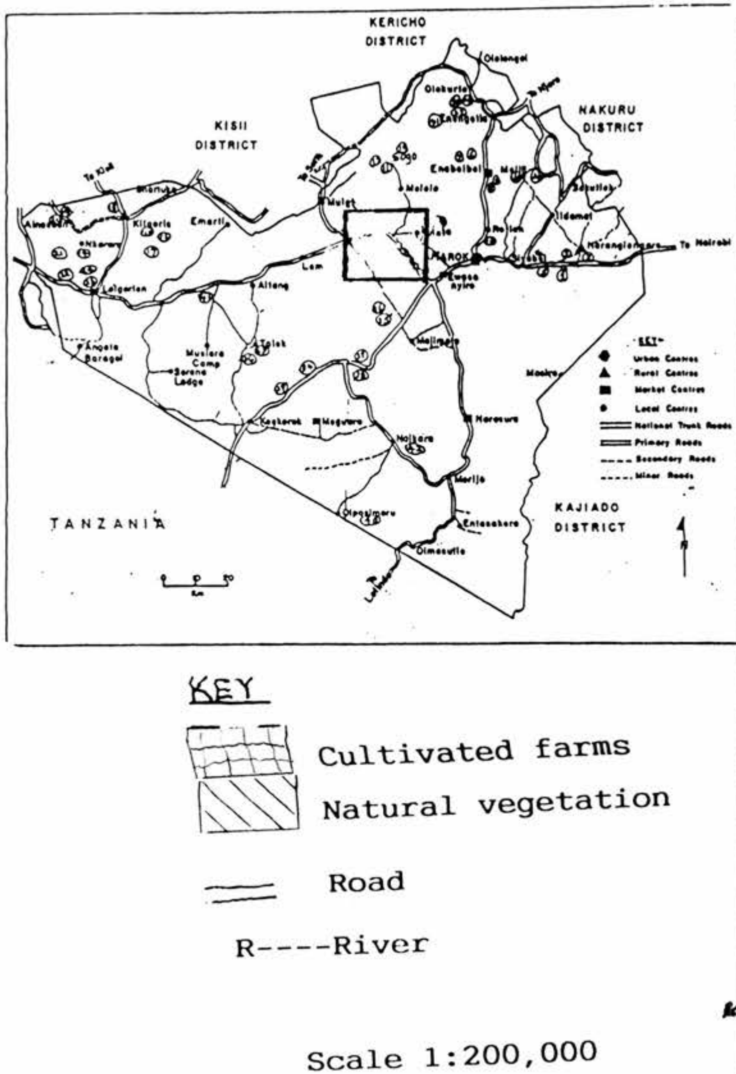


Fig. 5.2 Wildlife (Elephants, Giraffe, Zebra, Gazelle, Kongoni, Impala, Wildebeest, Topi, Buffalo, Eland, warthog, Ostrich) density distribution per km^2. Lowest densities are in settled/cultivated border areas and in woody communities. Highest densities are in the plains. Data for 1987 modified from Wargute (1989).



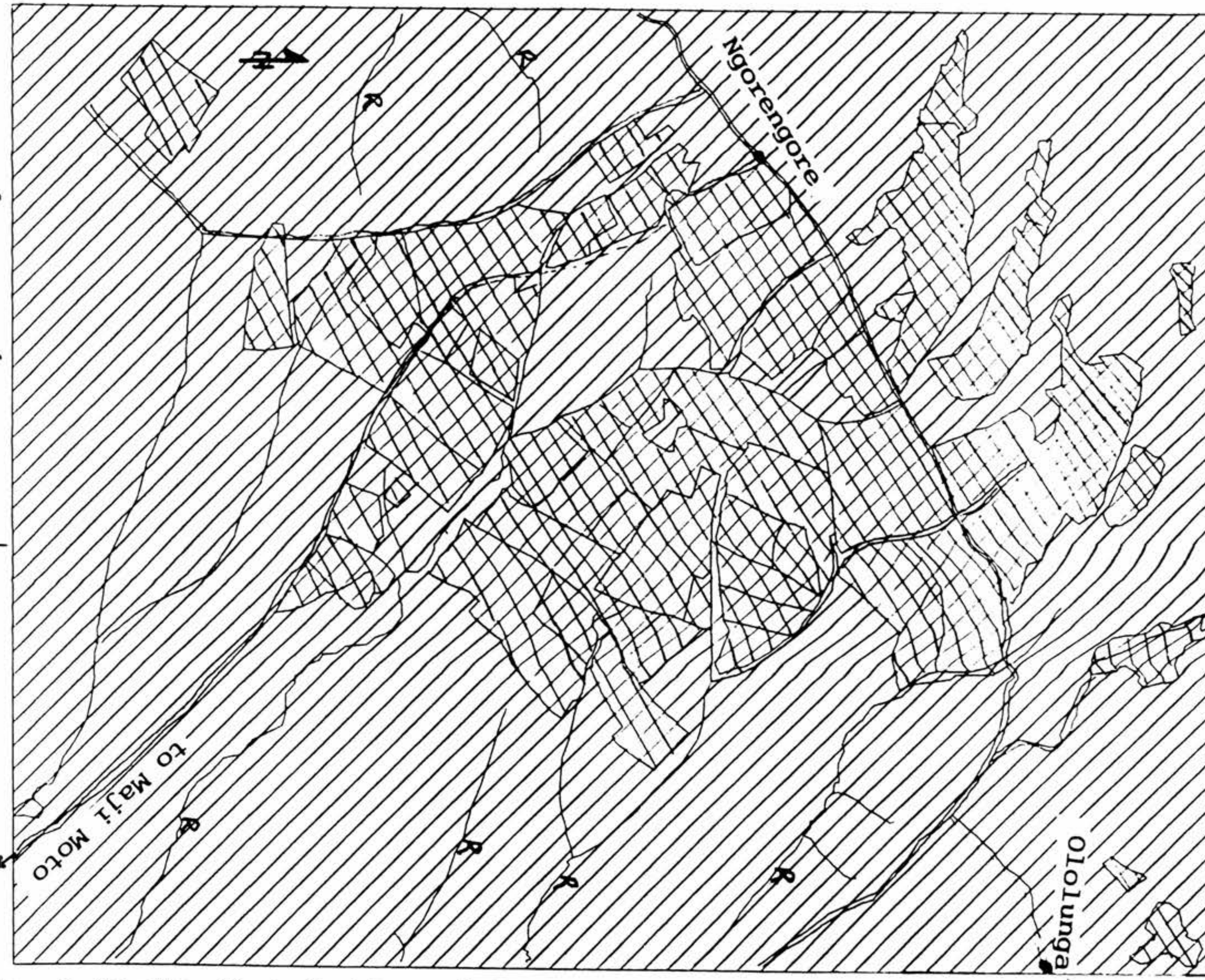


Fig. 5.3a The distribution of farms in 1984 in Ngorengore/Loita. The location of the sample area is indicated on the accompanying map.

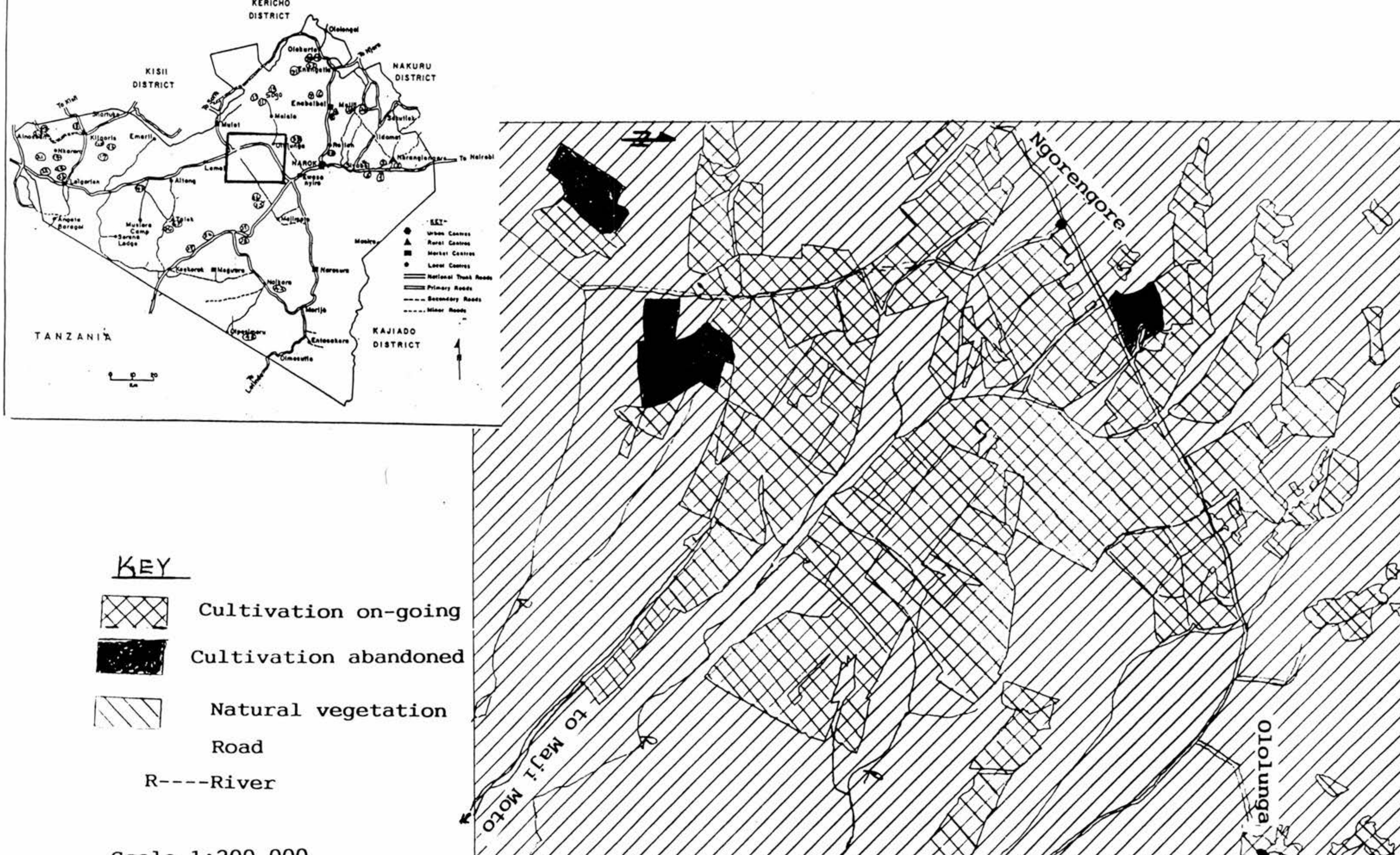


Fig. 5.3b The distribution of farms in 1989 in Ngorengore/Loita. The location of the sample area is indicated on the accompanying map.

Species.	Jan-March 1977 No.	SE	Jan-Sep1978 No.	SE	Nov-Dec1985 NO.	SE	April 1987 No.	SE
Live-stock	1029436	95325	1193106	109063	721462	79139	1013175	89056
Wildlife	536911	48233	953115	93128	366715	31858	354047	33277

Source: Modified from Wargute (1989:67)

Table 5.5 Estimated Wildlife and Livestock Numbers for 1977-1987
NO. - number, SE - standard error

Figures 5.1 and 5.2 show the distribution of animals in Narok District in 1987. Livestock is found throughout the District **except** in the MMGR and the wheat growing areas of Sakutiek-Meleli and in the forest communities. Wildlife distribution is lowest in the agricultural unit (Chapter 3) in the east, north and north-west areas bordering the agricultural Districts. The distribution of wildlife which include mostly wild herbivores is not confined to the game reserve. Instead, the animals appear widely spread in the plains and the neighbouring areas. Both livestock and wildlife are spread in low densities in the extensive bushlands in the eastern and south-eastern parts of the District.

5.4 DISCUSSION

5.4.1 **Introduction**

Before considering disturbance characteristics in detail, it is necessary to note the following limitations. First, due to insufficient information on time of disturbance occurrence and indicator species, the interpretation and description of disturbance characteristics has had to be supplemented with existing literature and questionnaire data.

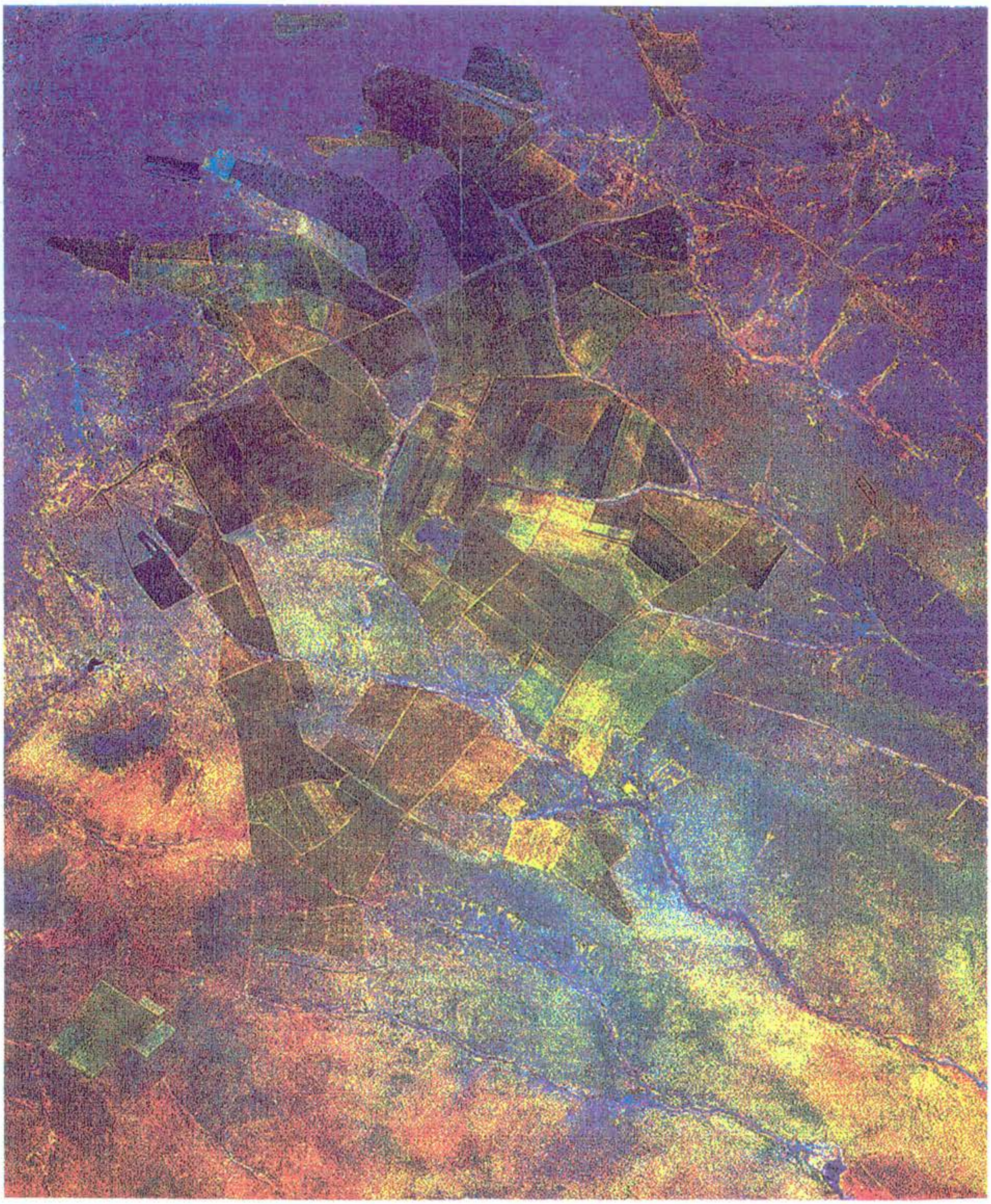


Fig. 5.4a Screen print showing the distribution of farms in Ngorengore/Loita in 1984. Scale 1:200,000.

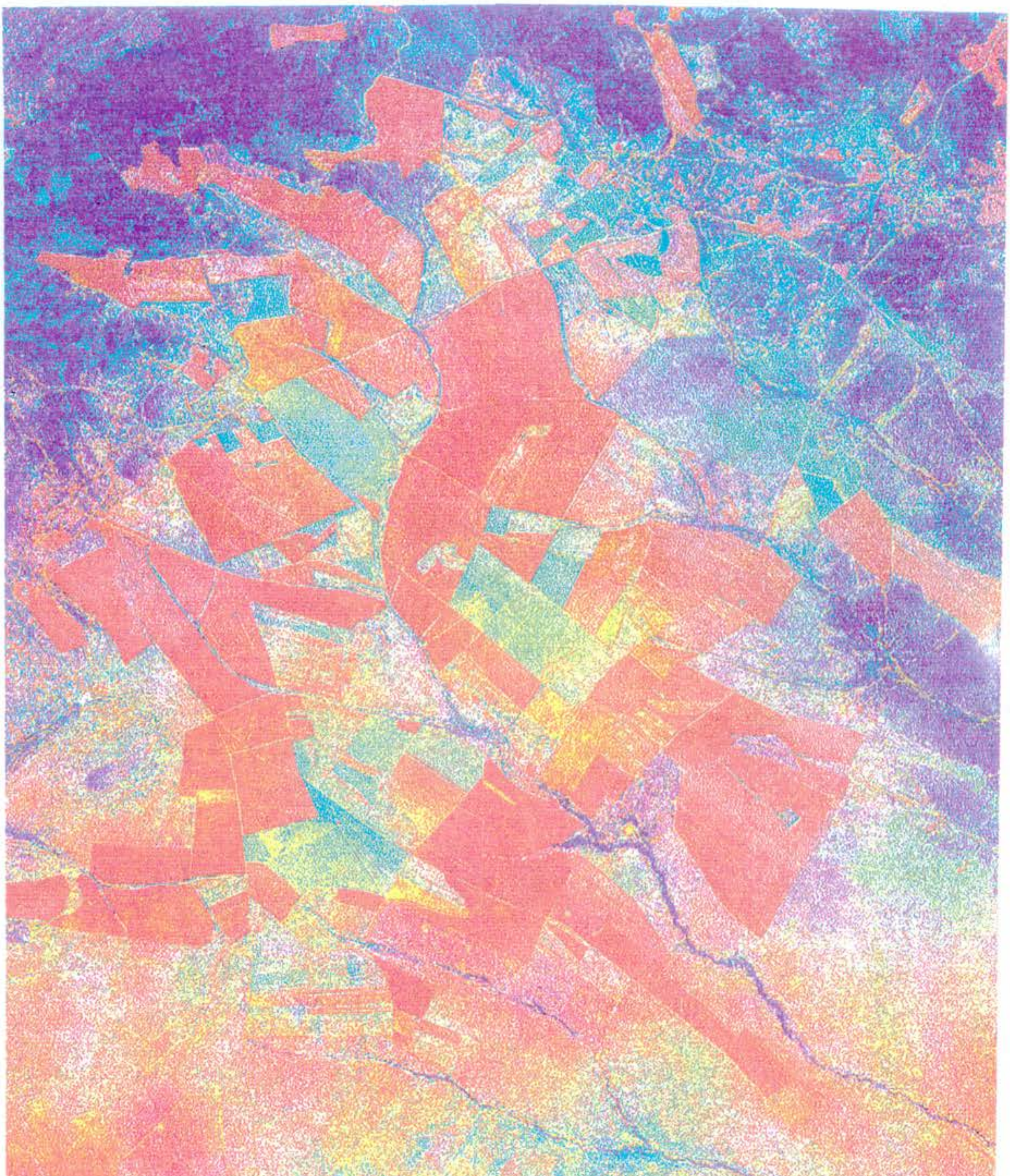


Fig. 5.4b Screen print showing the distribution of farms in Ngorengore/loita in 1989.
Scale: 1:200,000

Second, due to various logistical difficulties (Chapter 3), image analysis of the expansion of cultivation has not included ground truthing. Also, the intention of this study to map cultivation in both small- and large-scale farms was hampered by image conditions. The part of the 1984 scene with small-scale farms is under cloud cover. This restricted mapping to large-scale farms to a cloud free sub-scene, in the plains, limiting comparison of the impacts of different systems of cultivation on vegetation. Lack of existing up to-date large-scale maps and field-checks (see also Chapter 3), further, meant exclusion of detailed digital image analysis.

In order to obtain information so as to account for the observed frequency of disturbances (section 5.4.3), the following section discussses the distribution of animals. The underlying factors are also briefly covered.

5.4.2 Distribution of Wildlife and Livestock

Spatial and temporal variation in wildlife and livestock density distribution may be explained in different ways. The observed pattern is associated primarily with fluxes in grazing resources. These fluxes are seasonal and long-term depending on the underlying factors mainly rainfall patterns and the landuse type(s), respectively. It will be recalled from chapter 2 that temporal and spatial distribution of animal population in Narok District depend on the availability of grazing resources. The wet periods following the end of 1977 and 1984 droughts (Karime 1990; Wargutte 1989) is probably the cause of noticeable increase in animal numbers between 1977 and 1983, and the period after 1985 (Table 5.5). Grazing resource scarcity must have been exacerbated, firstly, by rapid landuse change characterized by massive cultivation increase late in the 1970s and early in the 1980s. Animal fluctuations prior to 1977 concide with the introduction of large-scale cultivation and massive influx of immigrant cultivators (Chapter 2). For instance, in Trans-mara, this was the time when wheat and barley trials were introduced (Chapter 4). In no doubt, animals must have been displaced and forced to look for habitats elsewhere. Secondly, grazing resource shortages during droughts may have increased due to preclusion of deferred grazing. Most of the large-scale farms established in former grazing lands of Ngorengore-Loita were fenced (Chapter 4). This means that they were not available for pastures even after crops had been harvested. Severe shortage of pastures in 1984 led to high animal death (NDER 1984).

The differences in observation of numbers of wildlife could also have been due to their migratory nature and their accidental or deliberate preclusion from settled areas. At the time data used in this study was collected, for instance, the plains were probably occupied by resident wildlife. The annual migrations of ungulates from southern Serengeti plains start by December, arriving in the Loita and the MMGR plains for the dry season by August-November (Maddock 1979; Stelfox *et al.*,1980). Therefore, the observed distribution of animals cannot be associated with migration populations. This leaves the preclusion of the local population from settled areas as the possible explanation. Both resident and migration wildlife populations are precluded from livestock frequented and cultivation zones, because they are associated with livestock diseases, they compete with livestock for decreasing pastures and water, and they damage crops (Chapter 4). Some wild animals have been forced to move away following the destruction of their habitats.

Although temporal and spatial change in animal numbers and distribution in the study area is historical (Chapter 2), it has been greatly interrupted by increasing cultivation and settlements. Extensive crop farming in the north-eastern parts of the District is perhaps responsible for low livestock and absence of wildlife populations. The high influx of immigrant cultivators into Narok District (Chapter 2) has no doubt contributed to significant loss of grazing land in the uplands. An examination of the hard copy satellite image (Chapter 3) indicates a concentration of the agricultural unit in this zone. Both small- and large-scale wheat and barley growing farms are common.

Wide distribution of wildlife in the central part reflects the nature of settlement patterns and the distribution of natural resources. These are rangelands which are sparsely populated. However, the small wildlife herbivores spend most of their time here because the vegetation is open and characterized by palatable herbaceous species.

Livestock distribution is associated with human ecology. In mixed farming areas of the Mau and Trans-mara, livestock density is low. The concentrations are high in Maasai occupied areas of Trans-mara, Naikara-Morijo and Narosura-Suswa. Its distribution is sparse in the MMGR where livestock is prohibited. However, as can be seen from Figure 5.1, grass poaching in the reserve is very common. The Maasai who stay in the neigbourhood of the reserve, occasionally push their livestock into the reserve for pastures. This practice is very common during drought years. It may, however, be seen as a reciprocal way of sharing resources with game which moves freely in Maasai grazing land. Low livestock densities in the central plains are associated with reduced resources due to low potential or due to competition from wildlife.

The following section is a detailed discussion of disturbance characteristics. An attempt is made to relate them to animal data, already covered, and human population (Kenya 1981).

5.4.3 Frequency Distribution of Disturbance Types

5.4.3.1 Burning

The low occurrence of fire observed during this study (Table 5.1) is not unusual. To be able to account for frequency distribution of burning, the ecology of areas where burning was not observed are examined.

The observed fire frequency may be attributed primarily to the change in fire regime over the last 10 to 30 years. The present fire regime is associated, predominantly, with increasing human activities which either require less use of fire or have reduced burning. Burning is recorded mainly in the grassland and bushland communities (Table 5.1). In woody communities, permanent cultivation is succeeding shifting cultivation, and this has reduced burning for clearing purpose. The frequent fires in the Olive wooded bushlands of Trans-mara, for instance, have been associated with shifting cultivation (Mwichabe 1988). The use of fire has therefore decreased due to a decline of once dense and impenetrable woody stands. Lack of burning in forest and woodland communities may therefore, firstly, be attributed to this change. Secondly, it may be attributed generally to low grass litter compounded with low temperatures characteristic of fires within these communities. It needs to be clear that although grasses in most sites are tall, the biomass cover is generally scanty (Chapter 7). Thus, the accumulation of litter by the end of the dry season is rarely enough to support fire.

Low fire frequency in non-woody sites, is associated with reduced grass quantity. Encroachment by cultivation, especially of formerly grazing land, has reduced burning by replacing grasslands which used to experience seasonal burning and by compressing the distribution of animals. Accordingly, seasonal movement of animals that allows grass recovery for the building up of combustible litter is dying out (Chapter 4). Accumulation of unpalatable grass is therefore becoming rare.

The sites where burning was recorded, are located in the semi-nomadic pastoral areas of Masurura-Moita (sites 17 and 23) and Nkoilale-Talek (sites 34 and 36)-Megwara, where grass height is highest (Chapter 7). These are areas occupied by the Maasai, where cultivation is absent or at the inception. Also, the presence of tse-tse fly in these areas has kept livestock density low, favouring litter accumulation. Lack of fire in settled and cultivated areas is therefore due to insufficient grass litter. As in the Loita plains, grass biomass in these areas is constantly low (Chapter 7) due to year-round grazing. Spatial and short-term change in grass height, due to seasonal changes of herbivore impact, is common in sites where fire is recorded. During the wet season, grass heights of species such as *Themeda triandra* and *Pennisetum mexicanum* in the reserve vary between 48cm and 180cm. These grasses are reduced to about 15cm high following wildebeest migration during the dry season. In drier years, seasonal removal of biomass is sometimes too much to allow any burning. On the contrary, during a prolonged wet season abundant herbaceous growth provides enough litter to support fires by the end of the dry season, even after heavy grazing by migrating ungulates.

The removal of standing crop by migrating herbivores in the Serengeti-Mara ecosystem has been approximated to 80-90% within a few weeks (McNaughton 1976; Boutton *et al.*,1988). The impact of short-term severe grazing is sometimes similar to that of year-round grazing. That is, it reduces grass to the extent that fires may not be supported during the dry season. In most parts of the District, grass height has decreased by 50 to 60 per cent over the last 10 to 30 years (Dublin 1986). Also, Belsky (1987) reported that grazing in the short grass plains, maintains the height of herbaceous vegetation below 5cm. At these fuel loadings, fires are bound to be less common.

Low fire frequency is, also, associated with the distribution and the number of sites. Of the 42 sites examined, only 10 are from the grasslands which are vulnerable to burning. This is a small coverage given the wide distribution of the grassland community (Chapter 3). Also, most sites were studied during the wet season when cases of fire are less common. This assumption is qualified by the increase in observed burning during a second visit to different sites. At this time, which concided with the dry season, there was burning almost within every 4 to 6 km radius in the plains. Grassland burning increases with the arrival of the dry season when the herb layer is dry. Unmanaged fires are lit mainly to clear away old grass and kill pests such as ticks. Dry season fires started by honey hunters are common in the open woody communities of Naikara-Morijo, the upland forests and the bushlands of Sikawa-Masurura. Increase in fire frequency during the dry season has been reported in different parts of the study area (e.g., Dublin 1986; Lamprey 1984) and from different parts of East Africa (e.g., Vesey-Fitzgerald 1973; Lamprey 1985; Sinclair 1979).

Some of the fires started by the pastoralists and honey hunters sweep into the game reserve and remnants of woody communities on hilltops. It was reported that most fires in the reserve originate from Tanzania. Although no immediate answer was obtained, this study assumes that the earlier arrival of the dry season (Chapter 3) and the higher amount of biomass by the end of this season are responsible for early burning. Also, pastoralists burn pastures early enough to discourage the invasion of grazing lands by migrating ungulates, particularly the wildebeest.

The findings on fire frequency in this study are contrary to those reported by Werger (1983:116), who generalizes that present human activities in the tropics have led to burning of grazing lands

"annually, many twice and some even three times a year instead of the original frequency of once in about four to seven years".

However, they agree with Lamprey (1985:217) who writes

"heavy grazing pressure...has reduced the quantity of standing grass to the extent that grass fires are rare or no longer occur ".

5.4.3.2. Charcoal Burning

The low frequency and distribution of charcoal burning observed during this study may be ascribed to two factors. Firstly, because it is illegally conducted (Chapter 4), and secondly, because charcoal is not widely used as fuel.

Charcoal burning is confined to sparsely populated woody communities where indigenous trees/shrubs are common. This allows selection of the species which are considered best for charcoal. This assumption is supported by lack of cultivation and total clearing in two of the sites where charcoal burning was recorded. Therefore, these sites are basically inaccessible, making it difficult for the government to intercept the people involved. The lack of charcoal in non-Maasai occupied areas of Trans-mara, Olkurto and Osupuko Divisions, is associated with increasing wood shortages (Chapters 4 and 7).

Due to economic constraints and cultural preferences, the use of charcoal as a source of energy is limited to a few urban dwellers. Despite wood shortages observed in chapter 4, the majority of Narok's population still rely on firewood as the sole source of energy. This is because firewood is easily available in most parts of the District. The other sources of energy such as charcoal, solar energy, electricity and paraffin are too expensive and not available to the majority of people. Therefore, charcoal which is burned in the District is either sold to a few urban centres or it is imported to the neighbouring Districts which are densely populated, more urbanised and have little vegetation left (Chapter 4). The influence of an outside market on charcoal burning is supported by the increase of charcoal selling along the border areas and roads. Outside the study sites, charcoal sacks are placed by the roadside awaiting transportation into urban centres for sale. The sacks are watched from hiding places.

The present research, however, postulates that charcoal burning in Narok District is more than was observed. Some tree trunks observed during this study appeared to have been cut for charcoal burning, but this could not be revealed because the illegal nature of the activity. Generally, charcoal burning which is involving a lot of Maasai women is being increasingly taken up despite its ban by the government.

5.4.3.3 Wood Cutting

To account for the observed widespread selective wood cutting, it is necessary, firstly, to consider the mode of wood consumption. Except where wood is scarce, only specific trees/shrubs are harvested for domestic use (Chapter 4). Table 5.2 shows that until recently wood consumption was predominantly selective (see also Chapter 2). Trees/shrubs are selectively harvested for construction of enclosures and huts, medicine, fuel, spear-shafts and walking sticks. This is because, for instance, the use of some *Euphorbia* spp, for firewood, is a taboo among the Maasai of Trans-mara.

Using Table 5.1 and Figure 3.8 (see also Kenya 1981), it is evident that selective tree cutting is highest particularly in low density population areas, restricted mainly to Maasai occupied woodlands and bushlands of Megwara-Aitong, Naikara and Masurura-Olenkasorai, and a few immigrant occupied areas. These are areas with high species richness and abundant mature trees (Chapter 7). Both factors attract selective tree harvesting. In predominantly non-Maasai occupied areas, reduced wood sources have confined selective wood cutting to non-gazetted forest reserves in the Mau uplands (e.g., sites 9 and 38) where wood harvesting is banned.

Although selective wood cutting has been carried out in Narok District for hundreds of years, there is a shift to total wood cutting particularly because of increasing cultivation and settlements. As will be seen from Table 5.1, for woody sites, cultivation is associated with total clearing. The fewer cases of total clearing, suggest that this shift from selective tree cutting is very recent. However, both methods of wood harvesting, are increasing in space, amount and repeatability so as to cope with the increasing demand for food, building and fuel materials. The general increase in wood cutting follows a rise in Narok's population (Chapter 2), a change in Maasai habit of wood consumption and continuing reliance of neighbouring Districts on Narok for wood products (Chapter 4). Along the borders, the trend of wood consumption is characterized by harvesting trees, predominantly, on the basis of availability and not on their relative abundance and variety.

5.4.3.4 Light Grazing and Overgrazing

In this study, light grazing is widespread because it involves both livestock and wildlife herbivores. In some sites, it occurs with browsing because some browsers accidentally cut grass along with seedlings. However, the observed frequency distribution of light grazing is not as high as would be expected. Its absence in grassland and intermediate woody community sites, which support ungulate populations (Figs. 5.1 and 5.2), may be due to its short-lived impact. The latter may be associated with the high turnover rates of clipped parts favoured by the heavy rains prior to and during the time of this study. Also, the lack of grazing evidence particularly in some woody communities is associated with low population of ungulates, for fear of being preyed on or being attacked by pests in the case of livestock.

The observed frequency of light grazing may also be explained on the basis of grazing patterns. Temporal change in foraging range is perhaps responsible for the lack of grazing evidence in potential sites. In spite of declining grazing resources, the distribution of ungulates change from season to season due to pasture preference or avoidance from predators. This assumption is supported by the observations made on grazing impact in tall grass plains during a visit made to the study sites later in the dry season. Seasonal grazing following fluctuations in pasture and water resources has also been reported in Narok District (Chapter 2, see also Belsky 1987). Gwynne and Bell (1968) and Bell (1971) describe grazing patterns as 'grazing succession' in which the non-ruminant zebra preceeds the ruminant wildebeest in the migration. The former browses and fells trees leaving the grass sward less disturbed for wildebeest grazing. The latter reduces herbaceous height making available scattered herbs and short grasses. Third in the succession are Thomson's gazelle which prefer short grass.

Further, limited light grazing, particularly in undisturbed grassland sites (Table 5.1) may be associated with changes in fire regime (see above). Reduced fires may have led to the increase of old unpalatable grasses that don't attract grazers. Small ungulates prefer the short grass plains which during the time of this study were endowed with resprouting pastures and water. Concentration of herbivores in grazing lawns has been confirmed by Boutton *et al.*,(1988) and McNaughton (1985). These authors, associate animal preference of open area with the high proportion of leaves to stems, and the generally high nutritional quality of the plants. A similar observation was made by Ross (1985) in the grasslands of the Simba Hills, Kenya.

Unlike light grazing, overgrazing is recorded only in 7 sites. Its low frequency suggests that there are only a few sites that have the pastures that are currently over-used. This observation should not overrule the seriousness of overgrazing in the study area. This is because it is widespread mainly in the plains, and particularly along animal tracks, and water and resting points. The high frequency of overgrazing in the plains is exacerbated by the low recovery potential of these areas and the lack of grazing selectivity. Therefore, its absence in most sites may be attributed to the distribution of sites and the higher rains during and prior to the time of study. Most sites were located far from animal frequented parts of the plains. From Table 5.1, overgrazing has been very common in the shrubland and grassland communities. Also, over the last four years, rainfall in Narok District has been sufficient, supporting quick recovery of vegetation from over-use by animals. When rainfall is enough, over-use of vegetation is less common because of diversified grazing pressure and trampling, and the relatively high plant resilience to grazing and trampling (Dublin 1986). Both factors, overshadow overgrazing impact.

5.4.3.5 Browsing

Browsing like grazing is widely distributed because it involves both livestock and wildlife. Both disturbances are historical (Table 5.2) in the study area which for hundreds of years has been the home of domestic and wild ungulates (Chapter 2). Observed frequency distribution of browsing can be explained on the basis of seedlings availability and the distribution of browsers. For instance, lack of browsing in sites 11 and 14 may be attributed to lack of seedling due to cultivation. The latter affects seedlings through weeding. Lack of browsing for sites which registered grazing may be associated with lack of seedlings below the browsing level. As will be seen in Chapter 7, browsing is confined to plants below 1m. Browsers will choose habitat types which produce large quantities of seedlings, a factor which compels them to move from one place to another. However, the presence of seedlings in itself is not enough to determine browsing. First, the presence of browsers is very important. From section 5.4.3, it is evident that both wildlife and livestock populations are widely scattered. The populations are low in woody communities, suggesting that these communities are not frequented by browsers. Also, seedlings may be avoided, lowering browsing frequency, due to unattractive structures and/or taste. Browsing selectivity was observed in different sites (Chapter 7). Although more subtle choices of the plants browsed are made, diet selectivity is very characteristic of most browsers (see Boutton *et al.*,1988; Viljoin 1989; Ross 1985). However, in the plains, high plant resilience (the ability for them to withstand perturbations) and the lack of continuous disturbance allows disturbed sites to recover rapidly. This partly explains why the Loita plains afford to support both resident and large numbers of migration ungulate populations, in spite of its drier conditions.

Low browsing may therefore be associated with rapid seedling recovery from browsing. As with grazing, seedling recovery could be associated with the relatively high rains during the time of study. Also, high rains may have contributed to low browsing frequency as most browsers switch to herbaceous species when in abundance (Dublin 1986). This observation further explains cases where grazing alone is recorded. Dependence of browsing on local weather conditions is very common in the Serengeti-Mara ecosystem (Norton-Griffiths 1979; McNaughton 1979). By affecting food resources, weather fluctuations determine browsing range for large herbivores. Therefore, it is also likely that most sites had not been visited by migrating browsers at the time of study or by grazers which sometimes pick seedlings along with grass. Like light grazing, increase in browsing observed during the second visit of this study supports this assumption. Dublin (1986) and Guy (1976) report that browsing is characteristic of large and small herbivores. These authors further indicate that large herbivore browsing is seasonal, being low during the wet season when grass forage is high. During this study, next to MMGR Research Station, we observed files of migrating buffaloes which browsed, trampled and grazed about 100m wide wooded grassland, leaving it open in less than 2 hours. Both herbaceous and woody layers were affected.

The low frequency of browsing recorded in forest communities (Table 5.1), may be due to methodological limitations. Generally, for woody communities, it was difficult to differentiate browsed seedlings from those cut or broken by animals or falling branches, the forest communities were no exception. This was true if the scars were faint and there was inadequate evidence to suggest browsing. A further explanation of low browsing in the forest sites could be related to low animal numbers in general and specifically a lack of browsers (section 5.4.3). As indicated earlier, browsers such as Impala and Thomson's gazelle prefer open grounds. The concentration of browsers in grasslands may be associated with their innate ability to switch to grasses when browsed species are eliminated (Dublin 1986). The few observations of browsing in the grassland community could be attributed to the 'naturally' small amount of seedlings (Chapter 7).

5.4.3.6 Trampling

Compared to most disturbances (Table 5.1), trampling has relatively high frequency. This observation may be ascribed to its association with browsing, grazing and overgrazing. Animals trample as they trail for pastures and water or at their resting points, as they over-use a site. Wildebeest, for instance, leave a lot of foot marks at water and resting points or along migration trails during their seasonal movement in large numbers. Thus, differences in spatial variation in trampling is associated with the distribution of animals and the size of dispersal areas. Trampling is common in the plains (sites 4, 25 and 26) because of high animal densities (Figs. 5.1 and 5.2). At the local scale, it is confined to enclosures where the animals stay overnight, at resting, salt licks and water points, and along tracks where they roam freely during the day. This observation is supported by Senzota and Mtahko's (1990) study in

Mikumi National park, Tanzania, which recorded concentration of trampling near water points (see also, Dublin 1986; Belsky 1987).

In the MMGR, other than in areas where wildlife concentration is high, trampling in a form of paths and roads/tracks is being intensified by tourism. Because of its large diversity and number of wildlife, the MMGR attracts a large number of tourists. Viewing of scenic and environmental resources involves a network of tracks which are characterized by ecological disturbances. Within the reserve and camping sites in the neighbouring Maasai occupied areas, a strip of about 100-200m along the routes and within lodges and camping sites show extreme wear due to intensive traffic. This area is either bare or has patches of annual plants and rootstocks. Off-road driving and foot paths, elsewhere in the District, further trample the vegetation. By the road-side trampling is evident where cattle traders keep their animals overnight.

5.4.3.7 Animal Droppings

Despite the widespread distribution of livestock and wildlife in the District the frequency distribution of animal droppings is very low (Table 5.1). Their absence in grazed, trampled and browsed areas may be associated, firstly, with rapid decomposition. Except for elephant, zebra and donkey dung, most wild herbivores and livestock dung disappears within 5 to 8 days (Chala per. comm.) or it is easily covered by litter or dust. Rapid dung decomposition might have been favoured by the unusually wet season prior to and during the time of fieldwork. Most decomposers come onto the surface when the ground is wet (Brady 1990). Like light grazing, dung is a small-scale disturbance, unless frequently disposed and in large numbers. Average dung size observed in this study is 0.14 to $0.26m^2$. Its impact on vegetation is obviously short-lived, a factor that may, further, explain its absence in animal frequented sites. Along with their short-term impact, low frequency of observation of animal droppings may further be associated with dust resulting from wind erosion and animal movements. A number of droppings were covered by dust. Also, some droppings were brown in colour making it difficult for them to be readily distinguished from soil. Herbivores such as Impala and Gazelle lick saline soils which make their droppings brown.

Secondly, observed low frequency of animal droppings may be associated with their spatial and temporal variations in disposal. Dung is either disposed in foraging areas or at the resting and water points. This assumption explains the lack of dung in bushland sites which have low livestock and wildlife densities (section 5.4.3). From Figures 5.1 and 5.2 and, Table 5.1, highest dung recordings are from disturbed sites which support the largest ungulate population. In the prairies of America, Coffin and Lauenroth (1988) found high concentration of cattle fecal pats in the lowlands where they spent most of their time. These authors further noted that the number of fecal pats increase with grazing intensity. On the contrary, the present research associates lack of dung in some overgrazed and trampled sites (Table 5.1) with these disturbances which, it may be assumed, influence dung decomposition. Trampling in particular, mixes dung with soil so that it is not easily identifiable, or it is fast decomposed by beetles and other decomposers.

5.4.3.8 Mining and Quarrying

The low frequency of mining and quarrying is associated with the recent nature of their development in Narok District and the nature of underlying rocks, which are poor in commercial minerals. Only salt licks, mainly, in the plains, have been in use since the turn of this century. Gold mining, which is confined to Lolgorein Division, followed the discovery and extension of Macalda mines of South Nyanza District in the middle of this century. Presently, it is dormant because of the scarcity of gold and inadequate mining facilities. Scattered salt mines, which through animal concentration have led to local destruction of vegetation, are common at Maji Moto.

Although quarrying is widespread for the provision of road murram, sand and building stones, its low frequency is associated with the greater dependence by the local people on wood products for construction of houses/huts. The volcanic rocks in the District are a potential source of ballast and blocks for house and road construction. Stone quarrying is limited to a few urban centres. For instance, there is a huge quarry next to Narok town. More quarry sites occur widely distributed along the roads and on the neighbouring hillslopes.

5.4.3.9 Soil Erosion

The absence of soil erosion at most sites could be attributed to the time of study and the limited number of sites. Areas which appear susceptible to soil erosion, were visited during the time when grass cover was high so that any evidence of soil erosion was obscured. Ogutu (1986) and Mutiso (1988) indicate that, in Eastern Africa, soil erosion occurs with the onset of rainfall when vegetation cover is poor. Therefore, the fact that soil erosion is among the least recorded disturbances (see Table 5.1) does not preclude its wide occurrence and/or its seriousness in the study area. For instance, water and wind erosion, even at severe stages, have been reported in large-scale farms and grazing lands where natural vegetation has been removed and the soil conservation measures are inadequate or absent (Chapter 4).

In the plains where animal densities are high and the vegetation cover low (Chapter 7) or absent, loose soils favour the development of soil erosion. Clouds of dust are common in the plains during ungulate migration. Also, soil erosion is favoured by low erratic seasonal rainfall. Gully erosion is common along animal trails, water and resting points, and along roadsides. The high frequency of exposed roots in the plains is evidence of the seriousnes of soil erosion. Both sheet and gully erosion are increasing in the contract wheat growing areas of the Ngorengore-Loita plains and Mau, particularly because of the destruction of vegetation.

Soil erosion is common in abandoned leased farms which, after cropping, are exposed to grazing becoming bare (Chapter 4).

Also, the vulnerability of the soils of Narok District to erosion has led to gully erosion in the hillslopes following cultivation. In the plains soil erosion is associated with cultivation and overgrazing. In particular, areas covered by volcanic soils are very sensitive to soil erosion (Jaetzold and Schimdt 1983). As with most disturbances, the present study considers the decreasing grazing land due to increasing cultivation to be the primary force behind soil erosion in the plains.

5.5 CULTIVATION

From Table 5.1 cultivation, which is relatively recent, is confined to Trans-mara, Mau and Olkurto Divisions. These are areas with greatest and earliest immigrant influence. Field surveys confirmed that only one site had on-going cultivation. The rest were fallow, having been abandoned for various reasons (Chapter 4). The lack of widespread cultivation can also be associated with different socio-economic factors (Chapter 4).

From Table 5.1 and Figures 5.3a and 5.3b cultivation expanded between February 1984 and March 1989. Refering to Figure 3.6, by 1976, the wheat farms were wholly confined to the area north of Ololunga-Ngorengore road. The farms are relatively fewer in number, about five, and smaller in size compared to those on the 1984 and 1989 extracts. The 1984 extract shows that since 1976, the farms increased in number spreading north of Ngorengore-Ololunga road and along Ngorengore-Maji-moto track. By 1989, they had spread covering the empty spaces between the 1984 farms, and the portion west of the Ngorengore-Maji-moto track.

Thus since 1976, the farms have expanded in all directions, but particularly, to the south and south-east. The expansion has been highest in these directions because of open grasslands and the low topography, which attract mechanization. Cultivation encroachment has been slow to the rocky outcrops in the west (next to Ngorengore-Mulot junction), the thick woody communities to the north and the drier, low fertility, parts to the south-east. The observed expansion of cultivation, is in line with the general expansion of cultivation in the District (Chapter 2).

The increase in land under crops is generally associated with the increasing pressure for land in the neighbouring Districts, the realization by the farmers from the neighbouring Districts of the potential of Narok District for different crops and provision of loan facilities, and also, because a few Maasai (formerly pure pastoralists) are taking crop farming seriously (Chapters 2 and 4).

The small number of farms abandoned over the five year period is an indication of the high potential of the land for cultivation and/or the application of fertilizers. In different parts of the District, including the area mapped for cultivation, farms are abandoned mainly because of lack of finance to purchase equipment and a fall in soil fertility (see Chapter 4). Also, a number of farms have been abandoned because of pressure, on immigrant cultivators, from the local people. This is either because of reduced grazing land or because of the fear that they may loose their land to the immigrants. The influence of the local people on abandonment of cultivation may be supported by the fact that two of the three abandoned farms lie close to the Loita grazing areas.

5.6 Disturbance Size

Table 5.3 shows that small gaps are frequent, recorded in more than half of the 42 plots. This is, firstly, because of the agents responsible and, in particular, the distribution of these agents. This disturbance category is caused mainly by animal activities, which are widely distributed (section 5.4.3). In most sites, livestock is the common disturbance agent. This is true of the forest community sites which hardly support wildlife. On the contrary, large gaps are fewer, and they are associated with cultivation and overgrazing. This observation about gap size distribution agrees with Bazzaz (1983) and Louck *et al.*(1988) who support the view that small-scale disturbances are common and short-lived whilst large-scale disturbances are rare and long-lived.

Small gaps are also characteristic of the sites in the pastoral areas where human population is low. Here, large-scale disturbances such as cultivation are, at most, in the inception (Chapter 4). The concentration of small gaps in the xeric plains and the surrounding areas, is associated with the low closure rates and the high number of disturbance agents. The former, suggests the significance of soil and climate in site recovery (Adedeji 1984; Goldberg and Gross 1988).

Although small gaps are abundant in grassland sites 25, 28 and

35, the overall rating (see Table 5.3) places them in the high disturbance category. This is because of the high number of small gaps observed. Therefore, the latter are perceived to be as devastating as a single large gap either because of their high repeatability or the overall area they disturb. Despite their high rate of recovery, medium and high potential areas have the highest number of large-scale disturbances which include abandoned and on-going cultivated farms. This is because of their long exposure to immigrant influence.

Immigrants were attracted to these areas initially, undoubtedly because of their high agricultural potential. It may, therefore, be argued that the recovery of a site from a disturbance depends primarily on the gap size, gap repeatability and the inherent potential of the site, among other factors. Generally, the smaller the gaps, the quicker the recovery because of the few plants killed and vice versa (Chapter 7, see also Coffin and Leunroth 1988).

Associated with gap size is gap shape. A mosaic and not homogeneous assemblage of vegetation is associated with small-scale disturbances. The removal of a single tree, for instance, creates circular or linear gaps, while the removal or clipping of a clump or clumps of grass leads to circular or U-shaped gaps. The shape of the gaps in herbaceous sites would be approximated even when the plants are mainly grazed or browsed and not removed. Generally, while gap shape was less definite for small-scale disturbances, large-scale disturbances such as cultivation create rectangular gaps. Also, most gaps which were associated with animal activities were irregular forming a network of linear trails intercepting circular patterns of water and resting points. Therefore, the influence of disturbance type is also evident in gap shape suggesting its consideration for the management of vegetation.

5.7 CONCLUSION

This chapter has revealed, firstly, that the sample sites are not homogeneously disturbed. Instead, they experience a combination of disturbance types and, a variety of different sizes. Secondly, large-scale (recent) disturbances are less frequent compared to small-scale (historical) disturbances. Thirdly, disturbance size ranges from very small (<1m) gaps created by cutting of individual tree/shrub or by the removal of a single clump of grass to very large (>1ha) gaps created by total clearing or cultivation. Fourthly, the existence of a disturbance either eliminates or attracts further disturbance, a phenomenon commonly called disturbance synergism.

Fifthly, disturbance occurrence tends to vary with human ecology and rainfall patterns. The second observation underscores the significance of the scale and timing in disturbance studies. It is also indicated that some disturbances are less seasonal due to changes in spatial and temporal patterns of the underlying agents. Lastly, Landsat data has confirmed a drastic expansion of cultivation which is an encroachment by non-Maasai Kenyans onto prime grazing land at the savanna-forest fringe and remnants of woody communities (Chapter 7).

CHAPTER 6 SOIL DESCRIPTION AND ANALYSIS

6.1 INTRODUCTION

The procedure for soil sampling in the field was outlined in chapter 3. This chapter describes and accounts for soil nutrients across the 30 sites. The findings are used to infer the impact of human disturbance on vegetation (Chapter 7). This is, mainly, because of the realization of the interdependence between vegetation and soil (Chapter 3). This means that changes in vegetation could be reflected in soil fertility status.

The following section presents the methods used to analyse soil samples. The results are reported and discussed later in this chapter.

6.1.2 Laboratory Soil Analysis

Chemical and fertility analysis of soil samples was carried out at the National Agricultural Laboratories (NAL) using the methods outlined by Hinga *et al.*,(1980). A brief breakdown of the methods is given below-:

pH : H_2O/1N KCL in 1:2.5 soil-water/salt suspension was measured with a pH-meter

% organic carbon : Walkey-Black method

% total nitrogen : Kjeldah method (after Bremner)

Available nutrients: extraction by shaking with 0.1N HCL/0.025N H_2SO_4 (at 1:5 ratio). Ca^{2+}, K^{+}, Mg^{2+} and Na+ were determined with a flamephotometer; P and Mn^{+} were determined colorimetrically.

Trace elements (Fe^{3+}, Mn^{2+}, Zn^{2+} and Cu^{2+}) were determined by atomic absorption spectrophotometer.

These are the elements that the NAL currently consider important in predicting fertility status (Table 6.1).

Element	Deficient	Sufficient		Rich or Toxic
Na	-	0-2.0	cmol/kg	>2.0
K	<0.2 cmol/kg	0.2-1.5	"	1.5+
Ca	<2.0 "	2.0-10.0	"	10+
Mg	<1.0 "	1.0-3.0	"	3+
Mn	<0.1 "	0.1-2.0	"	2+
P	<20 ppm	20-80	ppm	80+
N	<0.2 %			
C	<1.0 %			

Table 6.1 :The NAL Nutrient critical levels which form the basis of fertilizer recommendations.
Source: unpublished NAL material

Lack of equipment and resources made it difficult for this study to test other soil properties such as soil moisture or soil texture which are, however, exceedingly difficult to generalise in terms of vegetation association. The elements analysed are considered to be representative of vegetation response to human disturbance.

6.1.3 Data Organisation for Description and Statistical Analysis

Data are first organized for description. The objectives of data description are:

1). To examine the pattern(s) of data in each site. Different tables, diagrams and the mean are used to achieve this objective.

2). To establish whether the different nutrients are related. A non-parametric correlation coefficient is used to achieve this objective.

3). To establish whether sites identified as disturbed and undisturbed are distinguishable on the basis of nutrient characteristics. The findings from 1) and 2) above are used.

To show the status of different nutrients, data are presented as a sample-and-nutrient matrix in Appendix B. Because of the amount of data involved, histograms (Figs. 6.1 to 6.12), measures of central tendency and dispersion (Tables 6.2a and 6.2b) are used to summarize the characteristics and distribution of data. For ease of interpretation and comparison of nutrient variation, data are plotted on sample basis (Figs. 6.13 to 6.27). Because of the difficulty in distinguishing readily between disturbed and undisturbed sample categories by the preceding approaches, the mean (m) and standard deviation (s) of each variable in the 0 to 10cm depth has been calculated (Table 6.2b). This zone is chosen because it is most influenced by vegetation and conversely has the greatest influence on plant growth. It is therefore most responsive to vegetation disturbance.

After establishing trends in nutrient data (Figs. 6.13 to 6.27), a non-parametric Spearman correlation coefficient is used to show the relationship among them and, between them and vegetation (Table 6.3). Only the nutrient data in the upper horizon is used. To show the status of carbon and nitrogen in the soil, and the sum of the total exchangeable cations, the N/C ratio and CEC, respectively (see Appendix B), have been calculated and the results are included in the discussion for complete description of soil data.

Secondly, data are organized for statistical analysis. The general purpose is to summarize and advance the findings of descriptive analysis. The specific objectives of this analysis are:

1). To establish whether data, sorted on sample basis, suggest some structure that can be used to infer human impact on vegetation and/or underlying environmental factors. Ordination is used to achieve this objective.

2). To verify that the data for different identified sites truly represent the specific community site categories. Classification is used to achieve this objective.

To achieve objective 1, a discriminant analysis method known as Canonical Variate analysis (Digby and Kempton 1987; Digby *et al.*,1989), is used. This technique shows the scatter of samples, using variable values, from the centroid or group mean and also from the other samples on a two dimensional plot (SPSSx users manual 1990). Although the analysis is not commonly used, this study identified it as useful because of its power to take account of variation between and within samples by obtaining a set of directions such that the ratio of between-sample variability, $x' B x$ matrix, to within-sample variability, $x' W x$ matrix, is maximized ($SPSS^x$ users manual 1990; Digby *et al.*,1989).

Distance measures such as Wilks' lambda, Mahalanobis' distance and F ratio (see $SPSS^x$ users manual for details) are commonly used in discriminant analysis. In this study, Mahalanobis' distance was used because it is most effective in finding a set of variables that maximizes discriminating power. The sample coefficients obtained from discriminant functions have been plotted on a two dimensions samples ordination to display group membership and to determine the underlying structure, which is then related to environmental factors. Two ordinations are used. The first plots involve all the samples, the second plots involve only the sample centroids for each site. Discriminant analysis using a combination of different variables did not prove useful, and the results are therefore excluded.

To confirm that fieldwork data truely represent specific site categories, the second objective above, a cluster analysis has been performed on all data using the HCLUSTER subcommand in SPSS[x] computer package. Both complete and average linkage algorithms based on squared Euclidean distance are used (see Fig . 6.28). Site numbers have been included against the specific samples to facilitate interpretation.

6.2 RESULTS

This section reports the results of soil data obtained by using both descriptive and multivariate techniques.

6.2.1 Description of Soil Nutrient Data

The nutrients display different patterns within each profile, and between and within the different sample site categories (see Appendix B, Figs. 6.13 to 6.26). For instance, many of them differ in their vertical concentration gradient.

Using standard deviation, nutrients broken down on the basis of all sites (Table 6.2a), the distributions of P, Fe^{3+} and Zn^{2+} are most varied. Using the mean of variables for the first horizon, except for shrubland and grassland sites, base cations, P, N and C are predominantly higher in undisturbed than in disturbed sites (see Table 6.2b).

Variables	minimum	mean	maximum	standard deviation	
pH	4.50	6.05	7.80	0.64	
Na	0.13	0.66	3.55	0.55	skew
K	0.16	1.18	3.10	0.60	
Ca	2.40	12.88	50.00	8.73	skew
Mg	0.50	2.18	6.50	1.09	
Mn	0.11	0.79	1.910	0.48	
P	2.00	16.90	171.00	24.81	skew
N	0.04	0.23	0.65	0.15	
C	0.31	2.35	6.60	1.61	
Fe	0.00	45.21	205.00	45.91	skew
Cu	0.00	1.44	8.500	1.91	skew
Zn	0.90	16.70	59.00	18.97	
CEC	4.50	16.24	35.16	2.82	
C:N	2.60	9.70	22.7	0.72	

Table 6.2a: Description of Variables per plot using measures of central tendency and dispersion. Sample-size (n)=90

The frequency distributions (see Figs. 6.1 to 6.12) show that except for pH and K^{+}, most variables are positively skewed. Correlations are high between pH and exchangeable cations and P, between Ca^{2+} and N^{+}, P, Zn^{+2} and Cu^{2+}, between N and C, and P, C and the micronutrients mainly Cu^{2+} and Zn^{2+} (Table 6.3). Also, the correlations between vegetation latent vectors (Chapter 7) and N and C, and Zn^{2+} and C are high.

The following eight sub-sections report the results of different nutrients in detail.

6.2.1.1 Soil pH

Figure 6.4 shows that pH is normally distributed. Its variation over the 90 samples is generally small (Table 6.2a). Appendix B and Figure 6.13 show that pH varies from strongly acid to moderately alkaline with values ranging from 4.5 (at Olkurto, site 29) to 7.8 (at Eurokule, site 4). These two sites are located in the wet uplands and in the semi arid plains, respectively (Chapter 3).

Site type	pH	Na	K	ca	Mg	Mn	P	N	C	Fe	Cu	Zn
	Nutrients ------------------>											
UDF(m)	6.4	.59	1.34	19.5	2.9	.49	41.5	.52	5.05	15.5	.17	26.7
(s)	.54	.11	.39	14.7	1.0	.42	63.1	.12	.53	12.4	.20	17.9
DF (m)	6.3	.70	.92	12.1	1.52	.64	19.8	.37	4.8	27.1	.15	37.9
(s)	.70	.18	0.18	5.7	1.3	.53	4.0	.04	1.25	26.8	.3	16.2
UNW(m)	6.0	.39	1.3	24.0	4.2	1.02	20.5	.5	4.7	86.8	1.5	4.5
(s)	.42	.01	.47	0.0	1.1	.59	19.1	.14	1.9	102	.39	5.0
DW (m)	5.9	.30	.58	11.6	1.5	1.9	6.0	.25	3.1	42.3	1.2	2.3
(s)	.50	.01	.11	8.5	.42	.01	4.2	.11	.11	3.9	.18	.14
UNB(m)	5.9	.5	.64	12.8	2.2	1.3	7.0	.15	2.8	41.5	.4	1.9
(s)	---	---	---	---	---	---	---	---	---	---	---	---
DB (m)	5.4	.29	.47	8.5	2.0	1.1	4.0	.12	2.5	54.0	.38	2.2
(s)	.14	.14	.15	2.7	0.0	.1	1.4	0.0	.39	7.1	.04	.71
UNS(m)	6.0	.39	1.1	7.3	1.8	.43	14	.16	1.3	46.3	.5	6.3
(s)	.14	.37	.64	2.1	1.6	.1	0.0	.1	.7	44.2	3.2	6.0
DS (m)	6.9	1.3	1.9	12.6	2.3	.15	17	.97	.84	79.3	0.0	10.5
(s)	.71	.94	.90	5.4	1.3	.30	4.2	.19	1.1	74.6	0.0	8.5
UNG(m)	5.8	.37	.72	6.4	2.0	.59	8.3	.14	1.6	71.5	4.0	4.12
(s)	.59	.06	.36	2.8	.59	.30	5.3	.02	.46	90.0	2.9	2.4
DG (m)	6.2	.91	1.7	13.2	2.5	.9	37.0	.19	1.7	21.0	3.0	14.3
(s)	.79	.61	.48	8.9	1.7	.57	63.2	.10	1.6	16.4	1.9	21.2

Site type	**UDF**	**DF**	**UNW**	**DW**	**UNB**	**DB**	**UNSh**	**DSh**	**UNG**	**DG**
C:N (m)	10.23	13.0	10.1	13.6	18.7	21.1	10.6	13.5	10.9	15.4
(s)	2.1	3.3	6.6	5.7	--	3.2	9.5	13.0	2.8	10.8
CEC (m)	14.4	19.5	29.8	14.0	16.1	11.3	10.6	18.1	9.5	17.6
(s)	10.4	9.4	.69	9.0	--	3.0	1.6	8.5	3.7	9.5

Table 6.2b: The Mean(m) and Standard deviation(s) of the first (0 to 10cm) horizon for the different nutrients, calculations based on site category. UDF-undisturbed forest, DF-disturbed forest, UNW-undisturbed woodland, DW-disturbed woodland, UNB-undisturbed bushland, DB-disturbed bushland, UNsh-undisturbed shrubland, Dsh-disturbed shrubland, UNG-undisturbed grassland and DG-disturbed grassland (n=30).

Fig. 6.1 The general distribution of C (%) in the 90 samples

```
COUNT   MIDPOINT    ONE SYMBOL EQUALS APPROXIMATELY   .40 OCCURRENCES

  0        .133
 11        .467   ***************************
 10        .800   *************************
  8       1.133   ********************
 10       1.467   *************************
  7       1.800   *****************
  9   C   2.133   **********************
  3       2.467   *******
  5 (%oC) 2.800   ************
  5       3.133   ************
  0       3.467
  1       3.800   **
  6       4.133   ***************
  5       4.467   ************
  3       4.800   *******
  3       5.133   *******
  1       5.467   **
  1       5.800   **
  1       6.133   **
  1       6.467   **
  0       6.800
                  I....+....I....+....I....+....I....+....I....+....I
                  0         4         8         12        16        20
                           HISTOGRAM FREQUENCY
```

```
COUNT   MIDPOINT    ONE SYMBOL EQUALS APPROXIMATELY   .40 OCCURRENCES

  3         .04   *******
  7         .07   *****************
 11         .10   ***************************
 15         .13   *************************************
 11         .16   ***************************
  5         .19   ************
  6    N    .22   ***************
  3         .25   *******
  2   (%N)  .28   *****
  5         .31   ************
  2         .34   *****
  7         .37   *****************
  3         .40   *******
  0         .43
  2         .46   *****
  3         .49   *******
  0         .52
  2         .55   *****
  0         .58
  2         .61   *****
  1         .64   **
                  I....+....I....+....I....+....I....+....I....+....I
                  0         4         8         12        16        20
                           HISTOGRAM FREQUENCY
```

Fig. 6.2 The general distribution of N (%) in

Fig. 6.3 The general distribution of P in the 90 samples

```
COUNT   MIDPOINT    ONE SYMBOL EQUALS APPROXIMATELY   1.00 OCCURRENCE

  0         -3
 44          6   ********************************************
 25         15   *************************
 14         24   **************
  2         33   **
  1         42   *
  0         51
  1    P    60   *
  0         69
  1  (PPM)  78   *
  0         87
  0         96
  0        105
  0        114
  0        123
  0        132
  0        141
  1        150   *
  0        159
  1        168   *
  0        177
                 I....+....I....+....I....+....I....+....I....+....I
                 0         10        20        30        40        50
                          HISTOGRAM FREQUENCY
```

```
COUNT   MIDPOINT    ONE SYMBOL EQUALS APPROXIMATELY   .40 OCCURRENCES

  0        4.1
  0        4.3
  1        4.5   **
  2        4.7   *****
  3        4.9   *******
  3        5.1   *******
  6        5.3   ***************
  7        5.5   *****************
  6  pH    5.7   ***************
 12        5.9   ******************************
  8        6.1   ********************
 15        6.3   *************************************
 15        6.5   *************************************
  3        6.7   *******
  2        6.9   *****
  1        7.1   **
  4        7.3   **********
  1        7.5   **
  1        7.7   **
  0        7.9
  0        8.1
                 I....+....I....+....I....+....I....+....I....+....I
                 0         4         8         12        16        20
                          HISTOGRAM FREQUENCY
```

Fig. 6.4 The general distribution of pH in

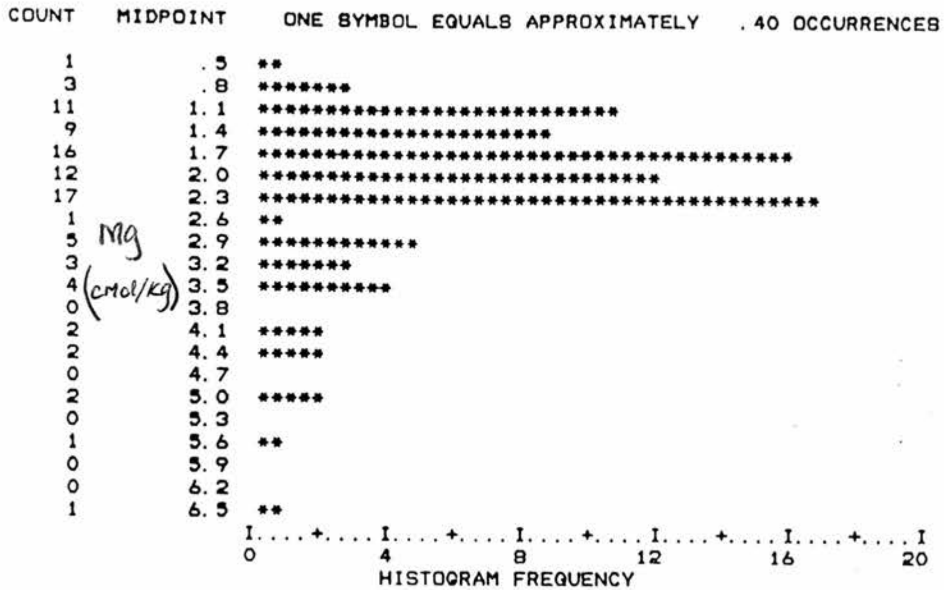


Fig. 6.5 The general distribution of Mg in the 90 samples

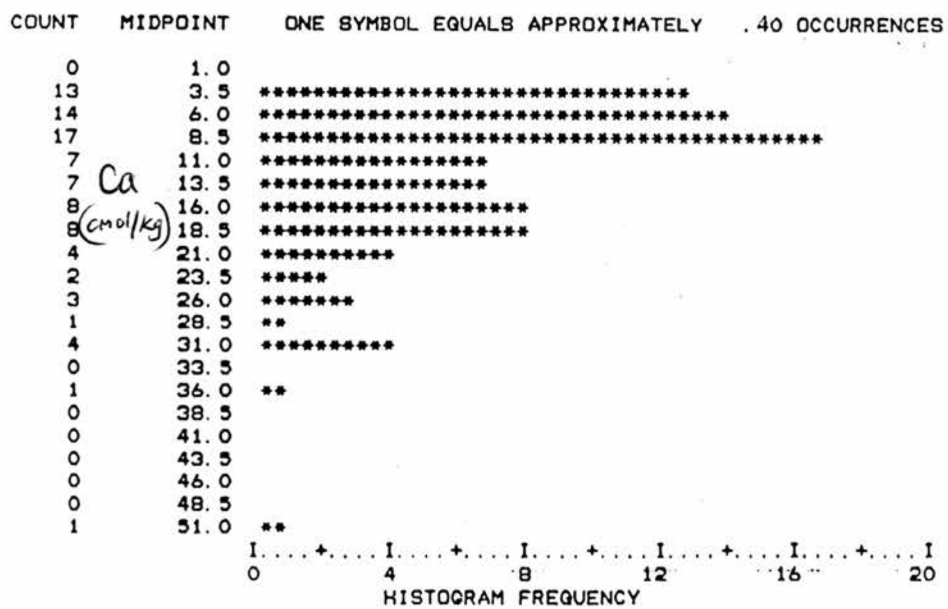


Fig. 6.6 The general distribution of Ca in the 90 samples

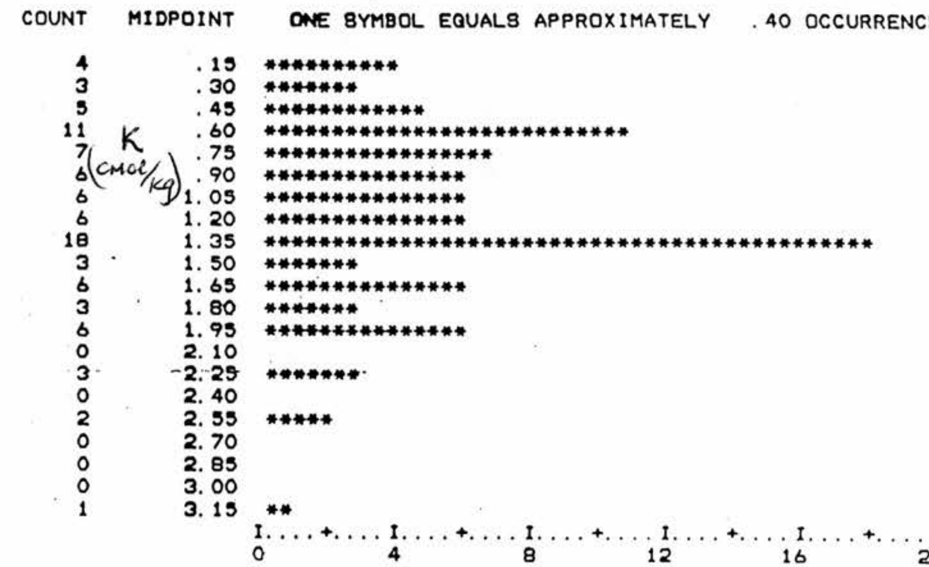


Fig. 6.7 The general distribution of K in the 90 samples

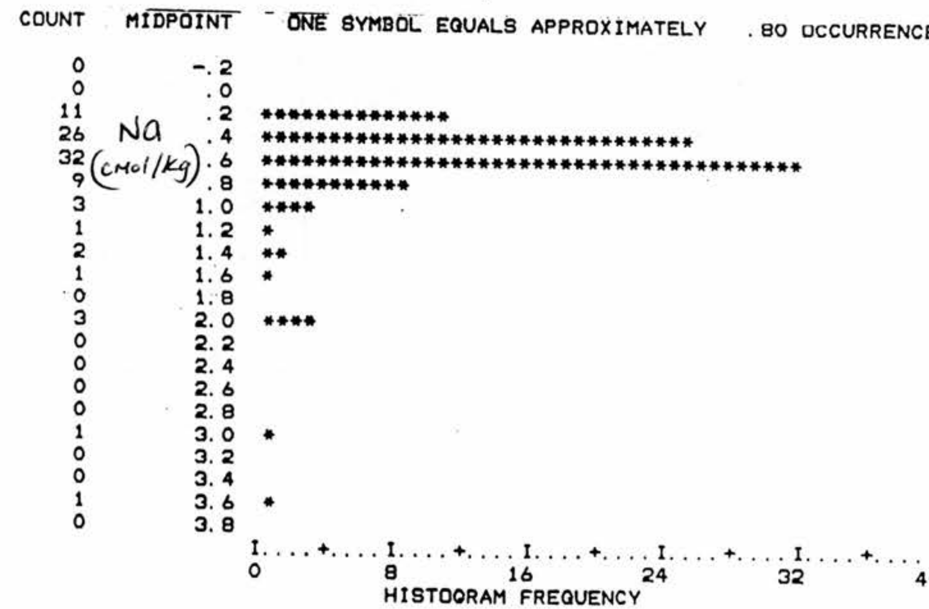
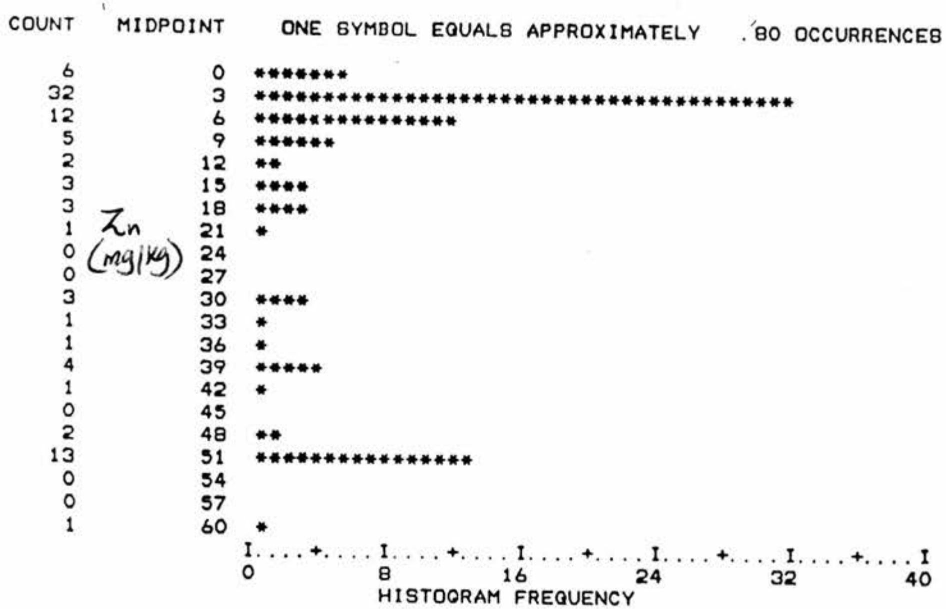


Fig. 6.8 The general distribution of Na in the 90 samples

Fig. 6.9 The general distribution of Zn in the 90 samples



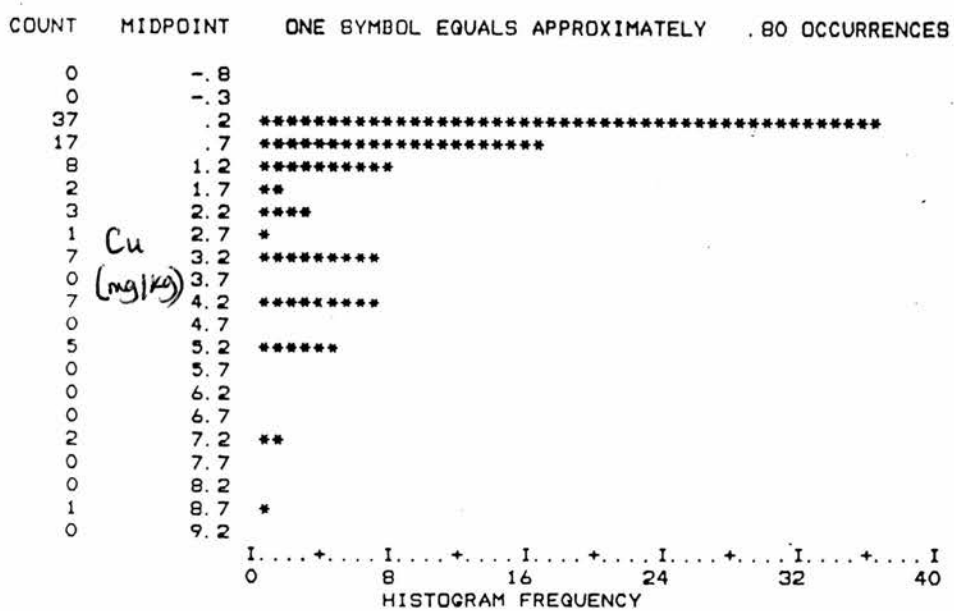
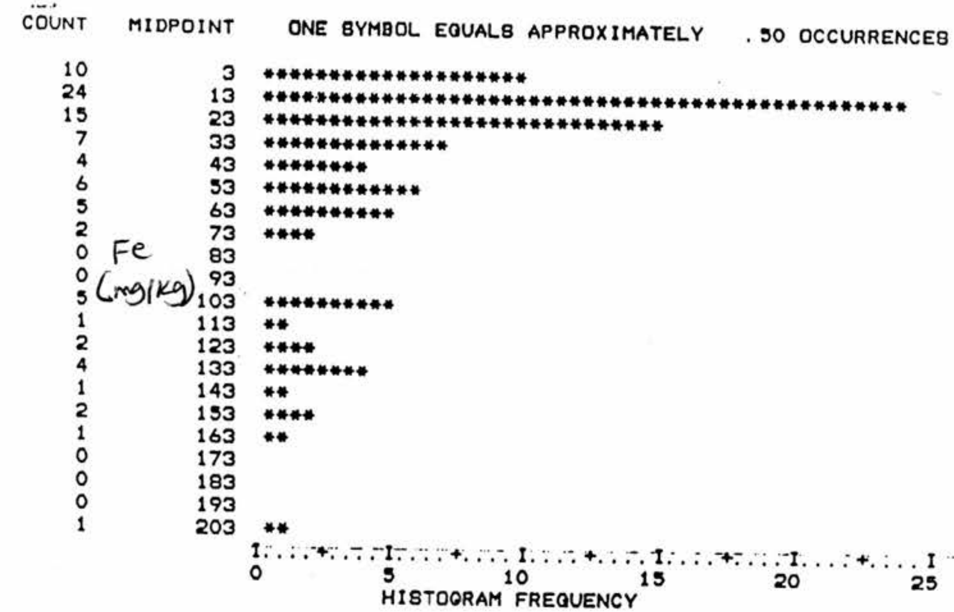


Fig. 6.10 The general distribution of Cu in the 90 samples

Fig. 6.11 The general distribution of Fe in the 90 sample



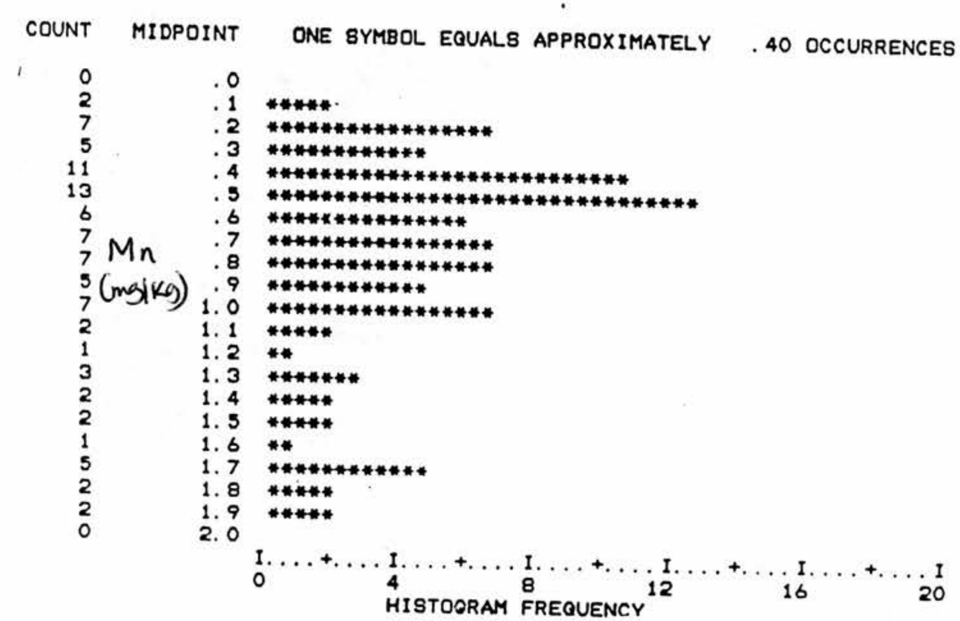


Fig. 6.12 The general distribution of Mn in the 90 samples

	Na^{+}	Ca^{2+}	k^{+}	Mg^{2+}	Mn^{2+}	P	N	C	Fe^{3+}	Cu^{2+}	Zn^{2+}	veg
pH												
(1)	0.46	0.60	0.32	0.22	-.36	0.53	0.23	-.07	-.26	0.03	-.01	
(2)	0.45	0.57	0.51	0.28	-.20	0.40	0.18	-.11	-.45	0.21	-.23	-.11
Na^{+}												
(1)		0.83	0.28	-.11	-.26	0.38	-.10	-.23	-.21	-.06	0.09	
(2)		0.76	0.21	0.04	-.23	0.40	0.02	-.01	-.12	-.30	0.32	0.14
Ca^{2+}												
(1)			0.40	0.03	-.23	0.49	0.12	-.12	-.27	0.06	0.12	
(2)			0.29	0.11	-.31	0.53	0.23	-.02	-.14	-.12	0.31	0.01
K^{+}												
(1)				0.31	-.06	0.35	0.47	0.36	-.35	-.01	0.16	
(2)				0.30	-.11	0.31	0.43	0.37	-.27	-.14	0.06	0.12
Mg^{2+}												
(1)					-.10	0.08	0.30	0.21	-.22	0.22	-.01	
(2)					0.14	0.20	0.43	0.25	-.33	0.23	-.04	-.03
Mn^{3+}												
(1)						-.45	-.20	0.04	0.17	0.32	-.28	
(2)						-.57	-.30	-.01	0.24	0.41	-.26	-.37
P												
(1)							0.42	0.30	-.13	-.39	0.55	
(2)							0.49	0.30	-.05	-.44	0.42	0.40
N												
(1)								0.71	-.23	-.17	0.43	
(2)								0.75	-.34	-.42	0.33	0.52
C												
(1)									-.07	-.39	0.60	
(2)									-.24	-.51	0.47	0.65
Fe^{3+}												
(1)										-.19	-.04	
(2)										-.03	-.15	-.08
Cu												
(1)											-.56	
(2)											-.59	-.83
Zn												0.41

Table 6.3: Non-parametric Spearman correlation based on the average amount of the variables in each profile (1) and the upper horizon (0-10cm)(2), and vegetation vectors (Veg) on axis 1 of the ordination space (see Chapter 7).

For all samples, pH changes little with depth. When the mean values (see Table 6.2b) are considered, pH has no consistent pattern. However, it is more widely distributed in all disturbed than in undisturbed samples. Therefore, it is not effective in distinguishing between disturbed and undisturbed site categories. However, for undisturbed forest sites, pH

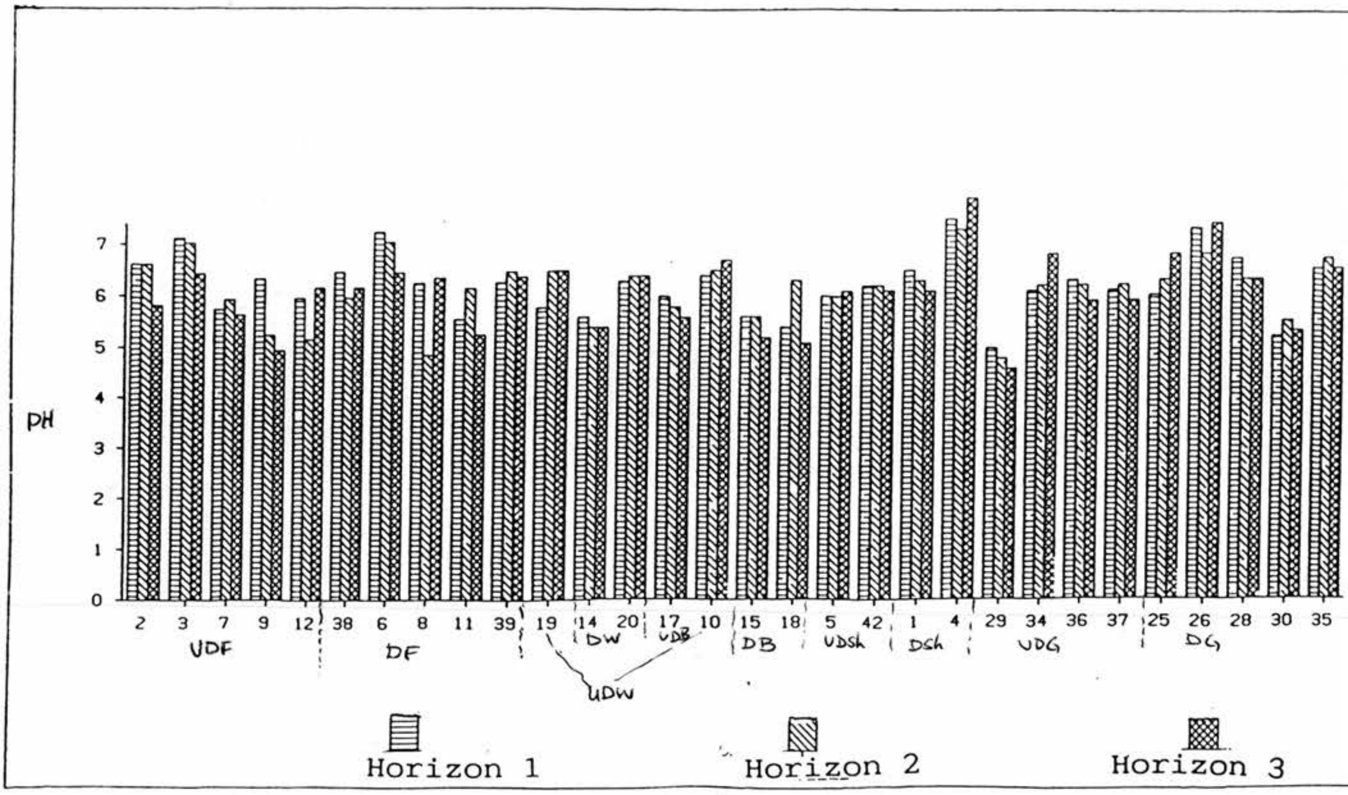


Fig. 6.13 The amount of pH in each horizon plotted on on the basis of sites

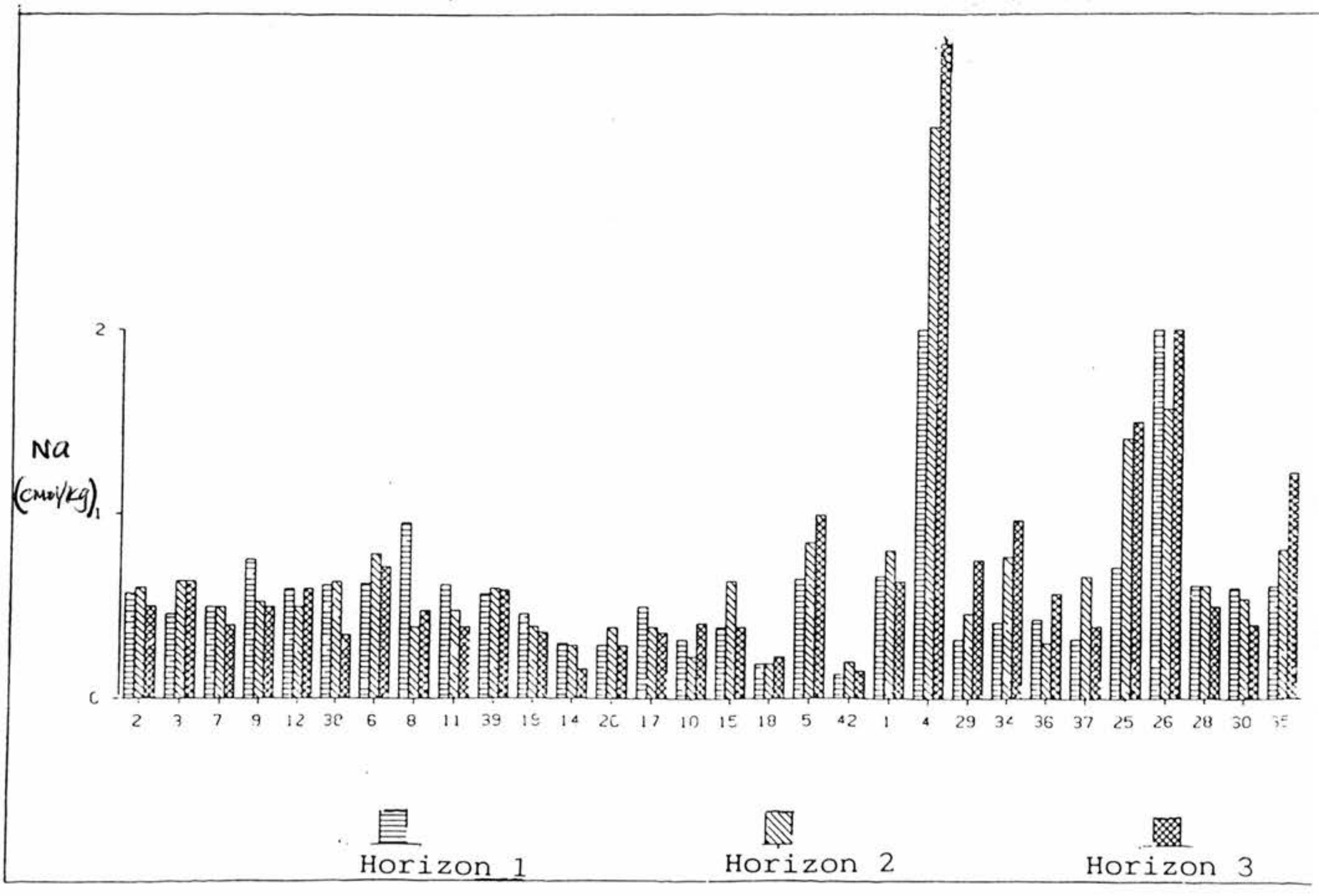


Fig. 6.14 The amount of Na in each horizon plotted on on the basis of sites

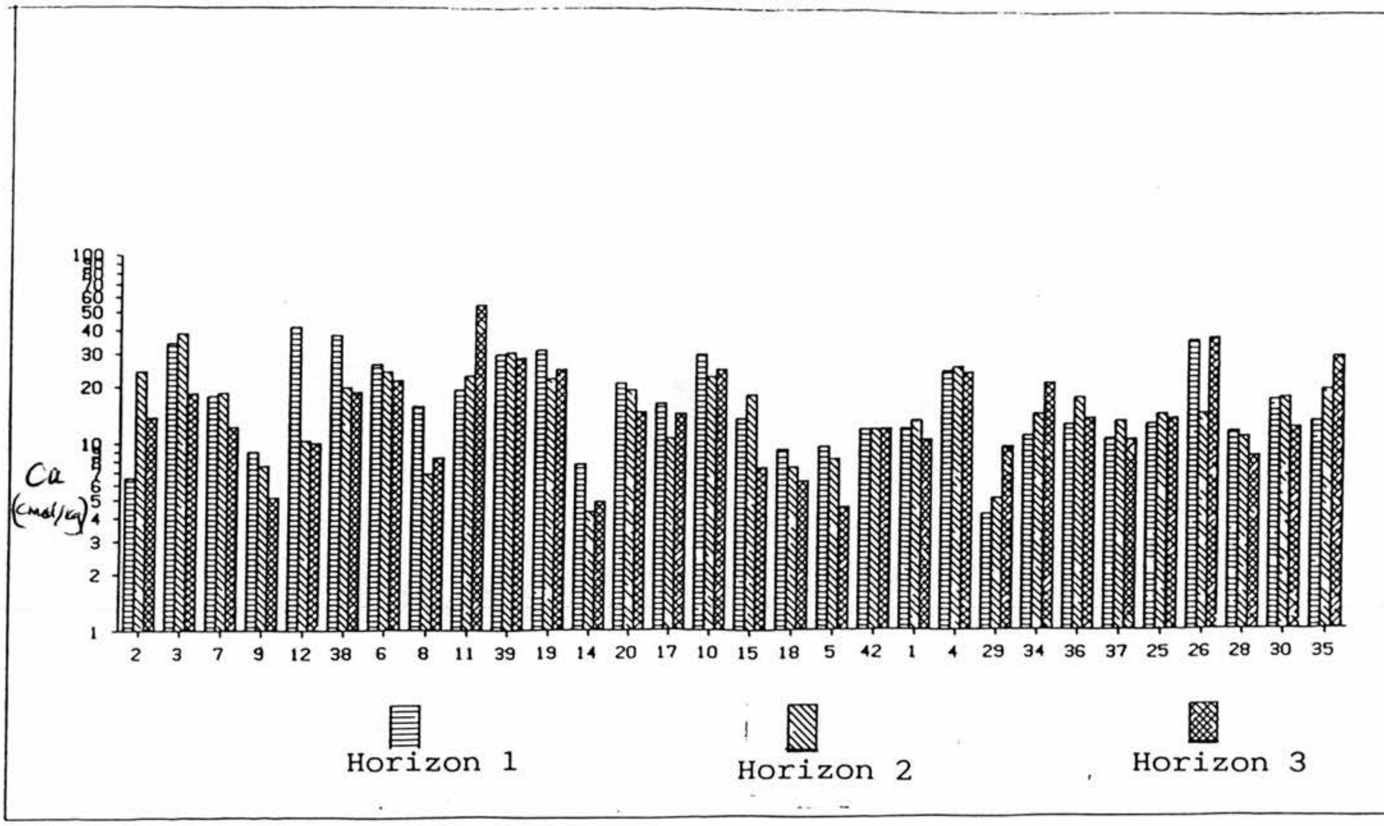


Fig. 6.15 The amount of Ca in each horizon plotted on on the basis of sites

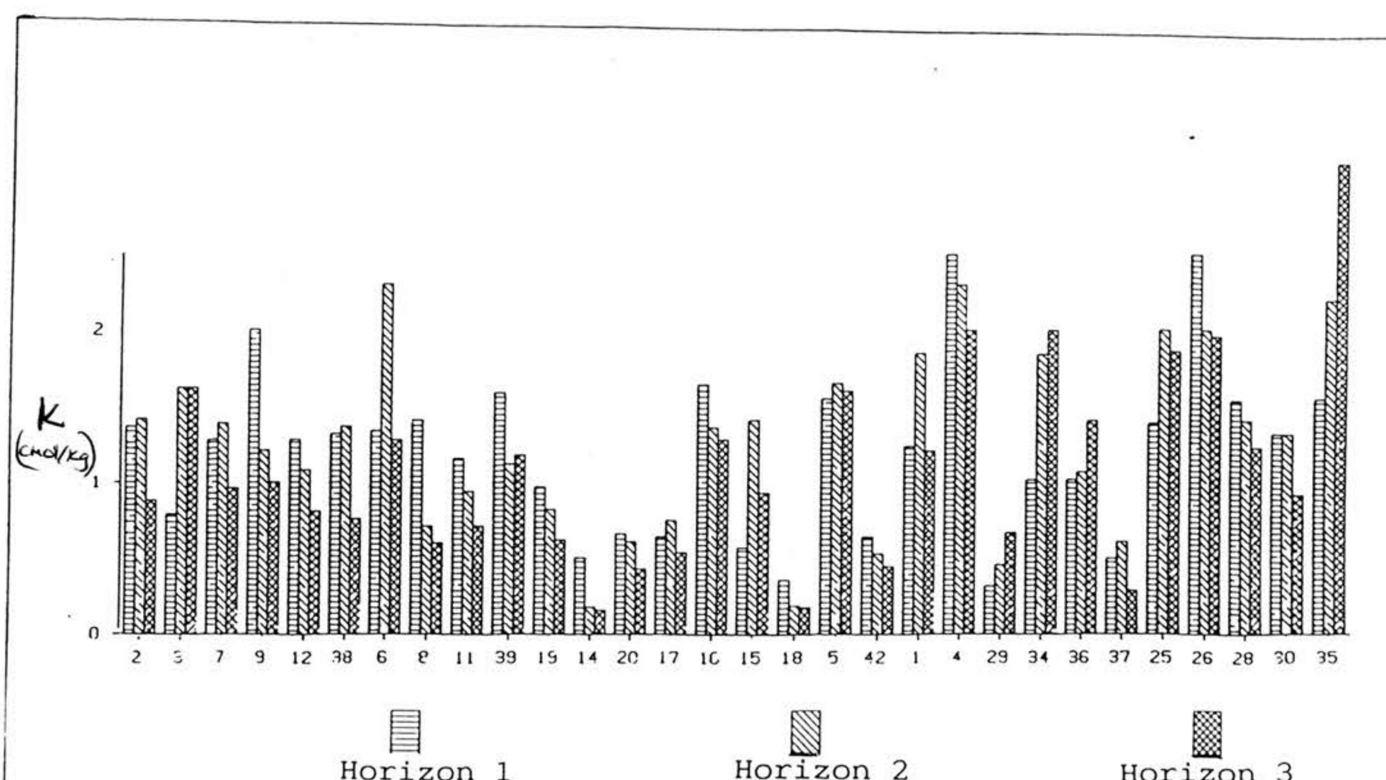


Fig. 6.16 The amount of K in each horizon plotted on on the basis of sites

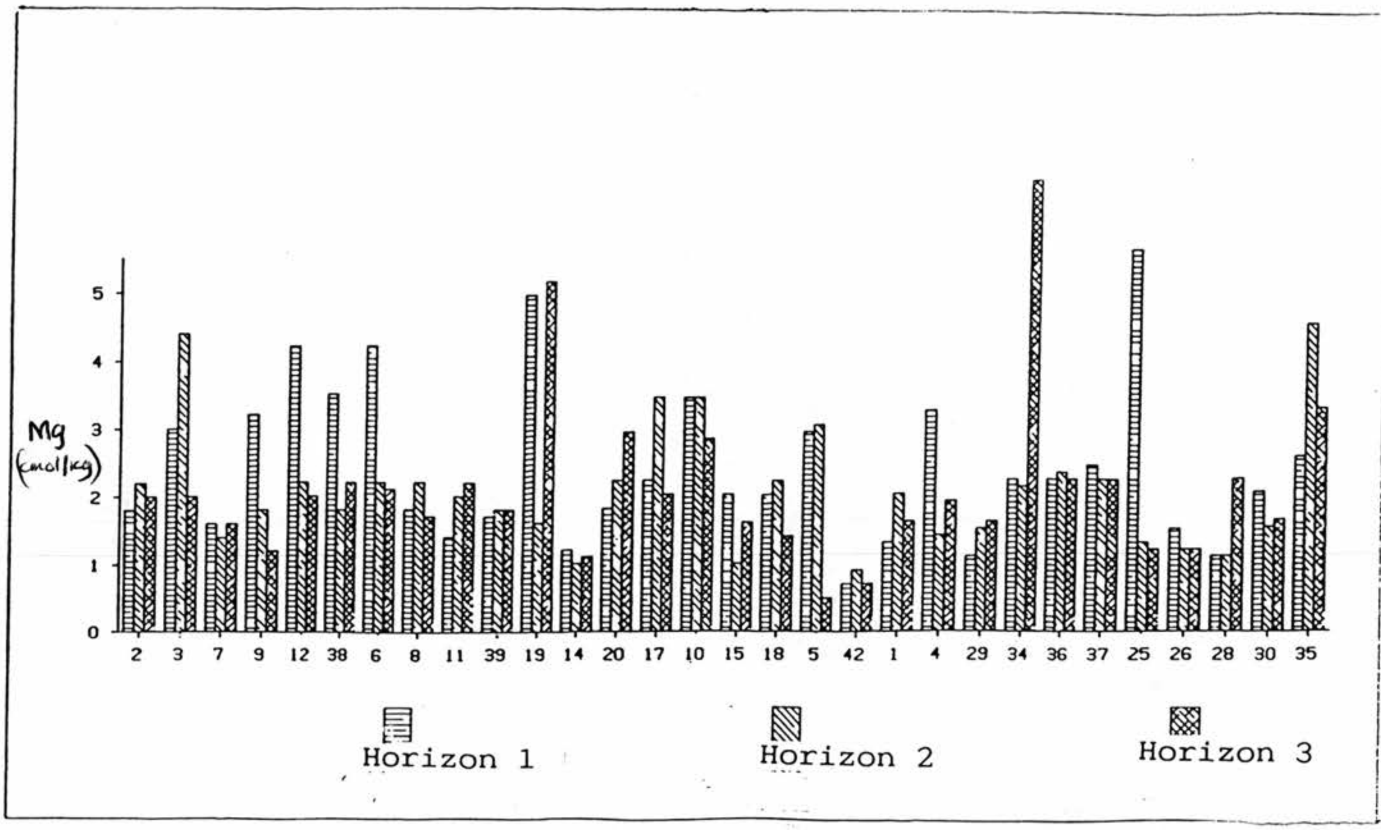


Fig. 6.17 The amount of Mg in each horizon plotted on on the basis of sites

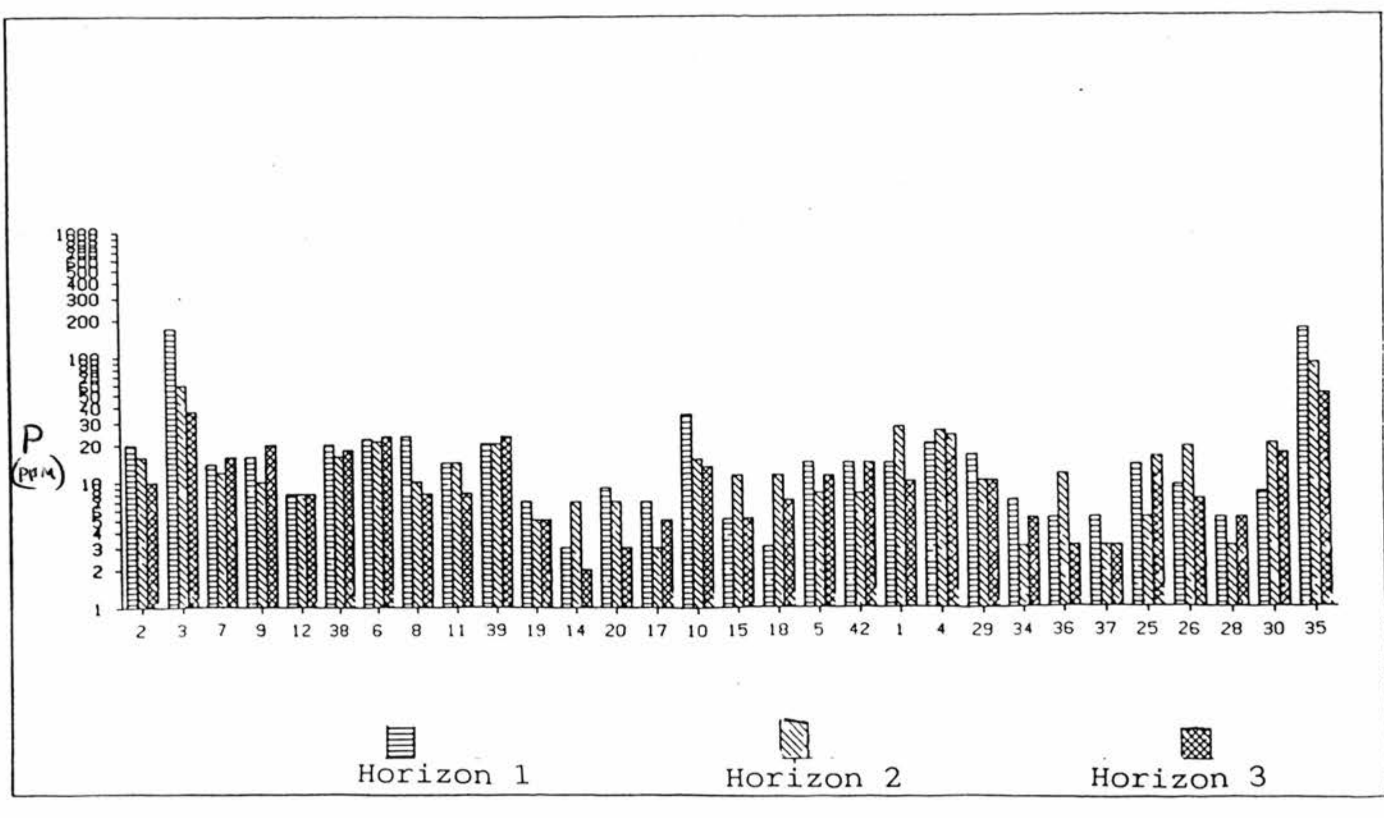


Fig. 6.18 The amount of P in each horizon plotted on on the basis of sites

persistently, decreases with depth.

6.2.1.2 Organic Carbon

When all samples are considered, organic carbon displays a positive skewed distribution (Fig. 6.1), and it is highly variable (Table 6.2a). Appendix B and Figure 6.20, show that organic carbon predicably varies with depth and is markedly concentrated towards the top. In most sites the amount of organic carbon is less than 3%.

Throughout the woody community sites organic carbon is moderate (1.86) to very low (0.08) at Ndulele and Eorekule sites 1 and 4, respectively. For grassland community sites, for all disturbed sites, it is generally very low (between 0.38 for site 26 and 1.62 for site 30). Generally, the sites (e.g., 6, 30, 38 and 39) with highest amounts of soil carbon are from humid areas. They include abandoned farms, and the upland grassland sites on the Mau. Sites with lowest values are from the drier part of the District, cropped/disturbed sites and from soils with high pH. With the exception of grasslands, mean organic carbon in the first horizon (Table 6.2b) is higher for undisturbed than disturbed samples.

6.2.1.3 Nitrogen

From Figure 6.2, nitrogen has a positive skewed distribution. Table 6.2a shows that it is consistent over the 30 sites. Appendix B and Figure 6.19 show that nitrogen is generally low for most sites, ranging from 0.04 (at Olalui, site 15) to 0.65 (at Meleli, site 38). Like carbon, it decreases rapidly with

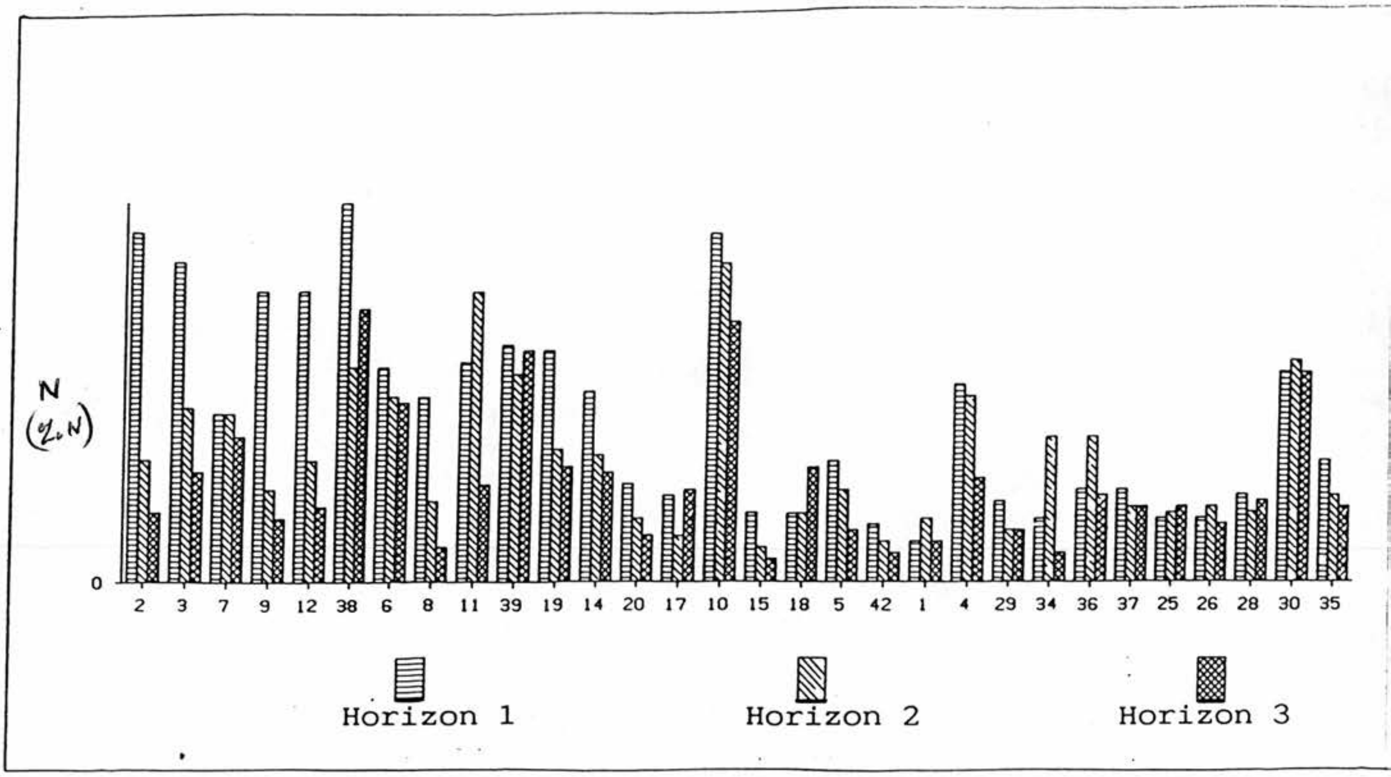


Fig. 6.19 The amount of **N** in each horizon plotted on on the basis of sites

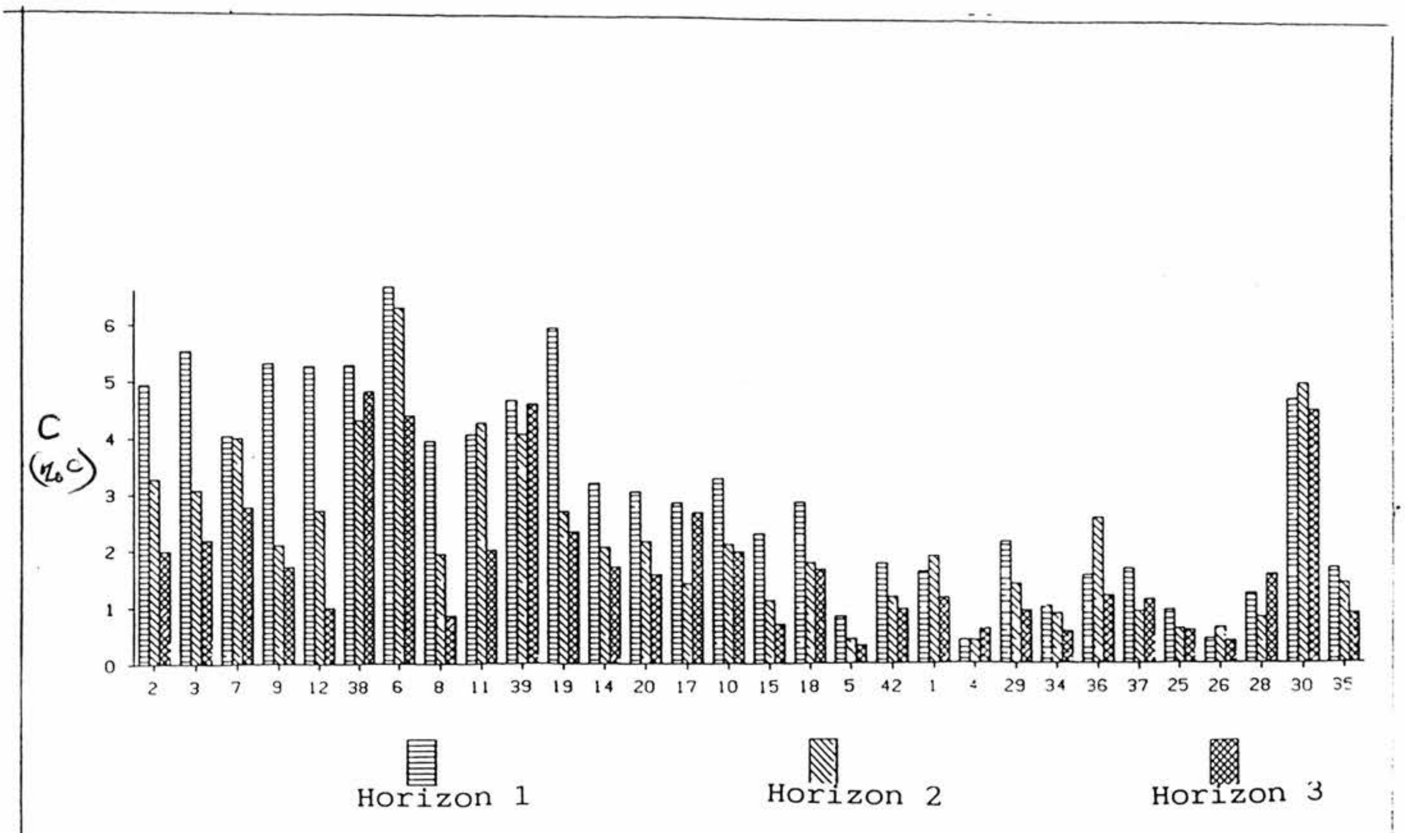


Fig. 6.20 The amount of C in each horizon plotted on on the basis of sites

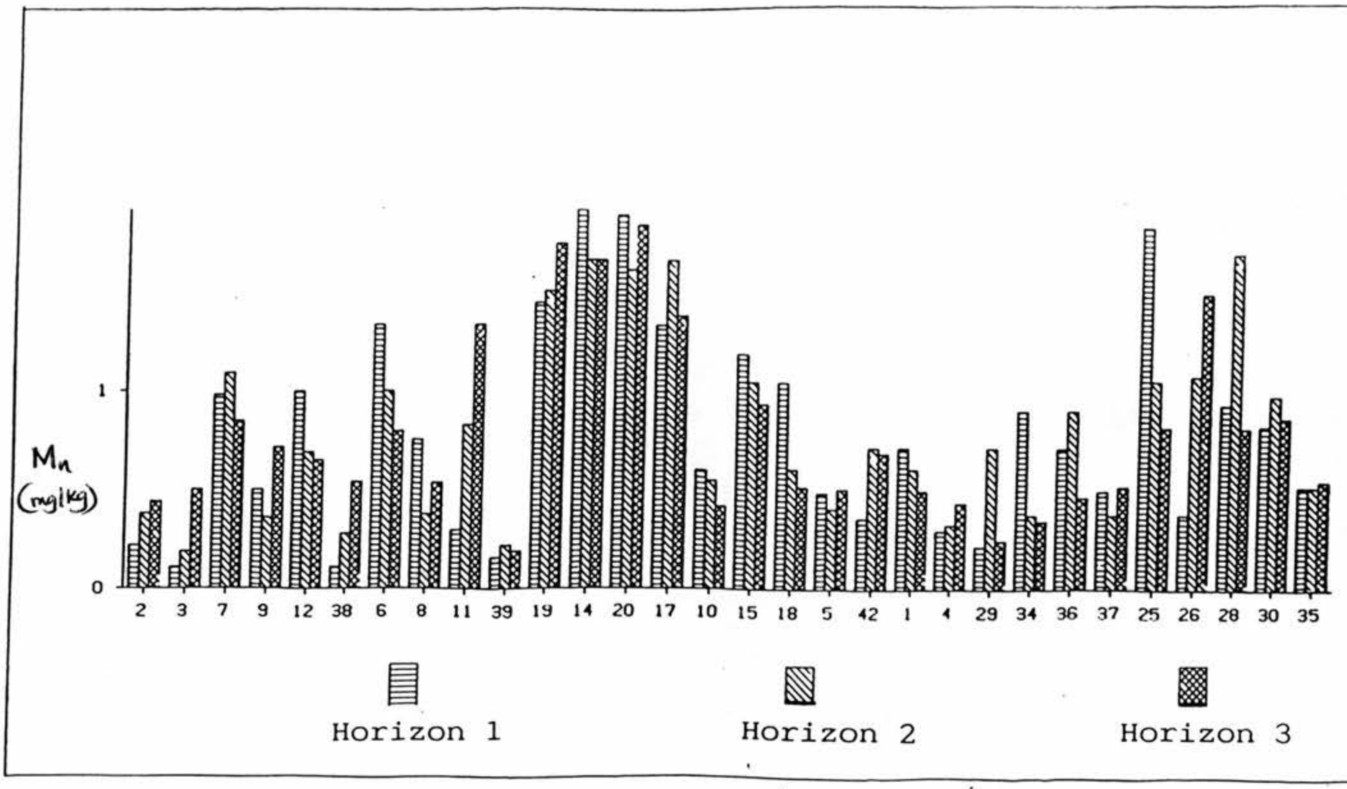


Fig. 6.21 The amount of Mn in each horizon plotted on on the basis of sites

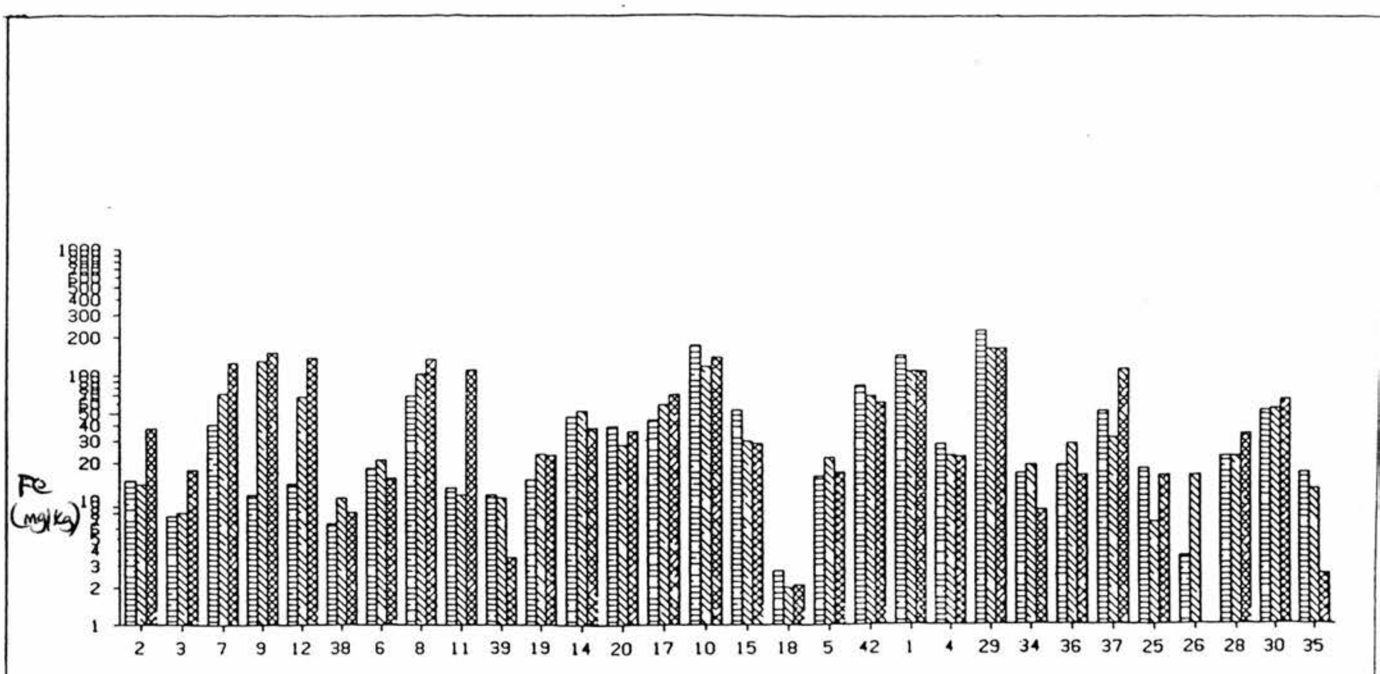


Fig. 6.22 The amount of Fe in each horizon plotted on on the basis of sites

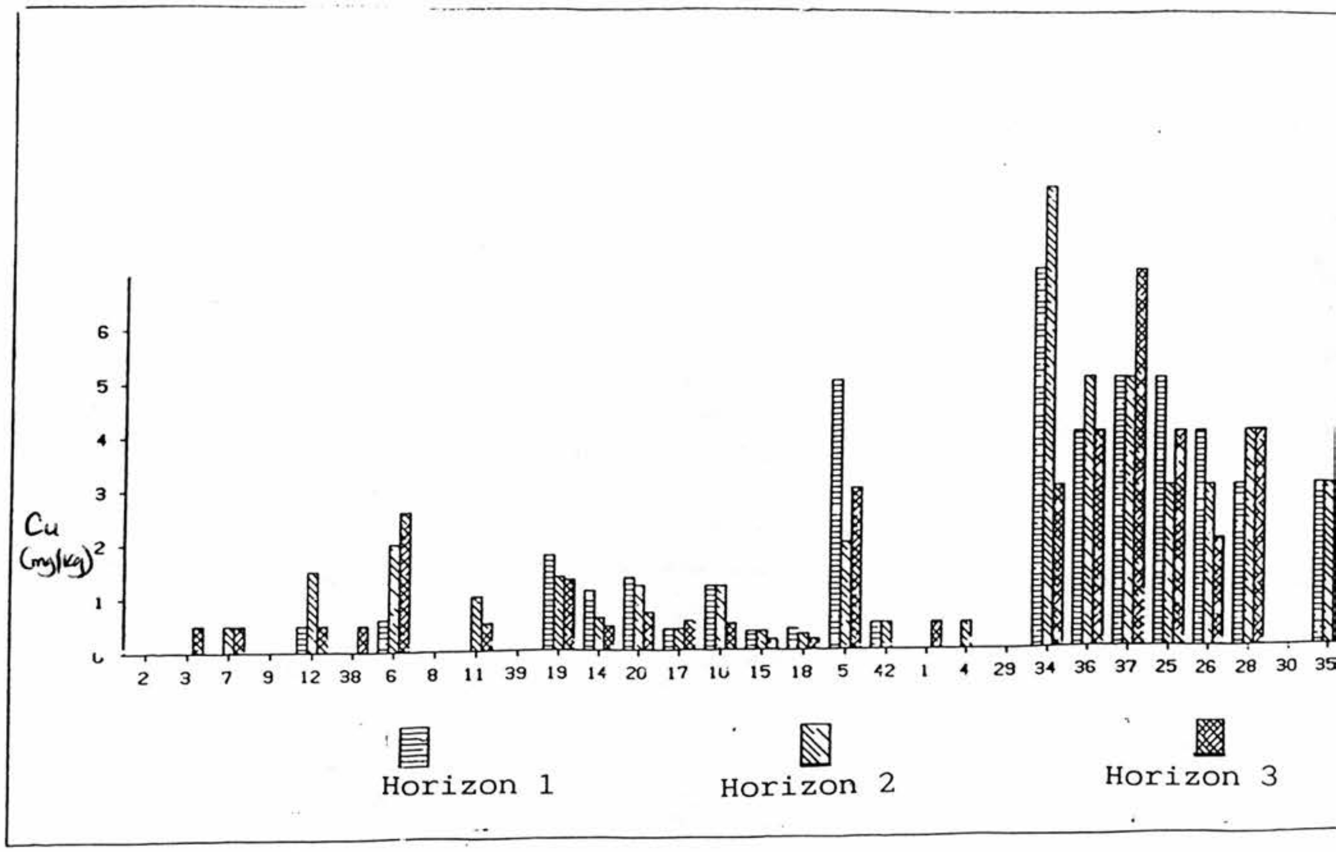


Fig. 6.23 The amount of Cu in each horizon plotted on on the basis of sites

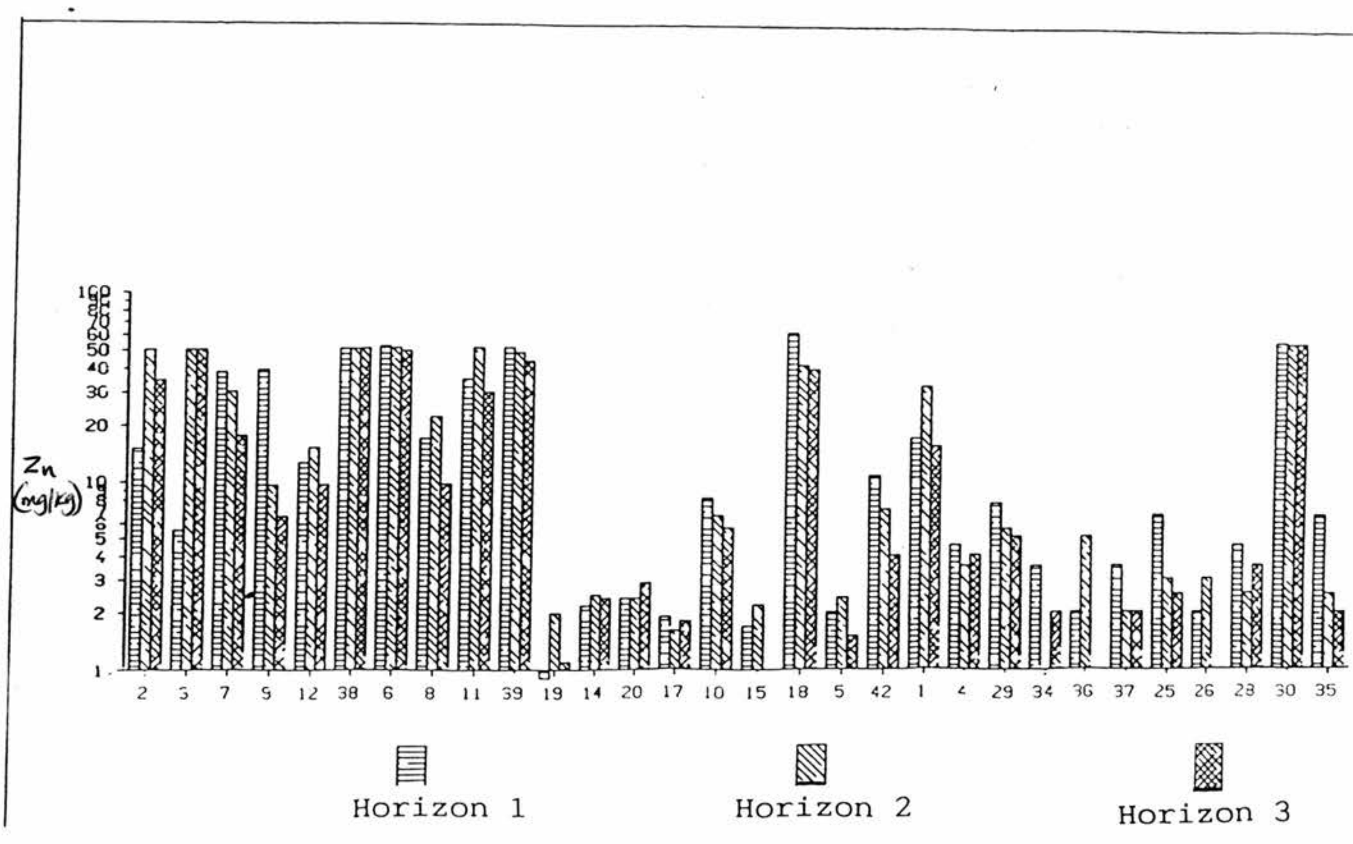


Fig. 6.24 The amount of Zn in each horizon plotted on on the basis of sites

depth. The carbon values in these two sites are among the lowest and highest, respectively. These two elements are strongly correlated (Table 6.3). The lowest values of nitrogen are from the grassland, disturbed bushland sites of Trans-Mara, and the shrubland sites east of Narok town. The amount of nitrogen in the top horizons of, mainly, undisturbed forest community sites is generally high (Fig. 6.19). For these sites, like carbon, nitrogen is very inconsistent. Table 6.2b shows low nitrogen levels for all disturbed samples, except for the shrubland and grassland samples.

6.2.1.4 C:N Ratios

A range of 20.7 of C:N ratios is obtained when all samples are considered. Variations in these ratios, tend to correspond, inversely, with changes in the amount of nitrogen (see Appendix B, Figs. 6.19 and 6.25). For most sites, they decrease with depth. Table 6.2b shows that except for grassland sites, the C:N ratios are higher in disturbed than undisturbed sites. These ratios are generally higher in wetter than drier sites.

6.2.1.5 Phosphorus

Generally P has a positive skewed distribution (Fig. 6.3) and it is highly variable (Table 6.2a). All soil samples except those from sites 3, 4, 6, 35 and 39 have inadequate supplies of phosphorus (see Appendix B, deficiencies underlined). From Figure 6.18, P has no consistent pattern between disturbed and undisturbed sites. However, except for shrubland and grassland sites, P is higher in all undisturbed than disturbed sites

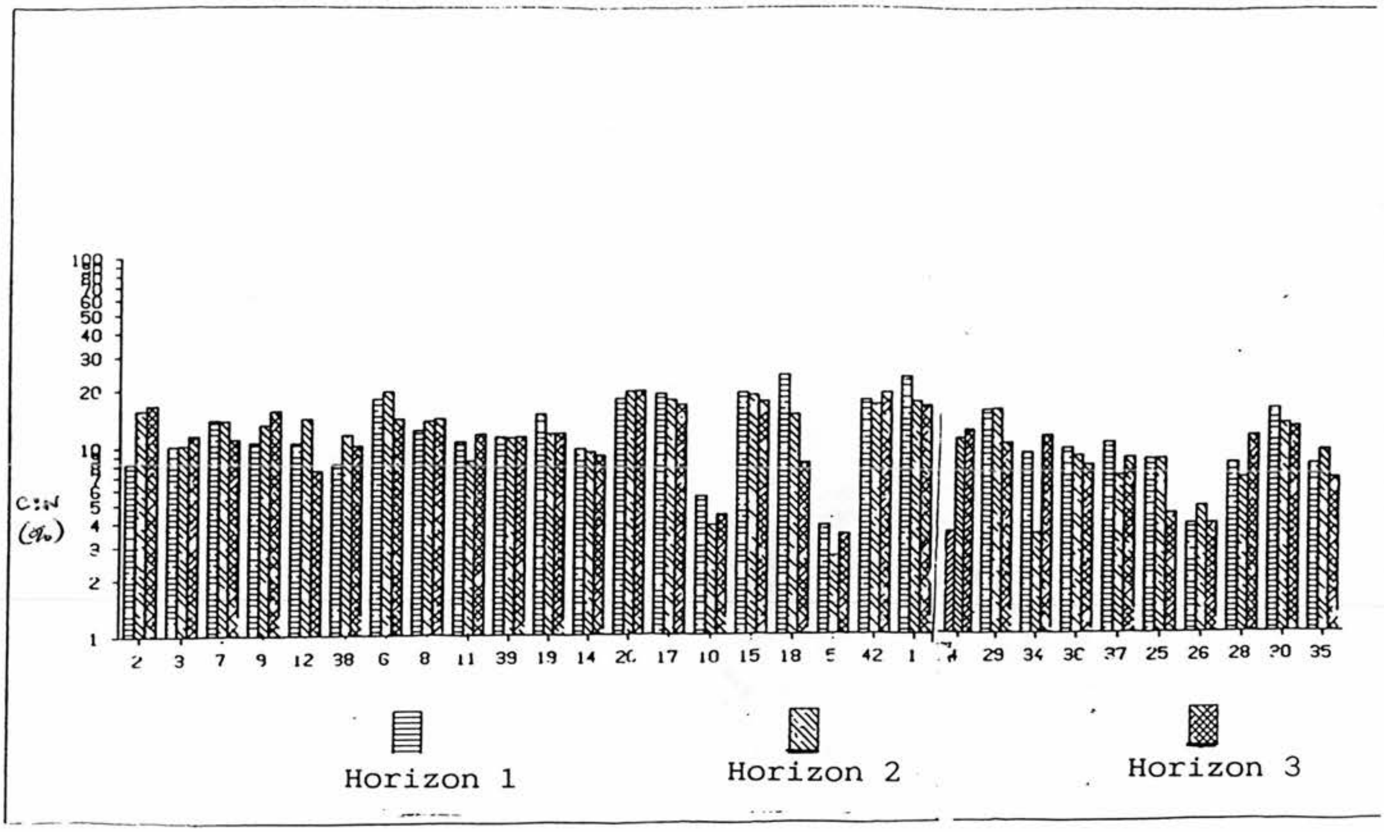


Fig. 6.25 The amount of C:N ratio in each horizon plotted on on the basis of sites

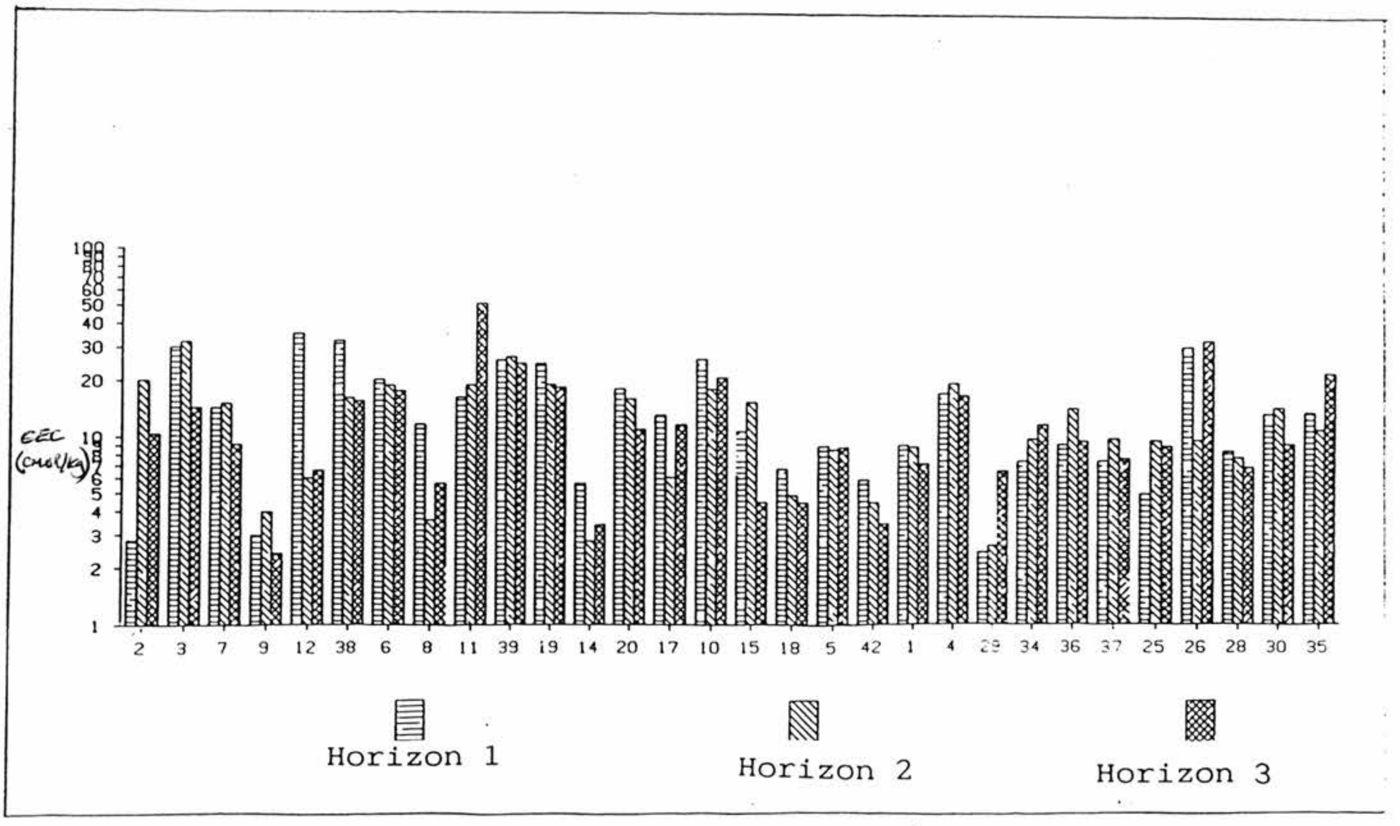


Fig. 6.26 The amount of CEC in each horizon plotted on on the basis of sites

(Table 6.2b).

6.2.1.6 Exchangeable Cations

Mg^{2+} is generally positively skewed (Fig.6.4) and has a low level of variations (Table 6.2a). For most sites it shows a weak pattern characterised by a decrease with depth for humid sites and an increase with depth for drier sites (Appendix B , Fig. 6.17). From Table 6.2b, except for grassland and shrubland sites, Mg^{2+} is higher in undisturbed than disturbed sites. However, undisturbed shrubland (Eorekule, site 5) registers abnormally low values of Mg^{2+}.

Na^{+} has a positive skewed distribution (Fig. 6.7) and a small variation (Table 6.2a). It is generally higher for drier sites from the plains. Disturbed shrubland site 4 and grassland sites 25 and 26 register toxic levels of Na^{+} (see Appendix B and Fig. 6.14). In most sites, both K^{+} and Ca^{2+} decrease with depth (Figs. 6.14 and 6.15). The distribution of Ca^{2+} is similar to that of Mg^{2+} (Figs. 6.5 and 6.16). Generally, Mg^{2+} and Ca^{2+} are the dominant exchangeable bases. In all communities, except for shrubland and grassland sites, the base elements are higher in undisturbed than disturbed sites (Table 6.2b).

6.2.1.7 Cation Exchange Capacity (CEC)

For most sites, CEC has a similar pattern to that of pH, that is, it is high when pH values are high and *vice versa* (see Figs. 6.13 and 6.26). This is expected since most cations, have a strong correlation with pH (Table 6.3). In particular, CEC shows a strong pattern for forest sites by changing appreciably with depth in undisturbed forest sites. The highest and lowest CEC values are for sites 11 (53) and 30 (4.14), which have relatively highest and lowest pH, respectively. In the first horizon (see Table 6.2b), except for woodland sites, the average CEC is higher in disturbed than in undisturbed sites.

6.2.1.8 Trace Elements

Like base cations, these elements are somewhat positively skewed (Figs. 6.8 to 6.11). Generally, Mn^{2+} is highly variable (Table 6.2a). It has a remarkable distribution, being highest in woodland and bushland sites of Trans-mara and disturbed grassland sites (Fig. 6.21). Table 6.2b shows that this element is inconsistent between disturbed and undisturbed sites. Mn^{2+} is weakly correlated with pH, but strongly correlated with P (Table 6.3).

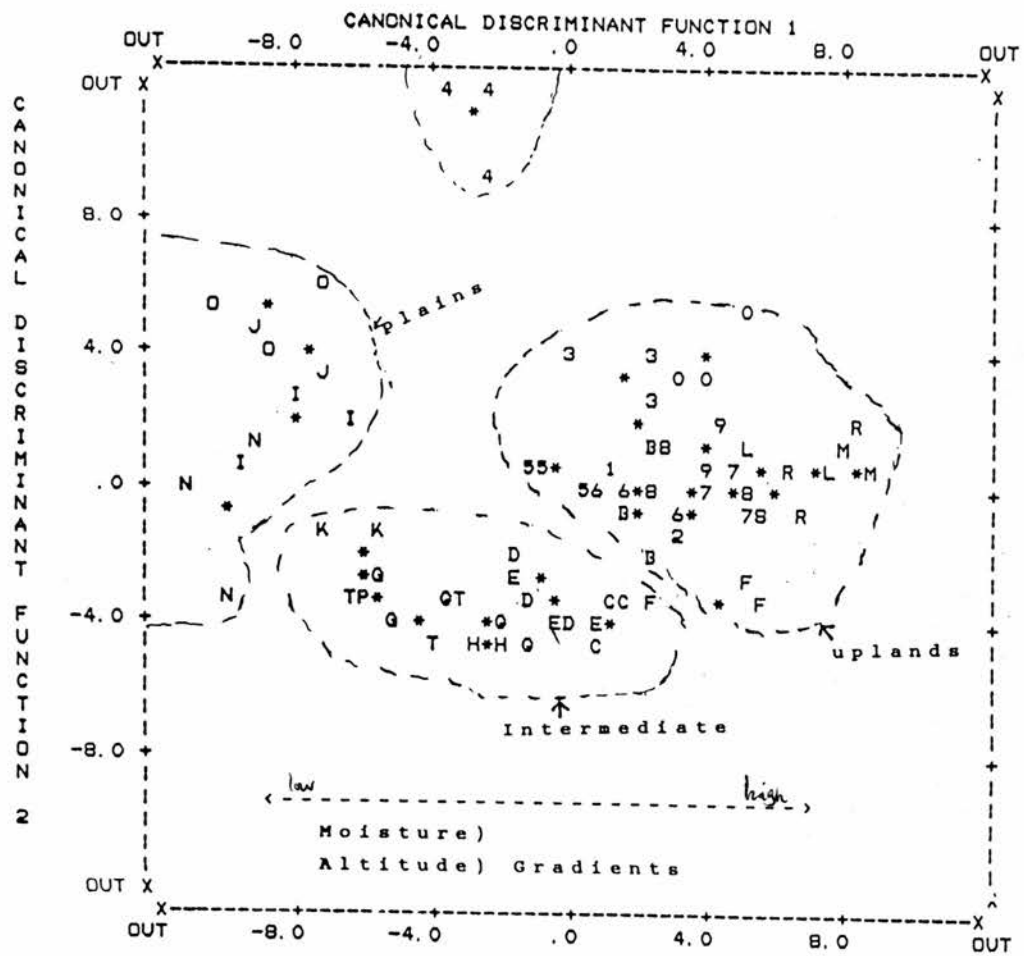
Cu^{2+} is highly variable (Table 6.2a) and it has no consistent pattern between and within disturbed and undisturbed site categories (Appendix B, Fig. 6.25). However, except for grassland sites, it is consistently low and/or deficient in most woody sites. In the first horizon disturbed sites have lower mean amount of Cu^{2+} than undisturbed ones (Table 6.2b). From Table 6.2a and Figure 6.10, Fe^{3+} is highly variable and positively skewed, respectively. Within the profiles, Fe^{+3} is also highly variable in most, but particularly in undisturbed forest sites (Appendix B, Fig. 6.22). Generally, it increases with depth.

Unlike Mn^{2+}, Zn^{2+} is lowest in soils from Trans-mara and highest in most disturbed forest sites (Fig. 6.24). Although it has the most diffuse pattern (Fig. 6.8), it is highly variable (Table 6.2a). Also, it varies closely with nitrogen and carbon. Both Cu^{2+} and Zn^{2+} have a strong negative correlation with carbon and nitrogen (Table 6.3). Except for woodland sites, Zn^{2+} is higher in disturbed than in undisturbed sites (Table 6.2b).

In this section, it has become evident that except for grassland and shrubland sites, disturbed sites are distinguishable from undisturbed sites. The means for carbon, nitrogen, P, base cations and copper in the first horizon are higher in undisturbed than disturbed site categories. Conversely, disturbed sites have higher mean zinc than undisturbed ones. The results obtained by other methods have no consistent pattern in nutrient distribution making it difficult to distinguish between disturbed and undisturbed sites. The following section, reports the findings of the pattern of nutrients obtained using multivariate analysis.

6.2.2 Data Analysis Results

Figure 6.27a is a scatterplot of samples ordination based on all variables. As will be seen, there is an overlap for samples from the same profile with only a few scattered away from their centroid. Generally, three major clusters can be seen with sample 4 appearing as an outlier. Ordination along discriminant function 1 (Fig. 6.27a) suggests the great influence of physiography on soil chemistry related to both climate and



SYMBOLS USED IN PLOTS Symbol	Site	vegetation type
1	1.00	DSh
2	2.00	UDF
3	3.00	UDF
4	4.00	DSh
5	5.00	UDSh
6	6.00	DF
7	7.00	UDF
8	8.00	DF
9	9.00	UDF
0	10.00	UDW
A	11.00	DF
B	12.00	UDF
C	14.00	DW
D	15.00	DB
E	17.00	UDB
F	18.00	DB
G	19.00	UDW
H	20.00	DW
I	25.00	DG
J	26.00	DG
K	28.00	DG
L	29.00	UDG
M	30.00	DG
N	34.00	UDG
O	35.00	DG
P	36.00	UDG
Q	37.00	UDG
R	38.00	UDF
S	39.00	DF
T	42.00	UDSh.
*	GROUP CENTROIDS	

Fig. 6.27a Sample ordination using Canonical Discriminant analysis. The samples appear to cluster into three groups, the sites from the plains, intermediate altitude sites and upland sites. Site 4 appears as an outlier.

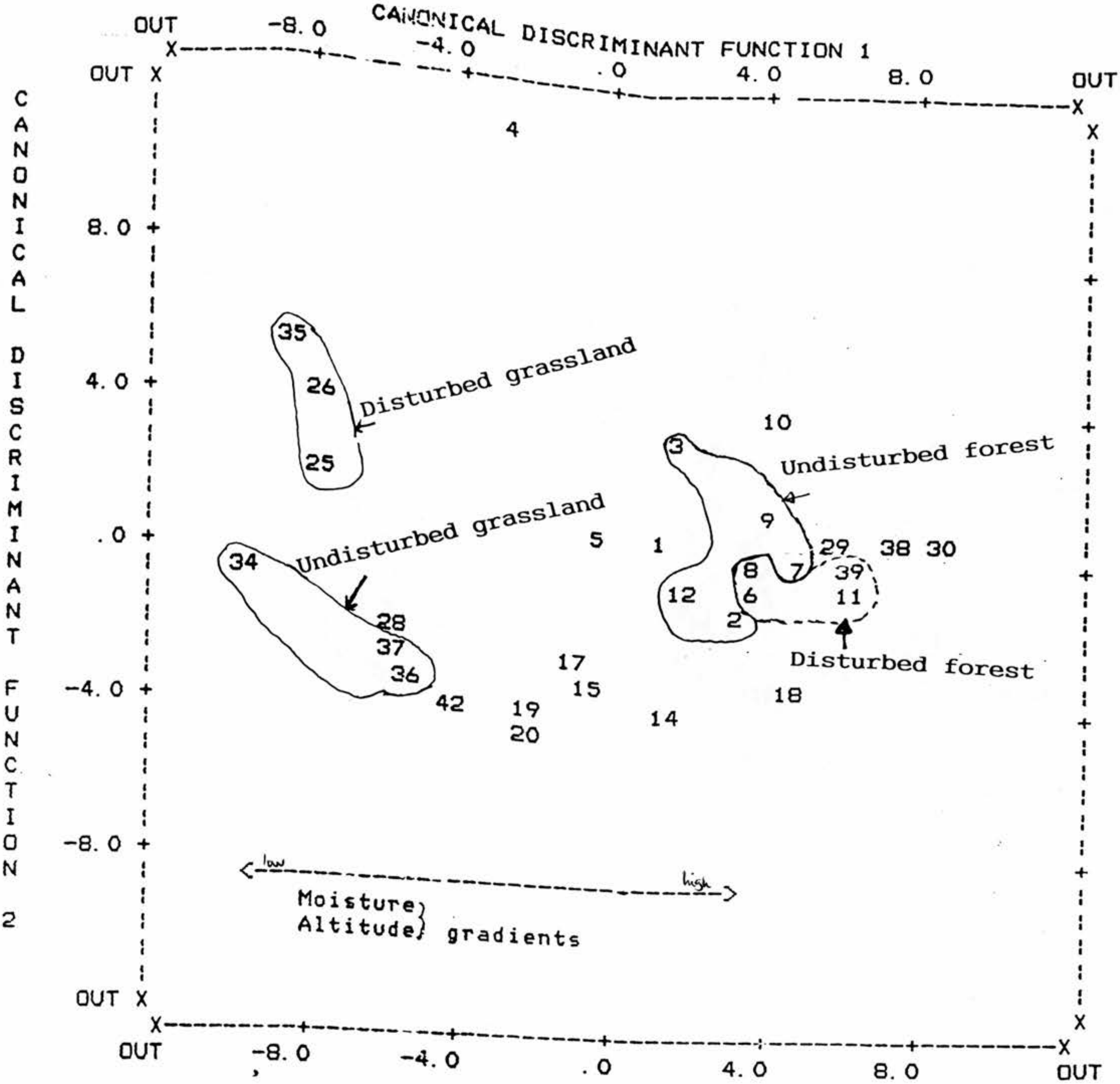


Fig. 6.27b Sample ordinations using Canonical Discriminant analysis. Group means used in the plotting. The sites have a pattern which fits moisture and altitude gradients (Chapter 3). Undisturbed grassland and forest sites are isolated from disturbed ones.

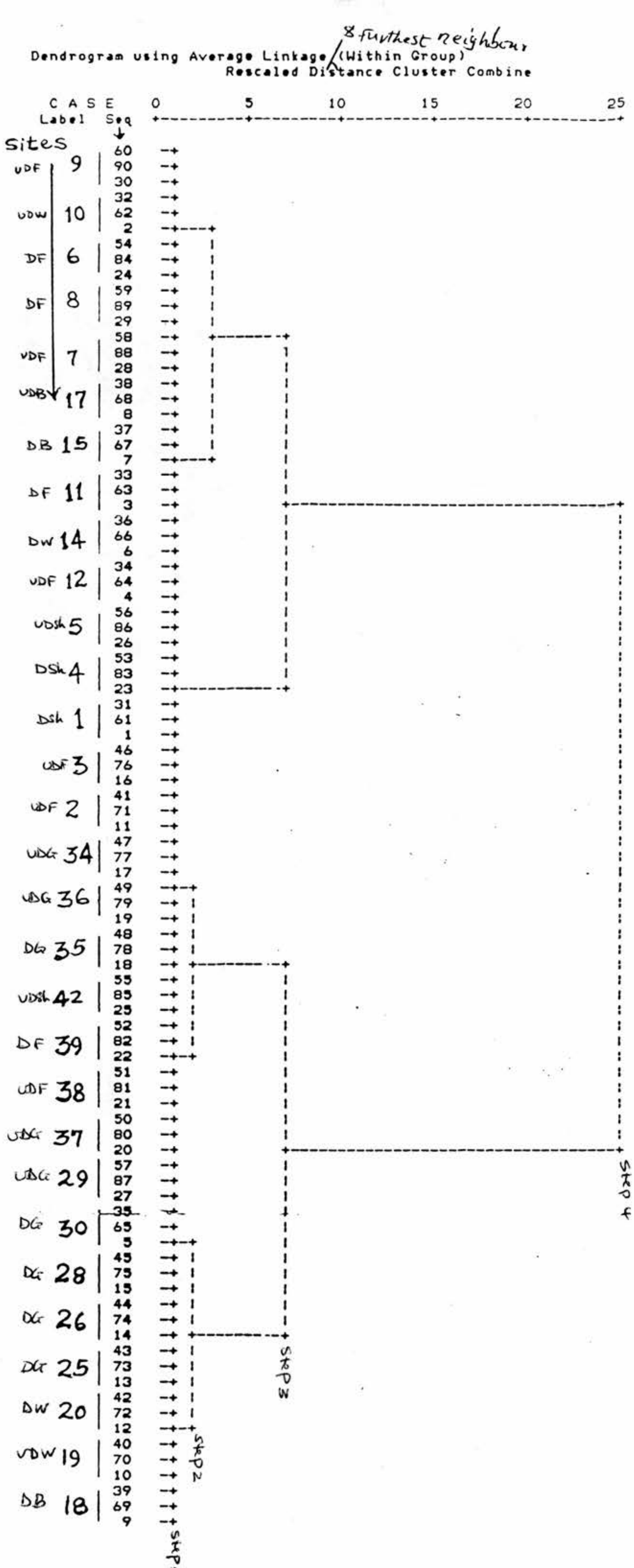


Fig. 6.28 Hcluster analysis dendrogram of 30 soil samples using both average linkage and furthest neighbour algorithms. Samples cluster on the basis of closeness (see Fig. 3.8 for location of samples). Disturbed grassland and forest sites are isolated, though diffusely, from undisturbed ones until step 3.

parent material. The influence of human disturbance becomes clear when Figure 6.27b is examined. Along discriminant function 2, disturbed grassland and forest sites are isolated from undisturbed ones.

Classification plot/graph (Fig. 6.28) of all data, using the first two discriminant functions to define axes, accounts for 92.2% of the total variation among the site categories. Generally, the samples are clustered on the basis of closeness. For instance, in the first step, samples from the same horizon are clustered together. This is followed by clustering of samples in proximity, predominantly, on the basis of physiographic and climatic conditions. The influence of human disturbance appears at step 3. Disturbed and undisturbed grassland sites from the plains do not fuse until at this step.

6.3 DISCUSSION

6.3.1 Introduction

Before examining the causes underlying the observed nutrient patterns, it is important to note the following limitations. Inconsistent data patterns, made it difficult to interpret and generalise the findings. This observation may be attributed to the wide variety of soils in Narok District. In conformity with the geology, topography and climate, the soils range from brown sandy loam soils on the wet mountains and hills to black heavy clays on the plains and seasonal swamps (Appendix C). However, closer examination of the results provide some useful information. However interpretation of this information is limited, generally, because of the lack of sufficient information on the soils of the study area. Also, the discussion on soil fertility is based on chemical data of a limited number of sample sites, nutrients and critical levels. The critical values used in this study (Table 6.1), form the basis for fertilizer recommendations in consideration with factors such as plant analytical data, crop type and climatic conditions (Langat J.K pers. comm.). The comments provided in this chapter are, of necessity, although very general.

6.3.2 Data description

In this section the results of the different variables are discussed in detail. No attempt is made to group the varibles into specific categories since this leads to the loss of soil chemistry differences between disturbed and undisturbed sites which will be useful in interpreting vegetation data (Chapter 7).

6.3.2.1 Soil pH

From Table 6.2b the mean pH between disturbed and undisturbed site categories is not consistent. Therefore, it is not effective in distinguishing the site categories. This observation is supported by the small variation in distribution of pH (Table 6.2a).

When pH is considered on horizon basis (Fig. 6.13, Appendix B) between community site categories, some interesting variations begin to emerge. For instance, in woody communities, it appears inconstent in undisturbed sites. Also, pH is low in undisturbed forest sites. Since these sites are located in wetter areas, the findings are a reflection of substantial leaching of cations down the soil profile due to high rainfall amount (Chapter 3). High rainfall and organic matter, in the uplands, increase acidity (see Brady 1990; Edwards and Grubb 1970; Foth 1988; Jordan 1984). Although the contribution of different acids to the concentration of hydrogen ions in the soil is variable the net effect is a dissociation into nitrates (NO_3^-) and bicarbonates (HCO_3^-), releasing positively charged hydrogen ions into the soil solution resulting in leaching of cations such as sodium, calcium and potassium. From Appendix B and Figures 6.13 to 6.17, it is clear that sites with lowest pH generally have low values of K^+, Ca^{+2}, Na^+ and Mg^{+2}. This observation is further supported by the relatively high correlations between pH and these cautions (Table 6.3).

Unlike most woody sites, pH in grassland sites from the plains increase with depth. This observation is attributed to high levels of Na^+, Ca^{2+} and Mg^{2+} cations and low rainfall which consipire to lower soil acidity.

Although the values of pH obtained in upland, humid, samples are unexpectly high, compared with those obtained from the plains, they are within the range of those reported for other tropical vegetation. For tropical montane forests, values ranging between 5.6-7.0 have been reported (Edwards and Grubb 1982).

6.3.1.2 Organic Carbon

In most sites (see Fig. 6.19, Appendix B), organic carbon decreases with depth, but rapidly in undisturbed sites. This may be attributed to differences in decomposition during and after incorporation of organic matter in the mineral soil. Decomposition changes abruptly in undisturbed sites. Also, this observation suggests that most carbon is utilized at the upper horizon, with little left for removal into lower horizons. This situation is associated with rapid changes in soil aeration and temperature due to the large amount of above ground biomass which reduces the amount of radiation going into the soil. Therefore, decomposition is highest in the surface soil where these conditions are favourable. The significance of decomposition of organic matter in determining soil carbon, has been reported by Foth (1988), Vitousek (1982) and Brady(1990).

The decrease of carbon with depth may further suggest the lack of vertical translocation of organic matter in the soil profile. Since this effect is most remarkable in undisturbed forest sites, it is likely to be associated with the trapping and breakdown of organic residues, including carbon, by tree roots in association with mycorrhizae (Jordan 1985; Brady 1990) in the surface layers. For most disturbed sites the decrease of carbon with depth is less remarkable suggesting that disturbance distributes carbon or carbon sources within the profile.

The small amount of organic carbon in disturbed sites, cropped or overgrazed is predictable since the organic matter produced by the vegetation instead of being returned to the soil, is removed for use by man and his animals so that relatively less finds its way into the soil. For instance, continuous cultivation in the Mau Narok has been associated with small amounts of organic carbon (Mbuvi and Njeru 1977). Also, cultivation and animal activities facilitate organic matter decomposition (Chapter 3), gradually, reducing the amount of carbon in the soil. Accordingly, low carbon content in extremely disturbed sites 4, 25 and 26 (Chapter 5) is ascribed to a more intensive landuse associated with animal activities. The effect of disturbance is further illustrated by the mean carbon (Table 6.2b). This estimate is higher in all undisturbed than disturbed woody sites.

The generally low carbon amount in non-woody sites may be associated with the type of biomass. Firstly, this situation may be related to differences in plant growth form and the way plant residues are incorporated into the soil. In chapter 7, it will be evident that sites from the plains are dominated by herbaceous species. This predominance is associated with human activities and climatic factors. The low amount of rainfall in the plains, supports less vigorous vegetation and, therefore, less organic matter is delivered into the soil. Lower biomass in herbaceous as opposed to woody communities in Ngorengore/Loita plains has been reported by Karime (1990). The situation is exacerbated by relatively higher temperatures, and high pH, which accelerate organic matter loss by encouraging continuous decomposition. This assumption may be true due to unusually higher rains, during the time of this study, which supplied water for decomposition. Otherwise, decomposition rates in drier areas are normally low because of inadequate moisture (Jordan 1985).

Secondly, herbaceous biomass consists mainly of grass litter which because of its nutrient content, is rapidly decomposed. This implies that carbon, and even its sources, can hardly accumulate in grassland soils. The high mineral content in herbaceous biomass has been reported in the MMGR by Boutton *et al.*,(1988). Reduced amount of available biomass may further be attributed to continuous grazing by the large number of ungulates in the grasslands. In no doubt, accumulation of biomass in the soil is reduced while its decomposition is facilitated. As was indicated in Chapter 5, most grazing herbivores ignore areas with largest accumulations of standing dead vegetation. Instead, they concentrate on frequently grazed areas which support nutritious pastures.

The highest amount of organic carbon in the forest/upland sites is attributed to low temperatures and high rainfall. These factors, by reducing the rate of decomposition and by supporting high biomass, respectively, favour accumulation of organic matter that leads to high organic carbon in the soil. A similar account of carbon accumulation in the humid tropics is made by Grubb (1977), see also Brady (1990). The high carbon values in disturbed forest site 6 may be associated with short-term increase in dead biomass in the soil following recent forest clearing for cultivation and its abandonment.

6.3.1.3 Soil Nitrogen

The rapid decrease of nitrogen with depth is most clear in undisturbed woody sites, except shrubland sites (Fig. 6.21, Appendix B). Thus like carbon, nitrogen decreases as a result of increasing distance from sources of organic matter. The low nitrogen amount in the lower profiles in undisturbed forest sites could also be associated with nitrogen loss in a form of nitrates due to high soil acidity. This situation is compounded with low temperature, which inhibits rapid breakdown of soil organic matter. Low amounts of nitrogen in tropical montane vegetation due to reduced nitrogen mineralization and nitrification have been reported by Marris *et al.*(1988), Vitousek (1982) and Grubb (1977). Under moist conditions, a large proportion of nitrogen is bound up in undecayed litter or unmineralized humus. Robinson and Gacoka (1962) found a rise in nitrogen in a Kikuyu red loam topsoil (0 to 5 cm layer), Kenya. They associated this with an increase in nitrification due to the rise in soil temperature.

On the contrary, consistent change of nitrogen with depth in disturbed sites, implies that disturbance may be useful for the stability of nitrogen in the soil. Jenny's (1962) and Hughes' (1986) studies in the Nile valley and in the Tana River Floodplain basin, respectively, associated remarkable changes of nitrogen with depth with the lack of disturbance. This situation leads to decreasing organic matter and microbiological decomposition with depth.

Specifically, the concentration of nitrogen in the upper horizon in undisturbed forest sites may be attributed to nutrient trapping effect by tree roots and other nutrient conserving mechanisms such as mycorrhizae (Went and Starke 1968; Jordan 1985). In both grassland and shrubland communities, higher nitrogen in disturbed than undisturbed sites suggests that disturbance increases mineralization necessary for the release of nitrogen in the soil. Higher animal activities in these communities (Chapter 5), could be additional sources of nitrogen in the soil (Chapter 3). In grassland sites, higher amounts of nitrogen in lower horizons (Fig. 6.19) are an indication of the supply of organic matter from below ground biomass.

The generally low amount of nitrogen in shrubland and grassland sites is due to the low amount of biomass and rapid decomposition (section 6.4.1.3). In these sites, vegetation growth is retarded by low rainfall amount compounded with shallow and relatively poorly drained soils (see Appendix C, Jaetzold and Schmidt 1983). The low amount of biomass is further exacerbated by severe depletion of organic matter by overgrazing which is characteristic of these communities (Chapter 5). For instance, site 4 is experiencing concentrations of livestock while sites 25 and 26 are experiencing year-round and seasonal grazing by resident and migrating ungulates, mainly the wildebeest. High temperatures characteristic of the plains, also lead to high rates of decomposition, exhausting the nitrogen source. In addition, seasonal fires that sweep through the plains appear to contribute to the more rapid nitrogen cycling and the general decrease in organic matter.

In this study, low nitrogen in cool humid undisturbed sites is therefore superimposed on a general trend of accumulation of organic matter in the soil, related primarily to the fall in temperature. Under these conditions, nitrification of organic matter is significantly retarded (Brady 1990; Kalpage 1974). Nitrogen consistency in disturbed sites suggests that disturbance increases mineralization and the distribution of nitrogen within the profile.

6.3.1.4 C:N Ratios

When all samples are considered a high range in C:N ratios, 20.7:1, is revealed. This variation can be explained by examining the factors associated with C and N inconsistency.

It is generally believed (Brady 1990; Jordan 1985; Kalpage 1974) that, since carbon makes up a large proportion of organic matter in the soil, which also is the source of nitrogen, the C:N ratio should be constant. This situation can be achieved after continuous decomposition of organic matter, involving the release of both nitrogen and carbon. The process proceeds until a level where C:N stabilises. At this stage, both elements are lost from the soil at approximately the same rate. In the tropics, this stable value ranges between 8 and 10 (Ahn 1970). In the study area, differences in climate and the type of organic matter may be attributed to high level of variation in C:N ratios.

Fluxes in productivity, associated with rainfall patterns, are likely to replenish organic matter lost due to decomposition. However, replenishment may involve different qualities of biomass, making it difficult for the C:N ratios to stabilise. This situation is applicable in the plains where seasonal biomass fluxes are common. In the uplands, climatic conditions and partially undecomposed organic matter, combined or in isolation, affect C:N ratios through the degree of humification. Secondly, unlike the drier climate on the plains, the wetter climate on the uplands, permit leaching of nitrogen more readily. The situation is compounded by low mineralization (section 6.3.1.3). Consequently, high C:N ratios are favoured. As will be seen from Appendix B, the C:N ratios are highest for wetter sites and lowest for sites in the warm drier climates. However, continuous production of biomass during the time of this study and animal droppings may have contributed to the generally higher microbiological activity and, the relatively higher amount of C:N ratios in disturbed than undisturbed grassland sites (Table 6.2b). Therefore it is suggested that these ratios are not a reliable indication of the amount of organic matter. Therefore, they cannot be used to distinguish between disturbed and undisturbed sites. However, the higher mean ratios in disturbed than in undisturbed forest sites (Table 6.2b) suggest that disturbance increases organic matter decomposition and mineralization while, perhaps, leading to losses of nitrogen through leaching.

The C:N ratios (which range mainly between 4:1 and 23:1) obtained for this study, are within those that have been reported for some tropical sites. For instance, 20:1, over 10 and 9-11:1 have been reported by Grubb (1977), Edwards and Grubb (1982), and Longman and Jenik (1987), respectively. Nye and Greenland (1960) found C:N ratios of 8:1 to 17:1 for different forest soils and 15:1 to 20:1 for high grass savanna of west Africa.

6.3.1.5 Phosphorus

Phosphorus deficiency in most sites (Appendix B) is as a result of its low solubility. Different explanations may be offered to account for phosphorus insolubility in tropical soils. Primarily, this is as a result of high soil pH combined with high concentration of Mn^{+2}, Fe^{+3} and Al^{+3} which results in fixation of phosphorus (Jordan 1985; Sanchez 1976). This assumption is supported by the strong positive and negative correlations between P and pH, and between P and Fe^{3+} and Mn^{2+} (see Table 6.3), respectively. The latter is associated with the effect of pH on iron, aluminium and manganese. As pH drops, these metals increase reacting with soluble phosphorus to form insoluble hydroxy phosphates leading to low soluble P in the soil.

Low P is commonly associated with allophane which is notorious for its phosphate-fixing properties at low organic matter. This assumption applies to the study area because of the predominance of volcanic ash which, it is believed (Sanchez 1976; Brady 1990; Jordan 1985), has high allophane. In humid conditions, volcanic ash weathers into allopane that rapidly forms complexes with P and immobilizes it. However, the higher amount of P in sites underlain with volcanic rock compared to those underlain with basement, granite and bukoban rocks (Fig. 6.20 and Appendix C), raises some doubt about the significance of allophane on P in the respective samples. Two explanations can be offered for high P in volcanic soils. Firstly, the high amount of organic matter in these sites is, perhaps, responsible for higher phosphorus availability. Organic matter contributes to P when the compounds that are synthesized by micro-organisms in decomposing organic matter release phosphorus from insoluble compounds (Jordan 1985; Herrera et al.,1978; Sollins *et al.*,1981). This assumption is supported by the positive correlation, although weak, between organic carbon and phosphorus (Table 6.3). The contribution of organic matter to P is further supported by higher mean P for undisturbed than disturbed woody sites (Table 6.2b). Human disturbances affect P through the removal or destruction of organic matter sources. Mbuvi and Njeru's (1977) study in Mau Narok associates phosphorus deficiency with low amount of organic matter, ascribing it to intense landuse.

Secondly, higher P in soils underlain with volcanic rocks may be associated with clays and simpler compounds of calcium, such as mono- and di-calcium phosphates which readily contribute to P in the soil. The contribution of P by calcium compounds is supported by the high correlation between P and Ca^{2+} (Table 6.3). Also, both elements have a similar pattern in the surface layer (Table 6.2b). The contribution of clay to P could also be significant. Most soils in Narok District have a high amount of clay (Jaetzold and Schmidt 1983). Nye and Bertheux (1957), and Kalpage (1974) associate higher P in soils developed over basic rocks with the presence of more clays.

The great age and intense weathering of the bedrock are largely responsible for the generally low P in Trans-mara soils. The latter which are underlain with the oldest rocks, and undoubtly highly weathered, contain a high proportion of immobilizing metals such as manganese (Fig. 6.23) such that the contribution of organic matter to soluble P is insignificant.

6.3.1.6 Exchangeable Cations

The levels of exchangeable cations obtained for this study (see Appendix B) are relatively high using the NAL scale (Table 6.1). This may be associated with contributions from both parent material and organic matter. The NAL values are representative of the crop layer, and therefore give little indications on the direct contributions of the bed rock to soil nutrients. The contribution of the bed rock appear to be more significant in poorly vegetated sites. Therefore, the highest amount of exchangeable cations in shrubland and grassland sites may be accounted for by the lack of leaching of base-forming cations as they are weathered from soil minerals. This situation is favoured by high pH and low rainfall. At Eorekule (sites 4 and 5), Talek (site 35) and Maji Moto (sites 25 and 26) cations particularly Na^+ and K^+ increase with depth supporting the contribution of the underlying parent material to Na^+ stock in the soil. These sites are located on young volcanic rocks which, it is believed (Brady 1990; Jordan 1985; Grubb 1977), have large quantities of cations. The contribution of volcanic rocks to potassium, for instance, is supported by its low amount in the bukoban (site 18) and granite rocks (sites 14 and 15) of Trans-mara. These are old rocks which have lost most of the minerals through long weathering and leaching.

According to Jordan (1985) most cations occur in primary minerals which compose various types of rocks. The nutrients are released into the soil solution once the bedrock is weathered and transformed, and may be brought to the top layers by illuviation. Illuviation appears the cause of high cations for sites 4 and 25 which have lost most of their humic layer due to overgrazing and soil erosion (Chapter 5). This assumption is based on a surface encrustation observed in site 25, suggesting Na^+ illuviation.

The contribution of organic matter to base cations in woody community sites is evident when the mean values are considered. The cations are higher in undisturbed than disturbed sites (Table 6.2b). This observation excludes sites from the plains which, as indicated earlier, have underlying rocks as an additional source of cations.

The relatively lower values of cations in humid sites compared with those in drier sites is associated with low pH. As such, they are rapidly lost from the soil by leaching. Lastly, Mg^{2+} and Ca^{2+} show a similar pattern, first, because pH for most sites, which is neutral to moderate, allows the predominance of these cations. Secondly, because of the relatively similar strength of adsorption by which these elements are held in the soil (Brady 1990; Foth 1988).

6.4.1.7 Cation Exchange Capacity

The close pattern between pH and CEC (Figs. 6.13 and 6.26) suggests that only a small portion of the pH dependent charges of organic colloids and some 1:1 type silicate clays hold exchangeable ions. A rise in pH is associated with the negative charges on 2:1 and some 1:1 clays, allophane, humus and even in iron and aluminium oxides (Brady 1990), thereby increasing the CEC. The low amount of 2:1 clays in the soils of the Narok District (Rachilo *et al.*,1988) in specific and the tropical region in general (Brady 1990) leaves organic colloids and the 1:1 clays the only factors determining CEC.

Generally, CEC is most inconsistent in undisturbed forest sites. Its decrease with depth in these sites suggests that it is generally low except for the thin layer at the top. This situation may, firstly, be attributed to base 'pumping-up', the uptake of cations by tree roots from great depths followed by deposition on the surface soils through litter and throughfall. Consequently, most cations are held in the above ground biomass.

Secondly, this observation may be attributed to mycorrhizae, a beneficial (symbiotic) association of fungal hyphae with plant roots which facilitates mineralization in surface soils releasing cations (Trudgill 1988; Brady 1990). Thirdly, since these sites are undisturbed (Chapter 5) most of the CEC could have been held up in the above ground biomass, with only some released to the soil surface by leaves and branches. Lastly, a decrease of CEC with depth may be attributed to leaching that results due to low pH. Conversely, disturbance reduces CEC variation in the soil profile. This is achieved through addition of organic matter by harvesting of standing crop, increases in decomposition and mineralization and through physical mixing of soil within the profile.

6.3.1.8 Trace Elements

Generally, most trace elements tend to be negatively correlated with the rest (Table 6.3). Lack of consistent pattern of these elements in the upper horizon, except for Cu (Table 6.2b) suggests that micronutrients are affected by both the bedrock and organic matter. The effect of organic matter on trace elements is demonstrated by the correlation between trace elements and organic matter (Table 6.3). Generally, organic matter appears to increase Zn while reducing the accumulation of Cu in the soil. High organic matter, by releasing organic acids, simply leads to the loss of trace elements by leaching. This assumption is supported by low values of trace elements in humid sites (Brady 1990). This further explains consistent negative correlation between micronutrients and organic carbon and vegetation latent vectors (Table 6.3).

The exclusively higher Mn^{2+} for sites from Trans-mara Division and for a few sites from the plains might be related to geology. Except for grassland sites 25 and 28, these sites are underlain with basement or granite or bukoban rocks (Appendix C). As indicated earlier, most rocks from Trans-mara Division are highly weathered and are therefore likely to be high in hydrous oxides of manganese (Kalpage 1974; Jordan 1985).

The high correlation between micronutrients and carbon and nitrogen values (Table 6.3) is partly because of their common source. This is true between carbon and Zn^{2+}. However, organic substances are only secondary sources of micronutrients, primary sources being inorganic substances (Brady 1990; Foth 1988). Like carbon and nitrogen, these elements are released into the soil solution through decomposition of organic matter. This may also be used to explain the lowest amount of Cu^{2+} and Zn^{2+}, in the humid parts of the District, where mineralisation is low (see Figs. 6.23 and 6.24). Zn^{2+} deficiencies (see Appendix B) are widespread in different community sites, except forest sites. These variations concide with changes in carbon distribution. Except site 19, sites with highest carbon experience no Zn^{2+} deficiencies. Deficiency of Cu^{2+} has been reported by Mbuvi and Njeru (1977) in wheat and maize growing areas of Mau Narok.

This section has demostrated that, except for grassland and shrubland sites, human disturbance is associated with low amounts of carbon, nitrogen, P, base cations and Cu in the upper horizon. Except for Cu, these elements depend on organic matter as their main source. Human disturbances either eliminate their source or increase their loss by increasing decomposition and leaching. Also, it has been demonstrated that human disturbance reduces nutrient variations within the soil profile.

It is also evident that different factors are responsible for variations of the amount of soil nutrients. These are mainly climate, bed rock, plant lifeform and human disturbance. This makes the use any one of them in distinguishing between disturbed and undisturbed sites less effective. This problem is partly overcome in the following section. The results of multivariate analysis are used to establish whether soil data of different site categories can suggest any pattern and whether the pattern relates to some environmental factors including human disturbance.

6.3.2 Statistical Data Analysis

The three major clusters comprising of samples 25, 26, 34 and 35 (predominantly from the plains), samples 1, 2, 3, 5, 6, 7, 8, 9, 10, 11, 12, 29, 30, 38 and 39 (from the uplands) and samples 14, 15, 17, 18, 36, 37 and 42 (from the intermediate zone) that emerge from Figure 6.27a, can be explained in two different ways. Firstly, discriminant function 1 clusters samples mainly on the basis of climate, geology and altitude. Soils from closely located sites are chemically similar, suggesting that the combined effect of these factors is similar. It will be clear in chapter 7 that closely located sites also support similar plant species. This could mean that closely located sites have a similar type and supply of organic matter and biomass. It should also be recalled (Chapter 3) that climate, geology and altitude are spatially related. This means that the effect of these factors on soil and vegetation will be similar. In chapter 7, it will be evident that both soil and vegetation data display a similar pattern in the ordination space. The inter-relationships among these factors has been supported by Wright (1967), Jaetzold and Schmidt (1983) and Mbuvi and Njeru (1977). The soils of Narok District, therefore, display a *catena*, with soil difference being associated with differences in relief.

Secondly, discriminant function 2, using (Fig.6.27b), suggests the influence of human disturbance in sample ordination. Grassland disturbed sites are isolated from undisturbed ones. Also, disturbed and undisturbed forest sites are distinguished, though diffusely, from each other. However, the overriding influence of climate and physiography on soil chemistry tends to overshadow human influence on most community sites.

As with ordination, HCLUSTER analysis combines samples at the first step on the basis of closeness. This further suggests the dependence of soil chemistry on climate and physiography. Thus, samples appear similar if they occur in the same geomorphic level under the same climate. Therefore, it would be worthwhile to put these soils into similar landuse types. Also, this analysis reveals the influence of human disturbance on the fusing of grassland and forest sites. Both disturbed and undisturbed grassland sites are fused at step 3. Forest disturbed and undisturbed sites are, also, weakly fused. These observations suggest that both grassland and forest sites are more responsive to human disturbance. Further it may be argued that disturbed and undisturbed sites in these two communities have different sets of soil types and soil characteristics.

Despite some limitations, statistical analyses proved useful in distinguishing between a number of samples identified in the field as disturbed and undisturbed. Isolation of various samples is, firstly, perhaps limited by the analyses having been made on soils from a single pit from each site (i.e., lacks spread throughout a sampling zone). Secondly, this may be associated with environmental heterogeneity in different sites. Thus, the interaction of different factors responsible for soil chemistry, may have overshadowed the human influence on vegetation change.

The young volcanic soils, associated with recent geological history of Narok District obscure the influence of man on soil fertility, through vegetation destruction. This is because both parent material and vegetation are significant sources of soil nutrients. However, vegetation contributes predominantly to P, organic carbon and nitrogen. Most base cations are supplied by both organic matter and the underlying parent material.

Therefore, the soils of the study area which are mainly of volcanic origin are quite rich chemically with deficiencies of P and a few trace elements. However, extremely disturbed areas have generally low amounts of nutrients.

Using both classification and ordination, this section has demonstrated that within profile data are closer to each other than to data from other profiles. This is because of the similarity of the factors affecting the amount of nutrients. Observed diffuse ordination of samples from the same plant community suggest an overlap in the factors influencing nutrients, and that human influence has had only little or no impact on the soil chemistry of most communities. Generally, the influence of human disturbance on nutrients has been overshadowed by nutrient contributions from underlying young volcanic rocks.

6.4 CONCLUSION

This chapter has highlighted the factors underlying soil chemistry. Human disturbance is increasing nutrient consistency in the soil profile through increased mineralization and the distribution of organic matter. Except for grassland and shrubland sites, the mean amount of carbon, nitrogen, P, base cations and Cu is lower in disturbed than undisturbed woody community sites. Human disturbance affects soil chemistry through the conversion and/or destruction of vegetation, affecting direct contribution of vegetation to soil nutrients and its role in tapping and/or pumping-up of nutrients.

However, in a few disturbed sites low soil fertility is evidence of the need to protect natural vegetation. This is true for upland soil, for which disturbance of vegetation has a lot of implications because of the moderating effect of vegetation on climatic and topographic impact on soils. Therefore, human activities that ameliorate soil conditions such as aeration and soil temperature, stimulating mineralization and intensifying soil erosion and leaching, by increasing the pool of soluble minerals, need serious consideration before they are introduced.

Both ordination and classification procedures have demonstrated that soil chemistry in both forest and grassland comunities are different between disturbed and undisturbed sites.

CHAPTER 7 : DESCRIPTION AND ANALYSIS OF VEGETATION

7.1 INTRODUCTION

In chapter 3 the fieldwork methodology to vegetation sampling was outlined. This chapter reports the findings of the analysis of the data collected and uses them to distinguish between and within disturbed and undisturbed sample categories. Appendix A presents the full list of vegetation data for the 42 sites. Five types of data can be identified. These are species type, the number of individuals per species less and more than 1m in height, average height per species and diameter at breast height for woody species.

The following section reports the ways in which data have been organised for description and statistical analysis. The results of data analysis are reported and discussed later in this chapter.

7.2 ORGANISATION OF VEGETATION DATA FOR DESCRIPTION AND STATISTICAL ANALYSIS

Figure 7.1 is a summary of the different descriptive and statistical procedures used to analyse the data.

7.2.1 Organisation of Vegetation Data for Description.

Data are organised to meet the following objectives:

1) To examine whether the vegetation in disturbed sites is distinguishable, floristically, from that in undisturbed sites.

2) To examine whether the vegetation in disturbed sites is distinguishable, physiognomically, from that in undisturbed sites.

3) To examine whether vegetation characteristics suggest successional trends.

In an attempt to achieve these objectives, three hypotheses are examined. These are:

> 'that species richness is highest in communities experiencing medium human disturbance'
>
> 'that plants from disturbed communities are physiognomically different from the undisturbed ones' and
>
> 'that the establishment and growth of plants to maturity is, perhaps, being promoted and not necessarily inhibited by different human disturbances'

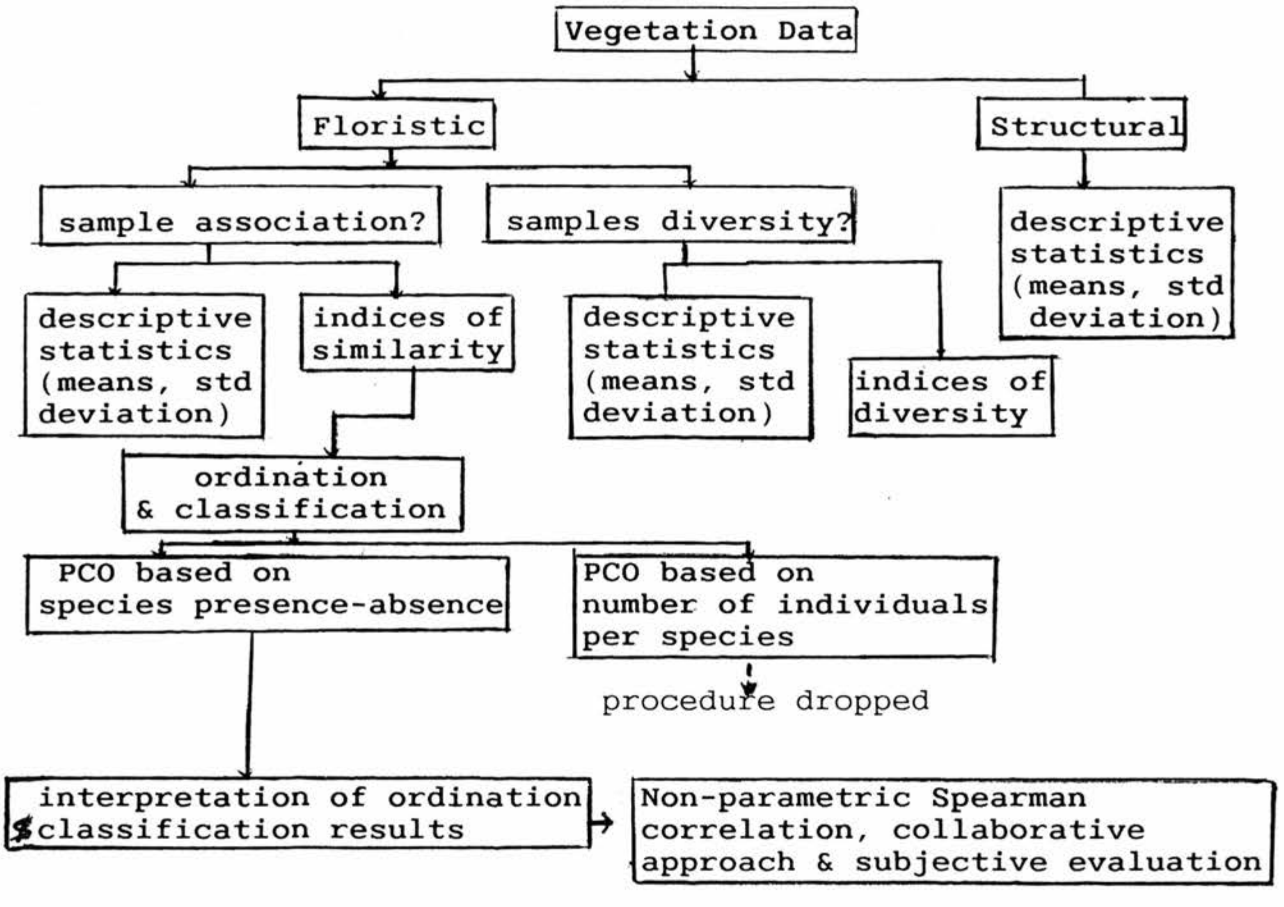


Fig. 7.1. Steps involved in vegetation data analysis. Different descriptive and statistical procedures were used.

In attempting to examine the last hypothesis, this study implicitly tries to pursue the compression hypothesis which was advanced by Caughley (1976). Basically, this hypothesis assumes that vegetation destruction by animals follows increasing human activities and the displacement and disruption of animal dispersal routes and habitats. The hypothesis ties well with vegetation change in Narok District which has been associated with the loss of land by the Maasai to the colonial government and later to cultivator immigrants, and reduced grazing resources and animal movements (Chapters 2 and 4). Description of spatial variation in plant structure and composition forms the basis for this argument.

In order to achieve objective 1 of vegetation description the data are, firstly, arranged as a sample-by-species matrix (Appendix A). The purpose is to summarize data so that they are easy to examine for possible patterns. Undisturbed and disturbed sites in each community are placed together for ease of interpretation and comparison of the effects of human disturbance on floristic composition. Secondly, abundance data involving the number of species and individuals per species are examined on samples basis using density (see Table 7.1a). These data are further summarized using the mean (Table 7.1b) which, it is believed (Rowntree 1981), to be the most reliable estimate of central tendency.

Both the mean and density cannot provide information about samples association. The latter is needed to establish whether there is some connection between and among site categories so as to make predictions about the underlying factors. This problem is solved by the use of indices of similarity. Also, the use of these indices follows the realization that a large

Plot	Number of species type	Individuals <1m	Individuals >1m	Total	woody spp
Undisturbed forest					
2	22	107	424	531	11
3	20	43	167	210	8
7	37	72	93	165	29
9	37	119	221	340	25
12	33	99	89	188	25
31	44	145	177	322	26
38	34	28	59	87	16
Disturbed forest					
6	48	80	28	108	18
8	32	123	182	305	16
11	26	40	34	74	13
13	24	14	13	27	12
32	48	59	16	75	13
33	65	516	421	937	31
39	36	36	0	36	0
Undisturbed woodland					
10	38	677	423	1100	27
19	49	140	144	284	30
40	39	66	33	99	21
Disturbed woodland					
14	31	31	0	31	4
20	46	170	61	231	17
41	32	84	14	98	14
Undisturbed bushland					
16	67	481	254	735	42
17	63	620	195	815	37
21	44	249	189	438	28
23	77	156	39	195	25
Disturbed bushland					
15	57	187	16	203	20
18	51	164	3	167	14
22	72	217	38	255	31
24	68	1063	42	1105	24
Undisturbed shrubland					
5	32	936	309	1245	26
42	25	47	23	70	9
Disturbed shrubland					
1	75	915	477	1392	28
4	24	101	75	176	16
Undisturbed grassland					
27	26	112	0	112	2
29	18	18	0	18	0
34	20	290	0	290	0
36	15	15	0	15	0
37	34	296	0	296	7
Disturbed grassland					
25	27	308	1	309	5
26	14	122	0	122	1
28	16	29	0	29	2
30	31	50	0	50	2
35	13	28	0	28	2

Table: 7.1a: Total Number of Species Types and individuals/class height/plot and the number of woody species per plot. Grassland plots are 25 by 25m whilst the rest are 50 by 50m plot size.

degree of error is inherent in subjective evaluation of abundance by density (Williams 1964; Digby and Kempton 1987; Kikkawa 1986; Gauch 1982). Therefore, Sorenzen's index of similarity (see Muller-Dumbois and Ellenberg 1974), SI= (2C/A+B)100 is calculated to measure similarity of pair samples. A and B are the number of species in the individual samples and C is the number of species in common. The purpose is to establish whether disturbed sites in each plant community, and among different communities, are more closely associated with each other than with undisturbed ones. For comparison, the analysis was repeated using Jaccard's index of similarity (Greig-smith 1983; Digby and Kempton 1987), defined as JI=C/A+B+C, - A, B and C are used as in SI.

After examining samples association, a measure of *alpha* diversity for individual saples (Whittaker 1967,1975; Kikkawa 1986), was calculated to estimate floristic heterogeneity. This is important for describing and inferring the impact of human disturbance characteristics (Chapter 5) on vegetation. Simpson's (1949), Yule's (1944) and log-series (Kempton and Taylor 1987) indices of diversity are used. Simpson's index, Si=N(N-1)/sum of $n_i(n_i-1)$

where N is the total number of individuals in the sample, and N_i is the number of individuals of species

is used because of its independence of any theory about the form of the frequency distribution of species abundance (Williams 1964; Kikkawa 1986). Basically this index is the probability that two individuals picked at random from a given population are of different species. The measure is independent of sample size in large samples (see Williams 1964) such as are used in this study. Yule's index, YI= N^2/sum of n(n-1),

where N is the total number of individuals in two samples, and n, n-1 used as in Si,

is attempted so as to compare the results obtained by Si. This is particularly because of its higher objectivity (Kikkawa 1986). As will be noticed, the coding used during data collection (Chapter 3) of non-individual plants made diversity indices less effective in differentiating sample categories. Since both Simpson's and Yule's measures are influenced by abundant species (Kikkawa 1986; Kempton and Taylor 1976), alpha is estimated for the log-series model (Williams 1964; Kikkawa 1986). This is obtained by solving S=@log(1+N/@)

where N is the total number of individuals in the sample, S the total number of species and @, the index of diversity.

According to Kempton and Taylor (1976:818) the use of the log-series

"enables the diversity statistics to be estimated much more efficiently than by direct evaluation from the relative frequencies".

The second reason of calculating this coefficient is to have variation due to the few commonest species reduced.

While floristic pattern is fairly effective in distinguishing between disturbed and undisturbed sites, the findings are qualified or supplemented by the use of structural data. This is what objective 2 is all about. To achieve this objective, plant structural data are first summarized using the mean (Appendix

A). The mean diameter and mean height for woody species, at least 1.3m high, are used to calculate the total volume of wood (WV) per sample using the formula :

WV=gh/2 where g- basal area of main stem at 1.3m (dbh)
h- tree/shrub height

(after Dawkins 1970 in Synott 1979)

The few woody species, at least 1.3m high, in grassland sites meant that they had to be included in the description of wood resources. Furthermore, the presence of scattered trees in these sites implies that they have the potential to support woody species. Since these calculations involve standing live trees/shrubs irrespective of their local use, it is suggested that the figures obtained do not reflect the amount of consumable wood available.

The number of plants cut and/or browsed has been summarized in Table 7.6a so as to provide insights into the plants most subjected to these disturbances. The data are further used to calculate the means (Table 7.6b). Also, these figures serve as estimates of disturbance intensity on vegetation.

To achieve objective 3 of vegetation description, plant structural characteristics in each site category are considered on the basis of species type. Plant height has been summarized using the mean (Appendix A). The results are classified viz: less than 1m and more than 1m, the data sorted by sample unit, so as to establish successional trends. The 1m height has been identified as the critical level of tree recruitment into the mature stage (Dublin 1986), especially because of fire and browsing.

7.2.2 Organisation of Vegetation Data for Statistical Analysis

Data are organised for the following purposes:

1) To establish whether there is a relationship between and among disturbed and undisturbed sample categories so as to try to understand the factors influencing spatial variation of vegetation.

2) To establish whether there is a relationship between vegetation data and the site history, particularly past and present human activities.

3) To verify that fieldwork data truly represent the specific plant communities, and do not contain intermediate vegetation types.

The first and second objectives are achieved by ordination while the third objective is achieved by classification.

To achieve objective 1, pattern analysis of samples association (Table 7.3) is attempted using different ordination techniques. The purpose is to summarize the association so as to see whether it can be explained on the basis of human disturbance, among other factors. This is particularly important since the use of rigorous statistical analysis is limited because of the non-normality of the data due to subjective sampling (Chapter 3). This means that the results obtained are purely illustrative.

Principal Co-ordinates Analysis (PCO) which is part of the Genstat package is used to ordinate the samples. PCO is chosen for this study because of its capability to reduce many-dimensional vegetation data into a few divisions so that they can be better comprehended, better communicated and more easily related to environmental factors (Gauch 1982; Orloci 1966; Goodall 1954). Also, it has the advantage of providing sample ordination scores in a single integrated analysis (Gauch 1982, Digby and Kempton 1987). The concept underlying this technique is that of association between samples. As the association measure increases, so is the proximity in sample similarity.

The effectiveness of PCO as with Principal Components Analysis (PCA) lies in the fact that the dominant pattern in the data are represented in the first few dimensions (Digby and Kempton 1987; Greig-Smith 1983; Gauch 1982). While PCA uses the euclidean distance as the distance between points in the species or samples space, PCO uses any general similarity or distance measure and thus has greater flexibility (Gauch 1982). Also, PCO has the ability to analyse matrix of distance measures between stands; thus, extending ordination to being based on structural parameters, and not mainly on floristic characteristics. Alternative, widely used ordination methods such as Correspondence Analysis (CA) and Detrended Correspondence Analysis (DCA) (Gauch 1982; Greig-smith 1983; Muller-Dumbois and Ellenberg 1974) were not applied to the data. Digby and Kempton (1987) found that these methods usually give similar results to PCO.

Two types of data are ordinated. Entire vegetation data are used to provide an ordination of all samples. Vegetation data for samples with soil data (Chapter 6) are ordinated so as to infer human impact on vegetation, using soil fertility. In both cases, Jacard coefficients of similarity matrix are used. A second matrix is computed based on the pairs of samples. This is then used to plot the results in a two-dimensional space. Since these results were based on species presence-absence similarity coefficients (Digby and Kempton 1987; Greig-Smith 1983), a second ordination, based on Manhattan metric or city block (Digby and Kempton 1987; Greig-Smith 1983) which uses distances among the number of individuals per species as the measure of association was investigated to see whether there was any improvement. The data are first transformed using the equation $x=\log(x+1)$ to exclude zero values and to reduce the influence of rare abundant species in the ordination space.

After establishing samples association using PCO, objective 2 of statistics analysis requires interpretation of these association in the ordination space. Three approaches are used. The first approach involves plotting of data on altitude, the number of animals (Chapter 5), average rainfall and the amount of different soil variables (Chapter 6) at the sample locus into the ordination space. Isolines have been drawn by eye to help establish whether there is a pattern in these variables. The lines are subjectively drawn to minimize deviations of samples not classified correctly. Only those variables with clearer results (see Figs. 7.6 to 7.9) are used in the interpretation. These are average rainfall, organic carbon, nitrogen and zinc. This approach to showing the relation of environmental factors through space has been used by Webber (1978), Chang and Gauch (1986) and Peet (1980). Two other approaches used (in this study) to interpret the ordination space are correlation coefficients and subjective evaluation.

After establishing some pattern between samples and the four environmental factors in the ordination space, a correlation coefficient is used to establish the relationship between these variables and first vegetation axis. Two commonly used coeffients are the Pearson and Spearman correlation coefficients. The use of the former to interpret the relationship between vegetation and environmental factors has been criticized (Webber 1977; Bray and Curtis 1957). Therefore, a non-parametric Spearman correlation coefficient which avoids making this assumptions has been used (see Table 6.3 in Chapter 6). However, this correlation coefficient also assumes that the relationships are simple, that low values for an environmental factor are at the one end of axis and the higher values at the other end. Despite these limitations, correlation coefficients are useful in interpreting ordinations environmentally (Peet 1980). Another approach, the commonest, also used in interpreting ordination space is subjective evaluation of the principal environmental gradients with no supporting data presented (Robertson 1978; Hill and Gauch 1980, Moral 1980; Chang and Gauch 1986).

To achieve objective 3 of statistical analysis, sample association (Table 7.3) is further summarized by hierarchical classification techniques commonly called cluster analysis (Sokal and Sneath 1963; Genstat 5 users manual 1989). The commonly used and ecologically useful clustering strategies are single-linkage or nearest neighbour, complete-linkage or furthest neighbour and average-linkage (Gauch 1982; Goldsmith *et al.*,1986; Digby and Kempton 1987; Muller-Dumbois and Ellenberg 1974; Hill 1975). The single-linkage sorting strategy, which is widely used in taxonomic research, is not used in this study because it produces straggly clusters which quickly agglomerate dissimilar samples (Hill 1975; Gauch 1982; Goldsmith *et al.*,1986). Instead, both average-linkage and furthest neighbour strategies, which are polythetic agglomerative strategies are used. The former gives the greatest correlation between data input and output (Sokal and Sneath 1973). Furthest neighbour produces tight clusters of similar samples. This strategy is based on the principle that two clusters fuse when their dissimilarity is equal to the greatest dissimilarity for any pair of stands with one in each cluster.

As with ordination, since infrequent species are dominant in most samples, all species sampled (610) and the 452 species for samples with soil data, are included in the analysis. Following the construction of similarity matrix the cluster strategies are used to fuse the samples into decreasingly larger clusters. For effectiveness of communication of classified groups, a dendrogram is used to visually display the results.

7.3 RESULTS

7.3.1 Vegetation Description

7.3.1.1 Type and Number of Species

Two important parameters of vegetation data for distinguishing between disturbed and undisturbed sites, are the type and number of species. Appendix A and Table 7.1a show variation in species and the number of individuals per species between and among sample categories. Only the means of individuals per species data (Tables 7.1c) distinguishes between disturbed and undisturbed site categories. Except for shrubland community, undisturbed sites have higher mean numbers of individuals than disturbed ones. The mean estimate for the number of species is not consistent between disturbed and undisturbed sites. As may be expected (see Appendix A, Table 7.1a), except for the shrubland community, there are more woody species in undisturbed than disturbed woody sites. For grassland communities, undisturbed sites have more or less the same number of species as disturbed ones.

Detailed examination of data on sample basis reveals that forest site 33, shrubland site 1 and bushland sites 22 and 24, identified as disturbed (Chapter 5), register a high number of species as undisturbed bushland sites 16 and 23. On the contrary, undisturbed forest sites 2 and 3, and shrubland site 42 register fewer species as disturbed forest site 13 and shrubland site 4. On the average, except for shrubland and grassland sites, undisturbed sites have more woody species than disturbed ones (Table 7.1d).

7.3.1.2 Samples Association.

The results of samples association may be summarized into three categories, arbitrarily chosen. These are sample pairs without association, those with intermediate association and those with highest association.

Community	Undisturbed		Disturbed	
	Mean	SD	Mean	SD
Forest	32	8.6	40	14.6
Woodland	42	6.1	36	8.4
Bushland	63	13.8	62	9.7
Shrubland	29	4.9	50	36
Grassland	23	7.5	20	8.2

Table 7.1b: Mean and Standard Deviation(SD) of total number of species types per community category. The high deviation for disturbed shrubland is attributed to degraded site 4

Community	Undisturbed		Disturbed	
	Mean	SD	Mean	SD
Forest	265	150.4	223	328.4
Woodland	494	532.6	120	101.8
Bushland	546	284.6	433	449.8
Shrubland	658	830.9	784	859.8
Grassland	146	139.6	108	119.0

Table 7.1c: Mean number and Standard Deviation(SD) of individuals per community category.

Community	Undisturbed		Disturbed	
	Mean	SD	Mean	SD
Forest	20	8.2	15	9.2
Woodland	26	4.6	12	6.8
Bushland	33	7.9	22	7.1
Shrubland	18	12.0	22	8.5
Grassland	2	3.0	2	1.5

Table 7.1d: Mean number and Standard Deviation (SD) of woody species per community category.

Tables 7.2 and 7.3 show lack of similarity (SI=JI=0%) between a pair of forest sites 2 and 11, grassland sites 29 paired with 25, 28 and 35 and woodland sites 40 and 14. The sites in each pair represent the ends of a disturbance spectrum, disturbed and undisturbed communities (Chapter 5), respectively. Therefore, it may be assumed that they offer different niches for recolonization. As would be expected, lack of similarity in species is also evident for grassland sites paired with most forest sites, and undisturbed shrubland site 42 paired with most forest sites (see Tables 7.2 and 7.3). This is also true of site 5 paired with sites 11 and 19, site 29 paired with sites 28 and 35, and site 20 paired with 7. The sites in these pairs are under different environmental influences, and therefore each is likely to support different life form characteristics of the different taxa (Chapter 3).

A second category of pairs which comprises a majority of samples, has similarity 0<SI<30% and 0<JI<14%. In this category, there is predominantly lower similarity between disturbed forest sites 6, 8, 11 and 13, and undisturbed forest and the other woody community sites. Similarity among woody sites, excluding shrubland sites, is generally higher. A third category of sample association with only 27 pairs, not necessarily from the same disturbance category or the same plant community, has the highest similarity, SI>30% and JI>14% (see Tables 7.2 and 7.3). In this category, a majority of the pairs, 12 out of 27 (Table 7.2), involve grassland sites. High association between

Site	3	7	9	12	31	38	6	8	11	13	32	33	39	10	19	40	14	20	41	16	17	21	23	15	18	22	24	5	42	1	4	27	29	34	36	37	25	26	28	30	35
2	52.4	13.6	22.2	18.2	12.1	17.9	8.6	14.8	0.0	17.4	14.3	18.4	10.3	26.7	8.5	11.1	0.0	8.8	7.7	15.7	18.8	9.1	4.0	10.1	5.5	8.5	11.1	22.2	4.3	26.8	21.7	4.2	0.0	0.0	0.0	7.1	0.0	0.0	0.0	3.8	0.0
3		10.5	28.1	18.9	15.6	29.6	17.6	23.1	8.7	22.7	23.5	21.2	21.4	17.2	5.8	13.6	11.8	6.1	11.5	13.8	21.7	9.2	4.1	18.2	14.1	13.0	13.6	26.9	0.0	23.2	27.3	8.7	0.0	10.0	5.7	11.1	8.5	0.0	5.6	11.8	6.1
7			32.4	22.9	17.3	19.7	28.8	17.4	6.3	6.6	14.1	9.8	8.2	16.0	9.3	10.5	2.9	0.0	5.8	11.5	14.0	12.3	3.5	8.5	2.3	5.5	5.7	17.4	3.2	18.	19.7	0.0	0.0	0.0	0.0	2.8	0.0	0.0	0.0	2.9	0.0
9				25.7	14.8	16.9	25.9	20.3	6.3	6.6	16.5	19.6	11.0	26.7	11.6	15.8	8.8	9.6	17.4	15.4	18.0	17.3	3.5	17.0	17.0	11.0	13.3	20.3	9.7	12.5	16.4	3.2	0.0	3.5	0.0	5.6	0.0	0.0	0.0	8.8	0.0
12					13.0	26.9	4.9	12.3	20.3	17.5	12.3	14.3	5.8	28.2	14.6	5.6	6.3	7.6	6.2	14.0	20.8	20.8	9.1	20.0	4.8	11.4	11.9	18.5	6.9	7.4	14.0	0.0	4.0	0.0	4.2	6.0	0.0	0.0	0.0	0.0	4.3
31						28.2	10.9	26.3	5.7	5.9	17.4	9.2	12.5	19.2	2.2	4.8	0.0	2.2	5.3	12.6	15.0	2.3	8.3	2.0	4.2	5.2	8.9	15.8	2.9	13.4	14.7	5.7	3.2	3.1	3.4	5.1	0.0	3.4	3.3	13.3	0.0
38							19.5	33.3	13.3	7.0	22.0	18.2	31.4	25.0	7.2	5.5	3.1	2.5	9.1	9.9	14.4	7.7	10.8	13.2	7.1	13.2	15.7	12.1	0.0	14.7	10.3	6.7	0.0	3.7	4.1	5.9	3.3	0.0	4.0	12.3	4.3
6								27.5	16.2	22.2	22.9	21.2	23.8	7.0	8.2	4.6	20.3	6.4	7.5	7.0	18.0	6.5	8.0	17.1	6.1	10.0	13.8	5.0	0.0	13.0	11.1	5.4	6.1	2.9	0.0	0.0	0.0	0.0	0.0	12.7	3.3
8									10.3	17.9	31.4	18.6	11.8	25.7	2.5	5.6	9.5	7.7	9.4	10.1	12.6	5.3	7.3	9.0	9.6	7.7	10.0	15.6	0.0	11.2	14.3	6.9	8.0	7.7	4.3	9.1	3.4	4.3	4.2	25.4	0.0
11										28.0	8.1	19.8	9.7	12.5	10.7	3.1	17.4	19.4	5.9	6.5	11.2	5.7	9.7	21.7	13.0	14.3	17.0	0.0	3.9	7.9	4.0	7.7	4.5	8.7	9.8	6.7	11.3	5.0	4.8	7.0	5.1
13											19.4	24.7	6.7	16.1	11.0	3.2	25.5	5.7	7.1	6.6	6.9	8.8	5.9	12.3	5.3	6.3	10.9	7.1	4.1	8.1	8.3	4.0	0.0	4.5	0.0	0.0	3.9	5.3	0.0	14.5	5.4
32												24.8	23.8	18.6	2.1	2.3	17.7	4.3	5.0	7.0	9.0	2.2	9.6	11.4	10.1	13.3	12.1	10.0	2.7	21.1	13.9	2.7	9.1	0.0	0.0	2.4	0.0	3.2	0.0	25.3	6.6
33													21.8	23.3	14.0	13.5	20.8	19.8	10.3	16.7	30.5	11.8	15.5	23.0	32.8	29.2	31.6	12.4	4.4	28.6	20.2	8.8	12.0	11.8	7.5	8.1	13.0	7.6	9.9	18.8	10.3
39														8.1	4.7	2.7	11.9	19.5	5.9	5.8	8.2	5.0	5.3	12.9	13.8	13.8	13.5	2.9	6.6	16.2	0.0	3.2	7.4	0.0	0.0	0.0	0.0	0.0	0.0	17.9	4.1
10															11.5	7.8	8.7	11.9	2.9	22.9	25.7	24.4	8.7	18.9	11.2	16.4	15.1	22.9	6.3	15.9	22.6	9.4	3.6	10.3	11.3	8.3	9.2	7.7	7.4	8.7	15.7
19																4.5	10.0	18.9	7.4	12.1	19.1	36.6	6.4	15.1	10.0	21.5	12.0	0.0	8.1	6.5	5.5	2.7	0.0	0.0	3.1	2.4	2.6	3.2	0.0	0.0	6.5
40																	0.0	9.3	39.4	15.1	25.5	9.6	10.3	8.3	13.3	18.0	18.8	14.1	25.0	10.5	9.5	0.0	3.5	3.4	7.4	13.5	3.0	7.5	3.6	0.0	3.8
14																		23.4	1.2	8.2	10.6	0.0	9.3	36.4	19.5	19.4	24.2	3.2	14.3	13.2	3.6	7.0	8.2	7.8	8.7	0.0	13.3	13.3	4.3	19.4	13.6
20																			12.8	14.2	22.0	13.3	11.4	29.1	24.7	28.8	19.3	5.1	22.5	18.1	5.7	16.7	15.6	12.1	16.4	12.5	16.4	10.0	12.9	13.0	13.6
41																				14.1	21.1	7.9	5.5	9.0	12.0	13.5	12.0	15.6	35.1	15.0	14.3	10.3	8.0	11.5	12.8	18.2	13.6	8.7	8.3	6.3	0.0
16																					29.2	12.6	13.9	19.4	27.1	15.8	20.7	16.2	10.9	18.3	15.4	4.3	2.4	0.0	2.4	5.9	4.3	2.5	2.4	4.1	5.0
17																						22.4	20.0	26.7	22.8	25.2	33.6	23.2	18.2	23.2	20.7	9.0	4.8	4.8	10.3	16.5	4.4	7.8	5.1	6.4	5.3
21																							6.6	11.9	8.4	15.5	7.1	10.5	5.8	6.7	14.7	.9	0.0	3.1	3.4	2.6	2.8	0.0	3.3	0.0	3.5
23																								10.4	20.3	30.9	33.1	9.2	9.8	18.4	7.9	5.8	4.2	10.3	8.7	12.6	9.6	8.8	10.8	7.4	4.4
15																									22.2	23.3	30.4	11.2	7.3	18.2	9.1	12.0	5.3	7.8	11.1	8.8	14.3	2.8	8.2	2.3	14.3
18																										30.9	25.2	4.8	15.8	23.8	5.3	10.4	8.7	11.3	12.1	11.8	10.3	12.3	6.0	19.5	18.8
22																											34.3	11.5	12.4	27.2	12.6	16.3	8.9	15.2	11.5	17.0	18.2	11.6	13.6	15.5	14.1
24																												14.0	12.9	25.2	6.5	17.0	2.3	11.4	7.2	23.5	18.9	14.6	14.3	10.1	12.3
5																													7.0	18.7	80.0	6.9	0.0	7.7	4.3	9.1	10.2	8.7	8.3	3.2	4.4
42																														12.0	12.2	11.8	9.3	13.3	15.0	10.2	15.4	10.3	9.8	7.1	5.3
1																															16.2	11.9	2.2	12.6	6.7	12.8	13.7	18.0	11.0	13.2	9.1
4																																12.0	0.0	13.6	5.1	13.8	15.7	5.3	10.0	3.6	10.8
27																																	4.5	39.1	39.0	23.3	41.9	25.0	42.9	7.0	25.6
29																																		5.3	12.1	7.7	0.0	12.5	0.0	28.6	0.0
34																																			28.6	25.9	29.8	23.5	44.4	11.8	18.8
36																																				28.6	23.8	32.3	4.3	4.3	42.9
37																																					13.1	25.0	24.0	9.2	12.8
25																																						29.3	41.9	3.4	30.0
26																																							33.3	44.4	29.6
28																																								4.3	34.5
30																																									0.0
35																																									

Table 7.2 Sorenzen's index (%) of similarity for the different pairs of samples. Three categories arbitrarily decided are dissimilar sample pairs (0%), intermediate similarily (0<SI<30) and highest similarity (SI>30).

Sites ↓

1	----																				
2	14.3	----																			
3	13.1	41.4	----																		
4	11.2	12.5	12.8	----																	
5	10.3	12.8	15.6	33.3	----																
6	7.0	6.2	8.1	6.0	2.6	----															
7	0.9	7.5	5.7	11.1	9.7	16.9	----														
8	5.9	8.2	13.0	7.7	8.5	16.2	9.7	----													
9	7.7	13.7	14.0	10.9	11.3	15.1	21.7	11.3	----												
10	10.8	15.7	13.7	12.7	16.7	3.7	8.8	14.8	13.6	----											
11	4.1	0.0	4.5	2.0	0.0	9.0	3.3	5.5	3.3	6.7	----										
12	3.8	10.2	10.4	7.5	12.1	2.6	13.1	6.6	16.7	18.3	11.3	----									
13	4.2	9.8	12.8	4.3	3.7	12.7	3.4	9.8	3.4	8.8	16.3	7.5	----								
14	7.1	2.0	6.2	1.9	1.6	11.4	1.5	5.0	3.0	4.5	11.8	3.2	17.0	----							
15	10.9	5.4	10.0	5.2	6.0	9.5	4.5	4.7	10.6	10.5	10.7	11.1	6.6	22.2	----						
16	10.2	8.9	7.6	8.5	10.2	4.7	6.3	5.4	8.5	13.2	3.4	7.7	3.5	4.3	10.9	----					
17	13.1	10.5	10.7	11.5	14.5	8.9	8.8	6.7	16.3	14.8	6.0	10.3	4.8	5.6	16.5	17.4	----				
18	13.5	2.9	7.6	2.7	2.5	4.3	1.2	5.1	6.0	6.0	6.9	2.4	2.7	10.8	13.7	16.0	12.9	----			
19	3.3	4.5	3.0	2.8	0.0	4.3	4.9	1.3	6.2	6.1	5.6	7.9	5.8	5.3	8.2	6.5	10.9	5.3	----		
20	10.0	4.7	4.5	2.9	2.6	3.3	0.0	4.0	3.8	5.0	10.8	3.9	2.9	13.2	18.4	8.8	11.2	16.9	10.5	----	
21	3.5	4.8	4.9	7.9	5.6	3.4	6.7	2.7	11.0	13.9	2.9	11.6	4.6	0.0	6.3	6.9	12.6	4.4	22.4	7.1	----
22	15.9	4.5	5.8	6.7	5.2	5.4	2.9	4.0	5.9	9.0	7.8	6.1	3.3	10.9	14.3	9.7	14.5	19.6	12.1	18.2	8.5
23	10.3	2.1	2.2	4.2	4.9	4.3	1.8	3.9	1.8	4.6	5.2	4.9	3.1	5.0	5.6	8.5	10.4	10.5	3.3	6.1	4.4
24	13.8	7.5	11.8	6.0	6.6	7.7	3.1	5.4	8.5	8.4	9.6	6.5	6.0	14.3	19.6	12.1	19.6	13.7	6.5	11.0	3.8
25	6.2	0.0	4.4	6.2	5.4	0.0	0.0	1.7	0.0	4.8	3.9	1.7	2.0	5.5	6.3	2.2	2.3	5.4	1.3	9.0	1.4
26	9.9	0.0	0.0	5.6	4.5	0.0	0.0	2.2	0.0	4.0	2.6	0.0	2.7	7.1	2.9	1.3	4.1	6.6	1.6	5.3	0.0
27	6.3	2.2	4.5	6.4	3.6	2.8	0.0	3.6	1.6	4.9	4.0	0.0	2.0	3.6	6.4	2.2	4.7	5.5	1.4	9.1	1.4
28	5.8	0.0	2.9	8.1	4.3	0.0	0.0	2.1	0.0	3.8	2.4	0.0	0.0	2.2	4.3	1.3	2.6	3.1	0.0	6.9	1.7
29	1.1	0.0	0.0	0.0	0.0	3.2	0.0	4.2	0.0	0.0	2.3	2.0	5.0	6.5	2.7	1.2	2.5	6.2	0.0	8.5	0.0
30	10.5	4.1	8.7	0.0	1.6	6.9	1.5	14.8	4.7	6.2	3.7	0.0	10.2	10.9	4.8	2.2	3.3	9.5	0.0	7.0	0.0
31	7.3	6.7	8.6	8.1	8.7	5.9	11.3	15.4	9.6	11.0	3.0	7.0	3.1	0.0	2.0	6.9	8.2	2.2	1.1	1.1	1.2
32	11.9	11.5	11.7	7.6	5.3	14.6	7.8	14.5	9.1	9.0	5.8	6.7	10.9	9.9	6.1	3.7	4.8	5.4	1.1	2.2	1.1
33	16.8	11.8	13.5	11.4	7.9	12.1	5.3	10.3	9.8	13.3	11.1	7.8	14.3	13.1	13.1	10.3	15.5	21.1	7.6	11.1	6.9
34	5.6	0.0	5.3	7.3	4.0	1.5	0.0	4.0	1.8	5.5	4.5	0.0	2.3	2.0	2.7	0.0	2.5	6.0	0.0	6.5	1.6
35	6.0	0.0	3.1	8.8	2.3	1.7	0.0	2.3	2.0	8.5	5.4	2.2	2.8	7.3	7.7	2.6	2.7	4.9	3.3	9.3	3.6
36	4.7	0.0	2.9	5.4	2.2	0.0	0.0	2.2	0.0	6.0	5.1	2.1	0.0	4.5	5.9	1.3	5.4	6.5	1.6	8.9	1.7
37	7.9	3.8	5.9	5.5	4.8	0.0	1.4	4.8	2.9	4.3	3.4	3.1	0.0	1.6	4.6	3.1	9.0	6.2	1.2	6.7	1.3
38	7.9	10.0	17.4	5.5	6.5	11.0	11.1	20.0	7.6	14.3	7.1	15.5	3.6	1.6	7.1	5.3	7.8	3.7	3.8	1.3	4.0
39	9.9	7.5	12.0	0.0	1.5	12.2	4.3	7.9	5.8	4.2	5.1	3.0	3.4	6.3	6.9	4.1	4.2	8.8	2.4	10.8	2.6
40	5.6	7.1	9.3	10.5	7.6	2.4	5.6	2.9	8.6	4.1	1.6	2.9	1.6	0.0	4.3	8.3	14.6	7.1	2.3	4.9	5.1
41	7.1	4.0	8.5	7.3	8.6	4.0	3.1	5.0	7.9	3.0	1.8	3.2	3.8	3.3	4.8	7.9	11.9	7.9	3.9	8.5	4.2
42	6.4	2.2	2.3	6.5	5.6	0.0	1.7	0.0	3.3	3.3	2.0	3.6	2.1	7.7	5.1	5.9	10.0	8.6	4.2	12.7	3.0
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	

22	----																				
23	13.7	----																			
24	22.5	21.7	----																		
25	8.9	3.0	10.8	----																	
26	6.2	4.7	8.2	17.1	----																
27	9.0	3.1	11.0	32.5	17.6	----															
28	7.4	5.8	8.0	26.5	15.4	40.0	----														
29	4.7	2.2	1.2	0.0	6.7	2.3	0.0	----													
30	8.6	4.0	6.7	1.8	4.8	3.7	2.2	17.1	----												
31	2.7	4.4	5.9	0.0	1.8	3.0	1.7	1.7	5.8	----											
32	7.3	5.2	6.7	0.0	1.7	1.4	0.0	4.8	16.7	9.8	----										
33	18.4	9.4	18.3	7.1	4.0	4.7	5.3	6.5	11.9	4.9	14.4	----									
34	7.1	4.4	6.2	17.5	13.3	24.3	24.1	2.7	6.4	1.6	0.0	6.3	----								
35	9.1	2.3	3.3	21.2	12.5	18.2	20.8	0.0	0.0	0.0	3.4	6.9	13.8	----							
36	6.2	3.4	6.7	16.7	16.0	28.1	19.2	6.5	2.3	1.8	0.0	3.9	20.7	33.3	----						
37	10.5	10.1	15.1	8.9	11.6	15.4	13.6	4.0	4.9	4.1	1.3	4.3	14.9	6.8	14.0	----					
38	7.1	5.8	8.8	1.7	0.0	3.4	2.0	0.0	6.7	16.7	12.5	8.9	1.9	4.4	2.1	3.0	----				
39	7.0	2.8	7.4	0.0	0.0	1.6	0.0	5.9	10.0	6.8	18.6	12.4	0.0	2.1	0.0	0.0	18.6	----			
40	10.0	5.6	11.8	3.1	1.9	3.2	3.8	0.0	0.0	2.5	2.4	7.3	3.5	2.0	3.8	7.4	2.8	1.4	----		
41	8.5	2.9	6.7	7.4	4.7	5.6	4.4	2.1	3.4	2.8	2.6	6.7	6.2	2.3	7.0	10.2	4.8	1.5	25.0	----	
42	6.7	5.3	7.1	6.1	5.4	6.2	5.1	4.9	3.8	1.5	1.4	2.3	7.1	2.7	8.1	7.3	0.0	3.4	14.3	21.7	----
Sites →	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42

Table 7.3 Jaccard's index of similarity (%) for the different pairs of samples. Dissimilar samples pairs (0%), intermediate similarity (0<JI<14) and highest JI > 14

disturbed and undisturbed sites, and between sites from different community types is also common.

7.3.1.3 Indices of Diversity

Species variation between and among samples is also evident when indices of diversity (Table 7.4) are examined. Although the

Plant Community /site		Simpson's index	Yule's index	Log-series
Undisturbed forest	2	3.68	3.68	4.6
	3	2.67	2.68	5.4
	7	12.64	12.72	14.8
	9	3.43	3.44	10.6
	12	12.66	12.72	11.6
	31	10.78	10.81	13.8
	38	12.14	12.29	20.8
Disturbed forest	6	43.77	44.18	33.1
	8	2.51	2.52	9.0
	11	7.44	7.54	14.3
	13	1.76	1.77	7.9
	32	29.52	29.92	59.2
	33	2.10	2.10	15.9
	39	*infinite*	*infinite*	2352.3
Undisturbed woodland	10	9.84	9.85	7.9
	40	19.02	17.19	17.1
	19	9.64	9.68	23.7
Disturbed woodland	14	*infinite*	*infinite*	1229.3
	20	2.18	2.19	17.3
	41	9.18	9.27	16.5
Undisturbed bushland	16	5.63	5.64	17.9
	17	2.60	2.60	16.0
	21	4.57	4.59	12.1
	23	20.67	20.78	46.7
Disturbed bushland	15	2.47	2.48	26.3
	18	4.84	4.87	25.0
	22	9.47	9.51	33.4
	24	1.29	1.29	16.0
Undisturbed shrubland	5	5.77	5.78	6.0
	42	12.85	13.03	13.9
Disturbed shrubland	1	4.80	4.81	17.0
	4	4.27	4.28	7.5
Undisturbed grassland	27	1.78	1.80	10.6
	29	*infinite*	*infinite*	705.4
	34	1.15	1.16	4.9
	36	*infinite*	*infinite*	666.5
	37	1.64	1.64	9.9
Disturbed grassland	25	1.50	1.51	7.1
	26	1.25	1.26	0.5
	28	4.46	4.62	14.7
	30	6.45	6.58	32.3
	35	3.15	3.27	9.4

Table 7.4: Alpha Indices of Diversity. Simpson's and Yule's indices show a similar pattern. Sites with, mainly, herbaceous species appear highly diverse. Sample-size = 42

results of the three indices suggest a similar trend, Si's and YI's indices are closer to each other than to those of the log-series model. The log-series results suggest that on the average, species diversity is higher in disturbed than in undisturbed sites (Table 7.5). For ease of description high *alpha* cases are excluded from the discussion.

For woody communities, undisturbed forest site 3 and, disturbed forest sites 8 and 13 are least diverse (Si=YI<3) while sites 6 and 33 of disturbed forest and site 23 of the undisturbed bushland are most diverse (Si=YI>20). Also, disturbed bushland sites 15 and 24 are less diverse while undisturbed woodland site 40 is highly diverse. For grassland sites, overgrazed sites 25 and 26 are least diverse (Si = YI < 2) while mediumly disturbed sites (Chapter 5) have a relatively higher diversity (3<Si=YI<7).

7.3.1.3 Plant Structural Characteristics

Appendix A shows that the average heights of herbaceous and woody species lie between 0.01 and 0.68m, and 0.02 and 28.2m, respectively. Estimates of the height of herbaceous plants on the basis of samples, using the means (Table 7.6a) show that grasses are taller for undisturbed than disturbed woody sites, and for woody than grassland sites. Severely disturbed woody sites 14 and 39 register no trees in the more than 1m class (Appendix A). Average heights of woody species in disturbed and undisturbed woody sites are similar. Data tend to suggest that plant size structure has a positively skewed frequency distribution. Thus, there are fewer species in the larger tree category with relatively many individuals.

Community	**Undisturbed**			**Disturbed**		
	Si	YI	LS	Si	YI	LS
Forest	9	8.3	11.7	15	14.7	23.2
Woodland	13	12.2	16.2	6	5.7	16.2
Bushland	8	8.4	23.2	5	4.5	25.2
Shrubland	9	9.4	10.0	5	4.5	12.0
Grassland	2	1.5	8.5	3	3.1	12.8

Table 7.5 Mean *Alpha* indices of Diversity per community category. Si- Simpson's index, YI- Yule's index and LS-Log-series. A total of 21 sites in each category is used.

Examination of diameter classes (Appendix A) shows that there are more stems between 0.02 and 0.5m dbh than those above 0.5m dbh. Generally, tree diameters are higher among undisturbed than disturbed woody sites. This observation is supported with data of wood volume (section 7.3.1.5). Out of 42 plots, 26 have trees/shrubs cut (Table 7.6a). Those with the highest number of trees cut are from mediumly disturbed woody sites, except for one (site 10) from undisturbed woodland (Chapter 5). This observation excludes sites which have been under cultivation for more than 10 years before the time of this study (Chapter 3). This is because of the difficulty in distinguishing the number of trees cut from those that may have died due to exposure following decomposition.

Firstly, on the average (Table 7.6b), browsing is inconsistent

Plant community	Plot	browsed	cut
	2	5	45
	3	40	31
Undisturbed	7	0	7
foret	9	0	36
forest	12	0	0
	31	19	1
	38	3	11
Disturbed	6	10	44
forest	8	0	18
	11	0	47
	13	0	44
	32	1	42
	33	82	55
	39	42	0
	10	108	120
Undisturbed	19	9	43
woodland	40	2	0
	14	10	0
Disturbed	20	10	8
woodland	41	18	9
	16	48	45
Undisturbed	17	19	22
Bushland	21	0	3
	23	9	0
	15	62	7
Disturbed	18	248	0
bushland	22	217	10
	24	8	14
	5	71	4
Undisturbed	42	41	0
shrubland			
Disturbed	1	422	87
shrubland	4	86	56
	27	16	0
Undisturbed	29	0	0
grassland	34	4	0
	36	2	0
	37	5	0
	25	581	0
Disturbed	26	12	0
grassland	29	0	0
	35	5	0

Table 7.6a: Number of browsed and/or cut trees/shrubs per plot. Sample-size=42, see details of sites in each category in chapter 3.

between disturbed and undisturbed sites. However, see Table 7.6a, the highest number of browsed plants is from disturbed sites 1 and 24, and undisturbed sites 5 and 10, which register relatively higher numbers of woody species in the below 1m class (see Appendix A). Secondly, detailed examination of

Community	Undisturbed				Disturbed			
	browsed		cut		browsed		cut	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Forest	8	15	19	18.3	19	31.6	38	19.4
Woodland	40	59.3	54	60.8	13	4.6	6	4.9
Bushland	19	20.8	18	20.8	14	116.8	8	5.9
Shrubland	56	21.2	2	2.8	254	237.6	72	21.9
Grassland	5	6.2	0	0	150	287.7	0	0

Table 7.6b: Mean number and SD of browsed and/or cut trees/shrubs per community category. High deviation is a reflection of extremes in original data (table 7.6a)

original data (Table 7.6a) shows that extremely disturbed sites such as site 14, and undisturbed sites 7, 9 and 12, register no browsing.

7.3.1.4 Wood Resources

Table 7.7a shows the volume of available wood in the 42 plots. It would be predicted that forest community sites will have a much greater volume of wood than successional/intermediate woody community and grassland sites. As may be seen, the situation is rather different. Disturbed forest sites 11 and 39 which experience cultivation, on-going and abandoned respectively, register a very small amount of wood or none. Thus,the wood situation in these plots is similar to that in disturbed woodland (see sites 14 and 20) and the grassland sites or

Plant community	Plot No.	Wood vol(m^3)	average grass(cm)
	2	144.77	16
	3	2299.61	12
	7	1875.16	48
	9	1306.44	105
Undisturbed forest	12	1299.23	0
	31	1625.40	31
	38	1704.16	54
Disturbed forests	6	1545.32	6
	8	332.21	40
	11	179.26	60
	13	414.07	30
	32	231.51	24
	33	278.51	24
	39	0	30
	10	740.62	30
	19	438.85	0
Undisturbed woodland	40	287.30	40
	14	0	35
Disturbed woodland	20	0	18
	41	24.7	10
	16	399.39	25
Undisturbed Bushland	17	618.22	28
	21	963.22	25
	23	51.35	40
	15	72.68	20
Disturbed bushland	18	0	8
	22	113.09	28
	24	120.19	52
Undisturbed shrubland	5	302.64	4
	42	364	12
Disturbed shrubland	1	98.25	8
	4	4.53	2
	27	0.85	25
Udisturbed grassland	29	0	10
	34	0	40
	36	0	12
	37	0	80
Disturbed grassland	25	9.01	6
	26	0	4
	28	6.28	13
	30	0	12
	35	0	9

Table 7.7a: Available (m3) wood and grass height (cm) per plot.

somewhat worse. For grasslands, only a few sites (e.g., 25 and 28) have their wood resources disturbed and, many have no trees to lose. On average (see Table 7.7b), except for grassland sites, the volume of available wood in undisturbed sites is higher than disturbed ones.

Community	Undisturbed		Disturbed	
	Mean	SD	Mean	SD
Forest	1465.0	676.2	425.8	510.5
Woodland	489	188.4	8.2	14.3
Bushland	508.0	382.8	76.5	55.1
Shrubland	333.3	43.4	51.4	66.3
Grassland	0.17	.38	3.1	4.3

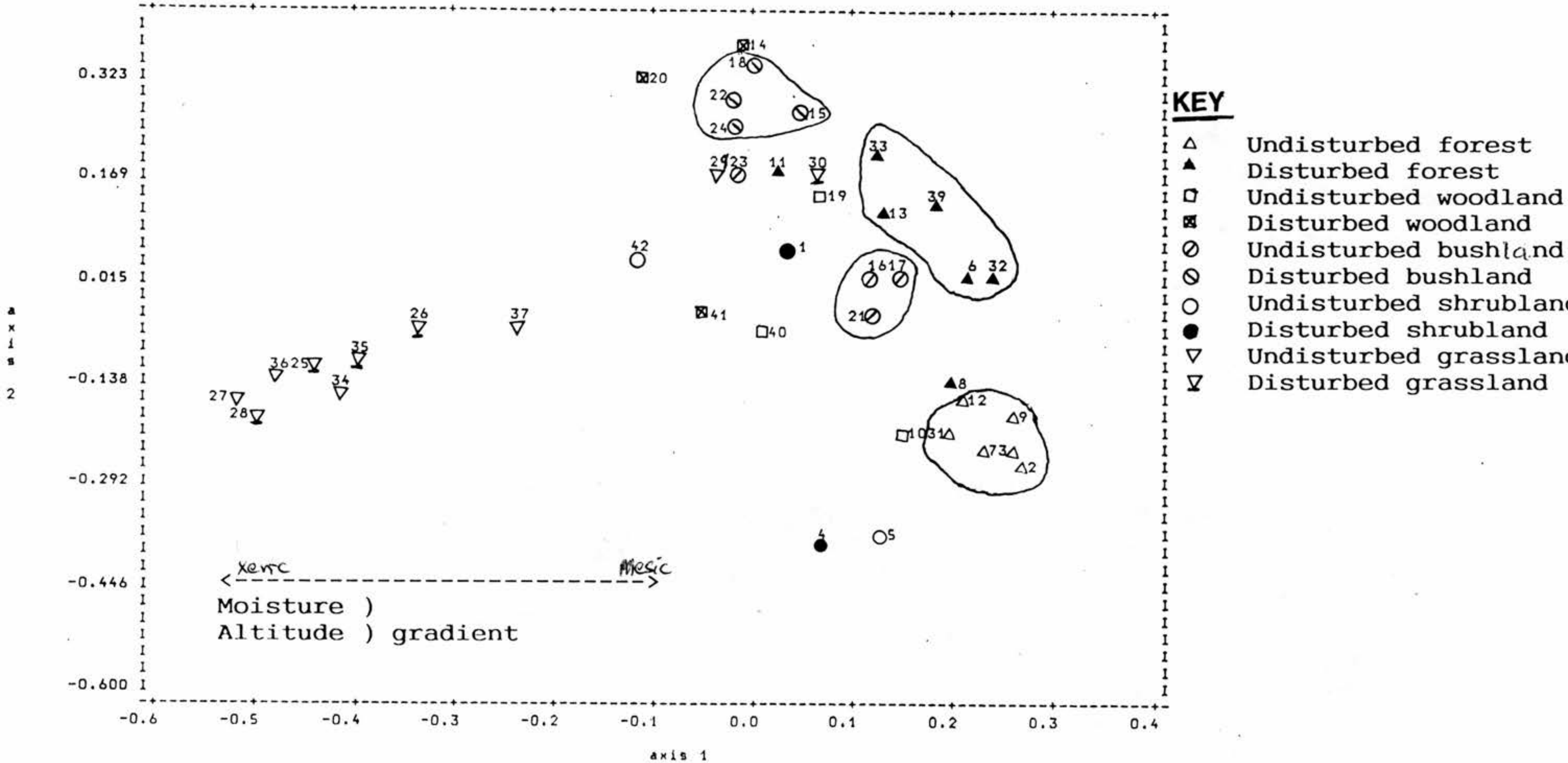
Table 7.7b: Mean amount and Standard Deviation(SD) of available wood (M3) per community category. Except for grassland sites, undisturbed site categories have higher means than disturbed ones.

7.3.2 Vegetation Analysis Results

7.3.2.1 Ordination Results

The results of vegetation analysis using descriptive methods have been reported in section 7.3.1. This section reports the results of vegetation analysis based on multivariate techniques. Most ordinations produce axes that can be interpreted in terms of variations in environmental and historical factors, mainly to three dimensions. In this study, the first two axes, although they have a small percentage in variation (Fig. 7.2), are used because they contain almost all the interpretable information.

Three patterns are evident in the ordination space. Firstly, there are diffuse clusters of samples from the same community suggesting existence of diffuse similarity in species composition. Secondly there, are sample ordinations that suggest a pattern associated with rainfall/soil moisture gradients. The isolines of average rainfall, carbon, nitrogen and zinc (Figs. 7.6 to 7.9) in the ordination space increase



Points coinciding with 12
38

Fig. 7.2 The pattern of sample sites on a two-dimensional ordiation produced by PCO using the sample matching (Jaccard's) coefficient for similarity. Disturbed forest and bushland sites are isolated from undisturbed ones along axis 2.

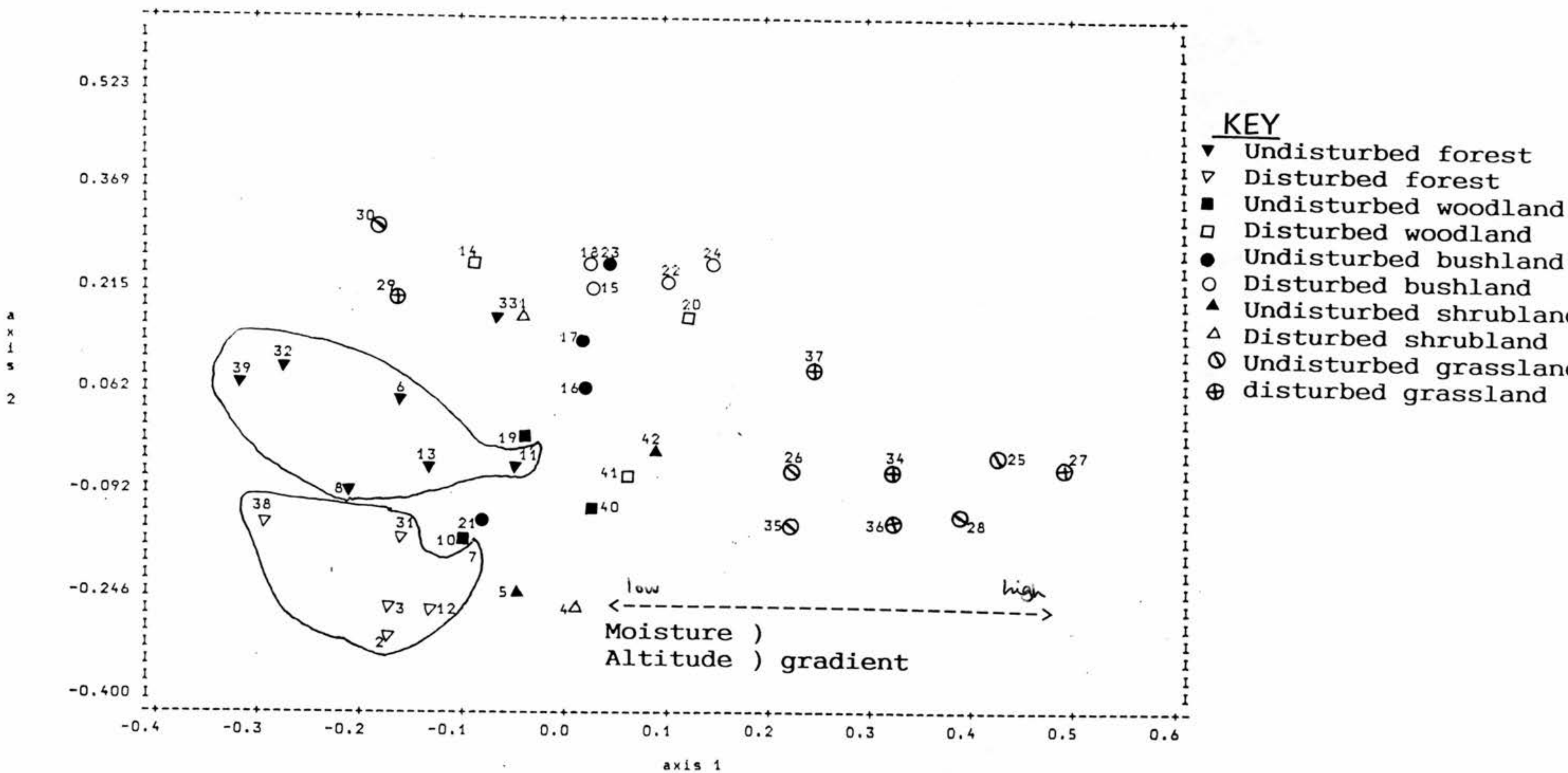


Fig. 7.3 PCO sample ordination based on the number of individuals per species. Disturbed and undisturbed sample categories, diffusely isolated from each other

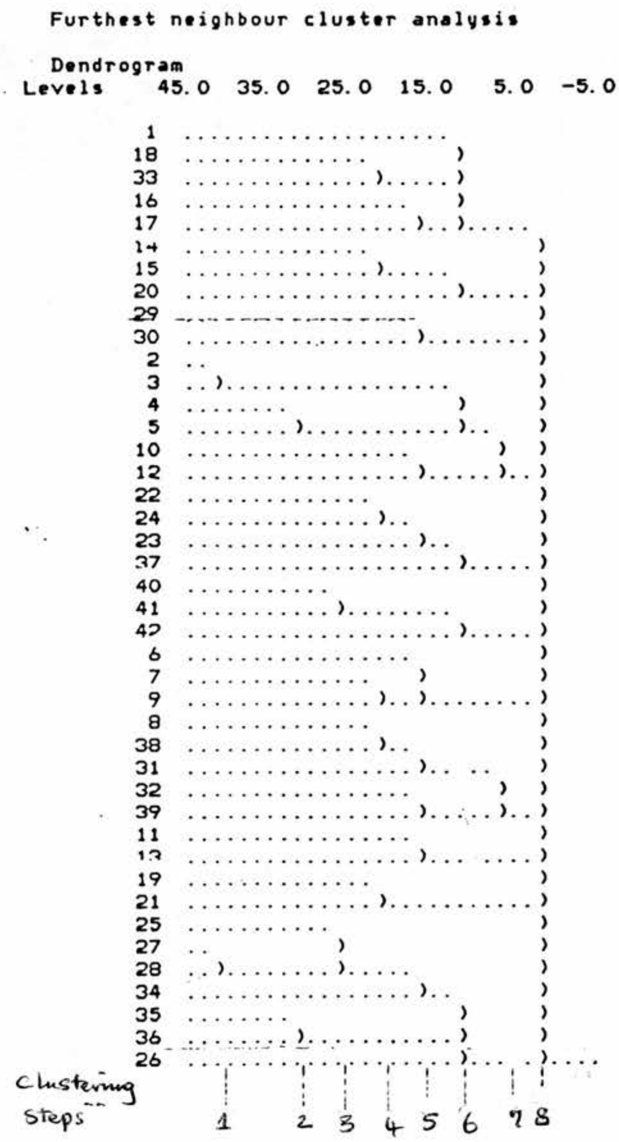


Fig. 7.4 Furthest **neighbour** hierarchical cluster analysis of sample association based on species type. With reference to Fig. 3.8, in the first steps the samples cluster on the basis of closeness. The influence of human disturbance on forest and woodland sites emerges at later stages (6.87). Levels = % similarity

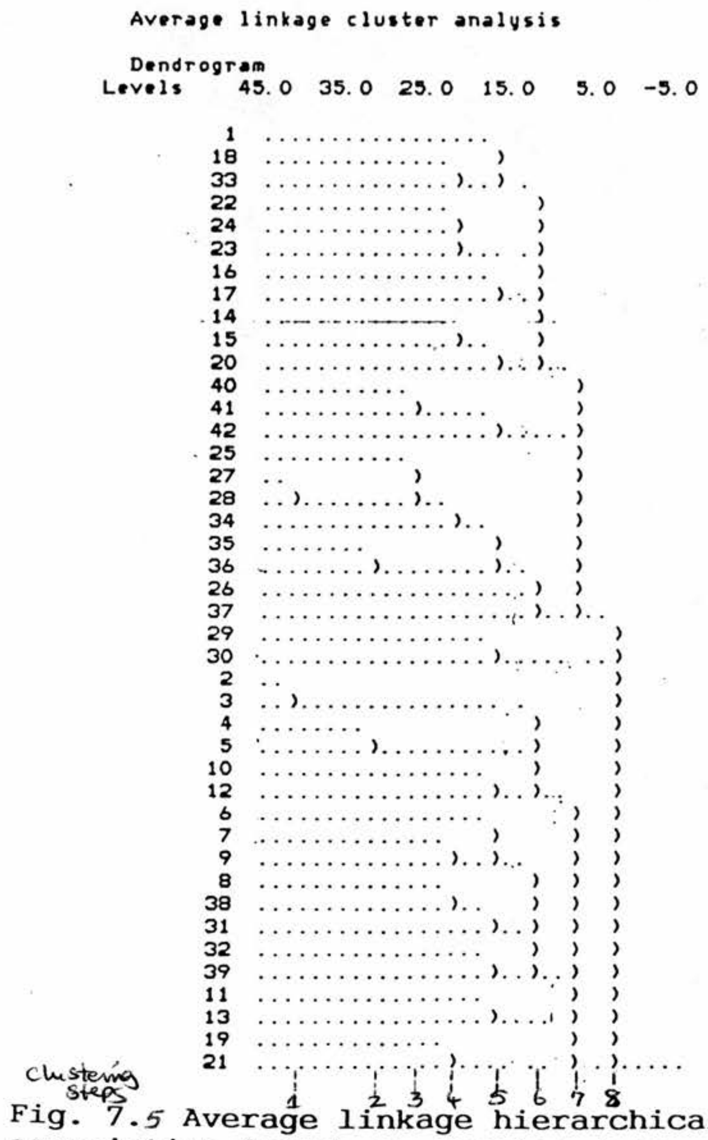
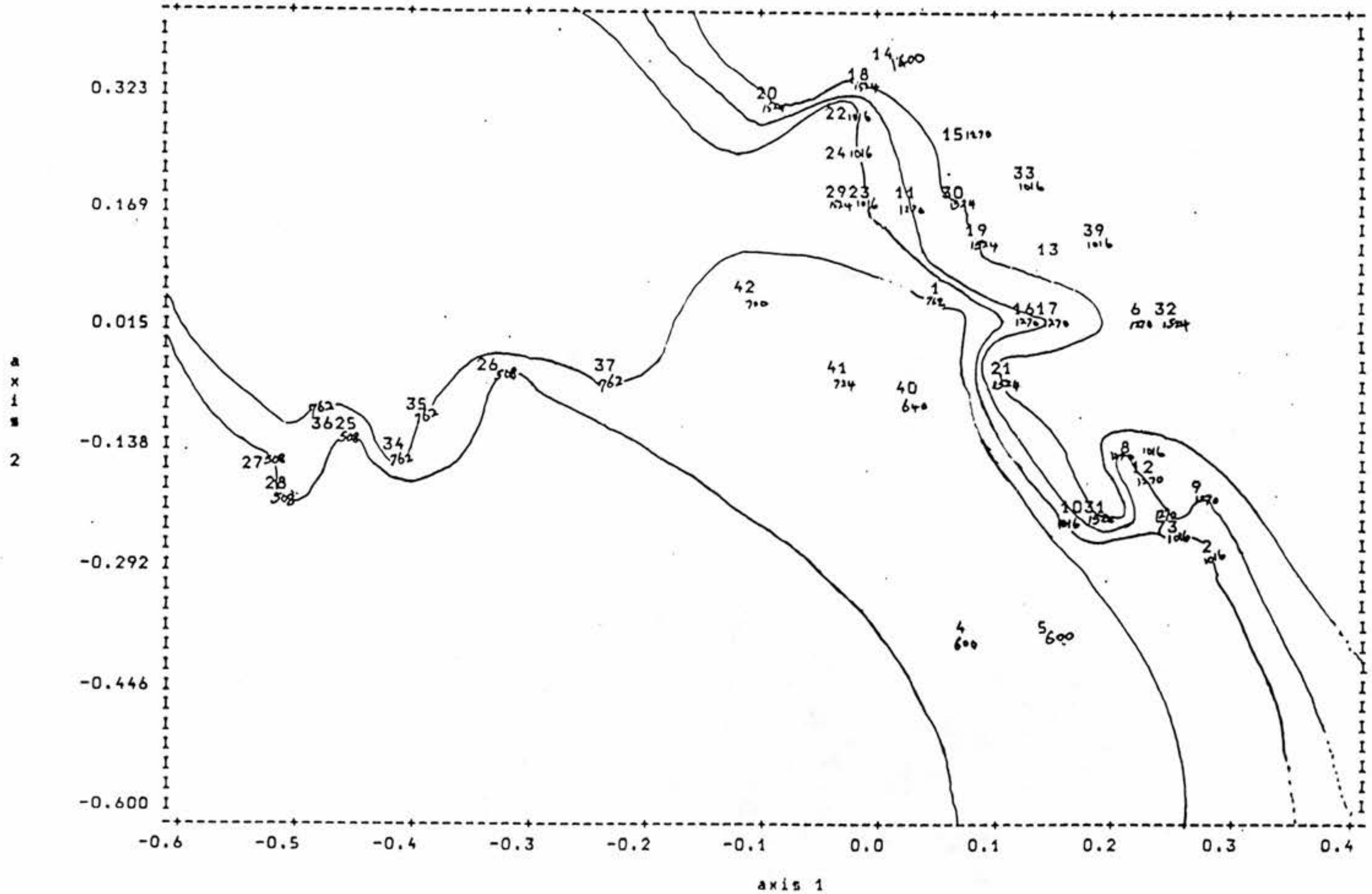


Fig. 7.5 Average linkage hierarchical cluster analysis of samples association based on species type. With reference to Fig. 3.8, samples cluster on the basis of closeness. The influence of human disturbance emerges at later stages (6-8) see clustering of forest and woodland sites. Levels equals to similarity



Points coinciding with 12
38

Fig. 7.6 Average rainfall isolines plotted on a two-dimensional ordination based on species type. As may be predicted, there is a gradient from left middle (plains) to the right (upland sites). Isoline 762 separates shrubland and grassland sites from the rest.

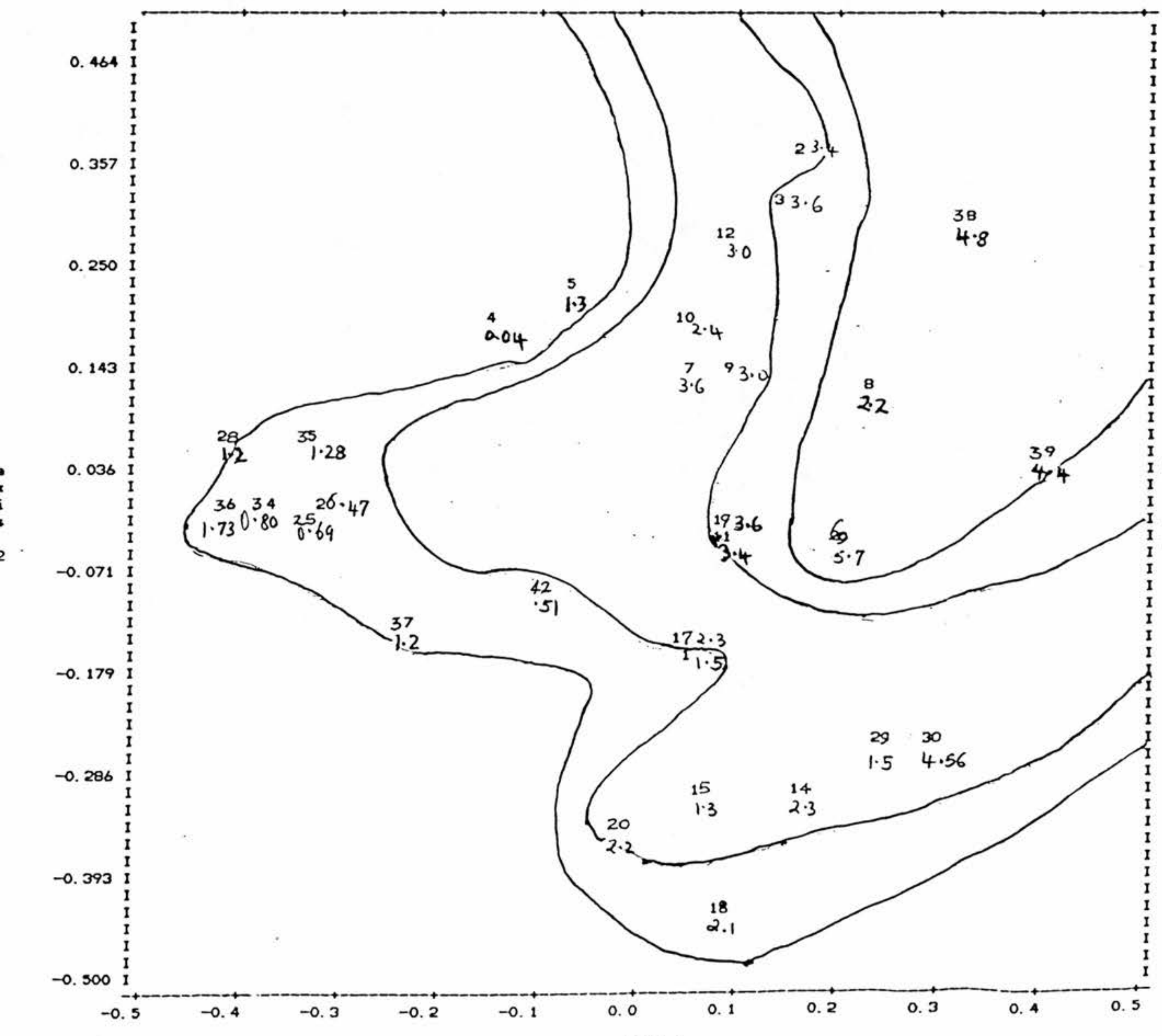


Fig. 7.7 Average organic carbon isolines plotted on a two-dimensional ordination based on species type. Carbon increases from the left (grassland sites) to the right (woody community sites) suggesting an increase in biomass.

from the bottom left to the top right. Also, the correlation between vegetation vectors based on species presence-absence data and average rainfall, carbon, nitrogen and zinc are 0.51, 0.52, 0.65, and -0.81 (Table 6.3), respectively. The ordination of samples with both vegetation and soil data gives a pattern which is fairly similar to that of soil variables (Figs. 7.10a and 7.10b), suggesting that these two are interdependent (Chapter 3). The third pattern suggests the influence of human disturbance. Ordinations along axis 2 distinguish, mainly, undisturbed forest and bushland sites from disturbed ones (Fig. 7.2).

Further examination of Figure 7.2, suggests an involuted pattern, normally called an arch or horseshoe effect (Digby and Kempton 1987; Greig-Smith 1983; Gauch 1982). The use of the Manhattan equation, which is additive, eliminates the arch effect (see Fig. 7.3) but makes interpretation of ordinations difficult, leading to the abandonment of this line of investigation.

7.3.2.2 Classification Results

Figures 7.4 and 7.5 show the fusing of different sample clusters using average-linkage and furthest neighbour cluster strategies, respectively. The sequence of the samples is indicated along the abscissa. The levels 45% to -5% on the ordinate indicate, retrogressively, less finer clusters into increasingly heterogeneous groups. The two cluster strategies produce similar cluster patterns. Figures 7.10a and 7.10b are clusters of samples

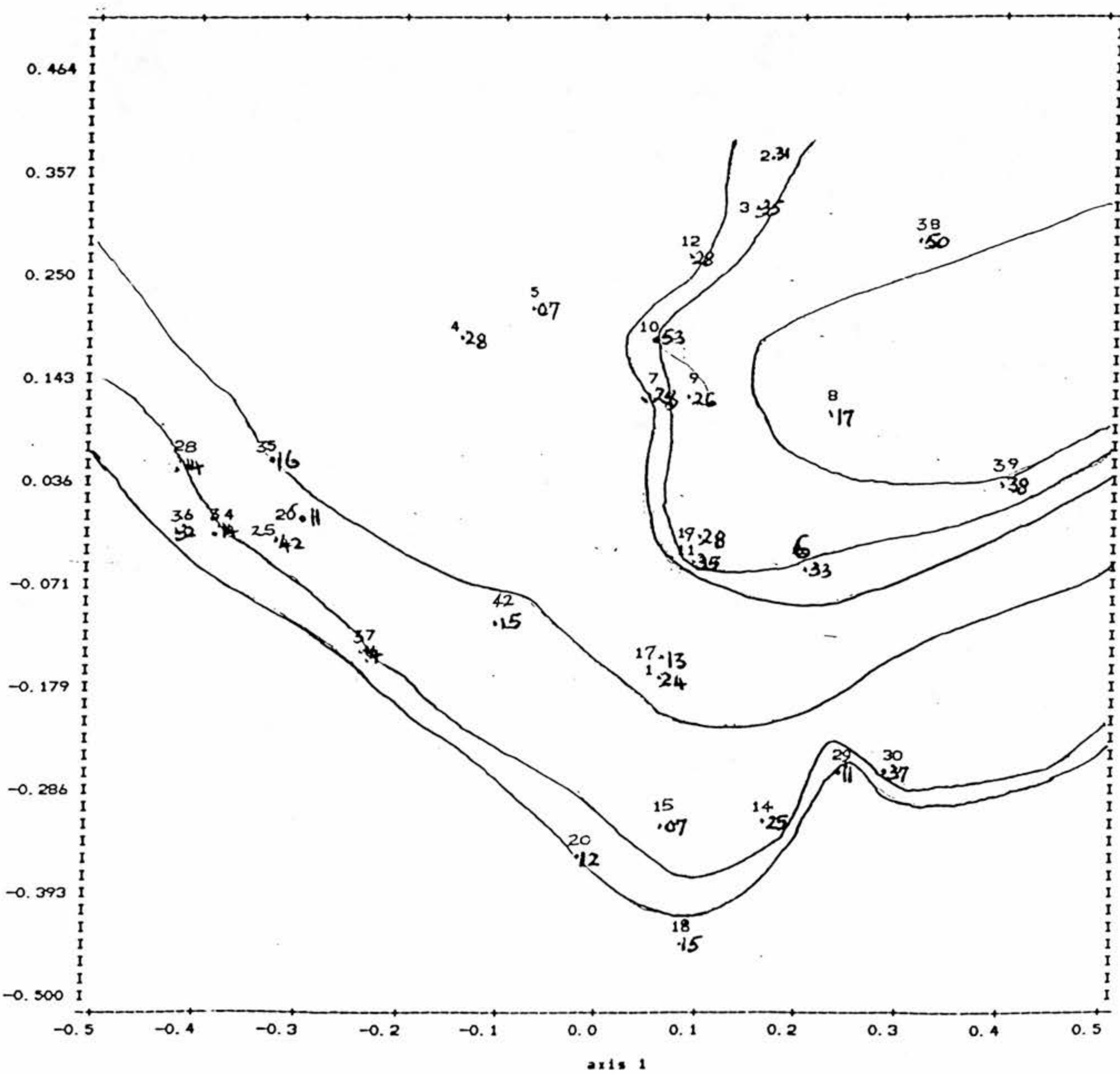


Fig. 7.8 Average soil nitrogen. Isolines plotted on a two-dimensional ordination based on species type. Nitrogen increases from the left (grassland sites) to the right (woody community sites) suggesting an increase in biomass.

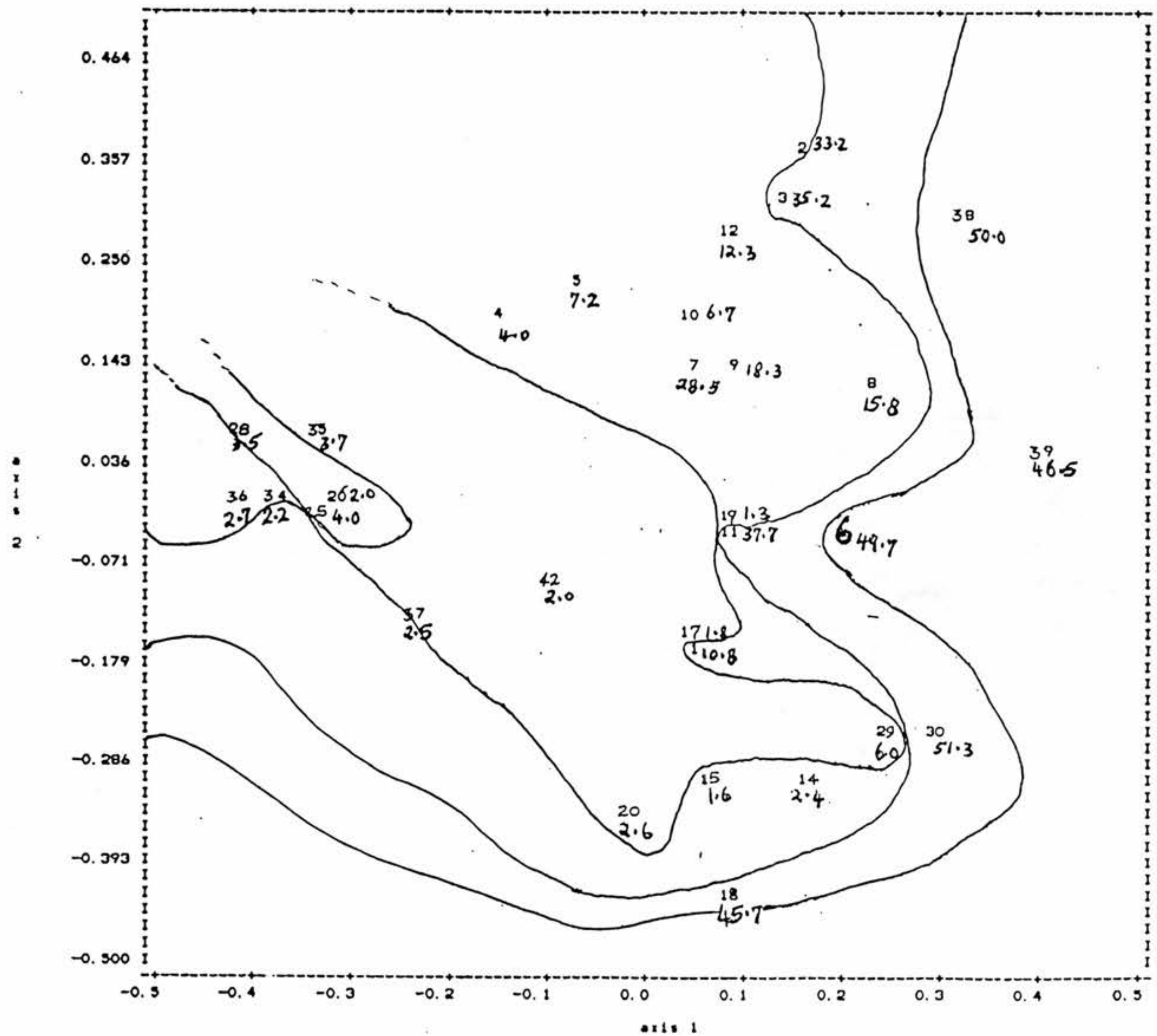
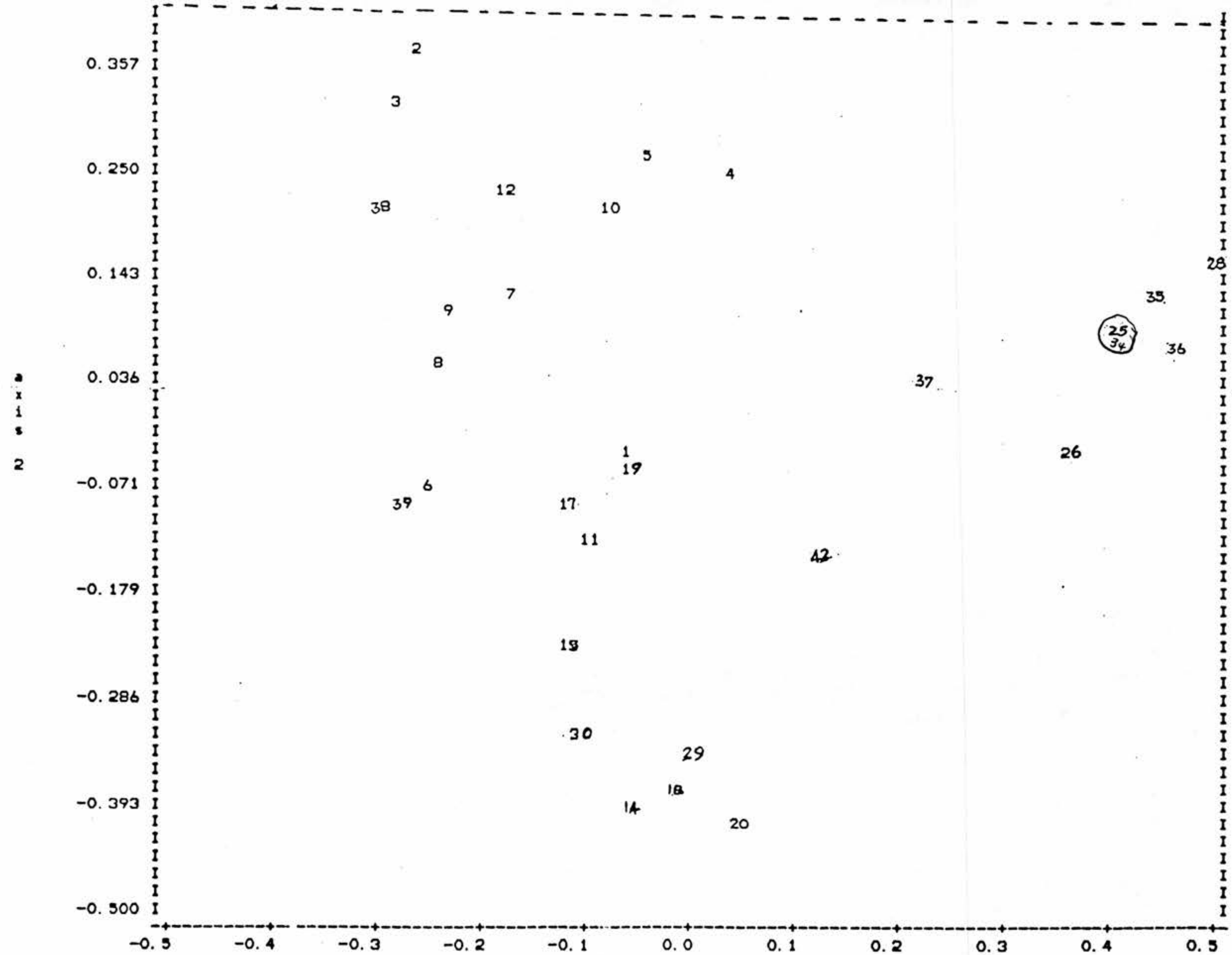


Fig. 7.9 Average zinc isolines plotted on a two-dimensional ordination based on species type. There is a general increase from the grasslands to the uplands in Trans-mara and Mau.



Points coinciding with 25
34

Fig. 7.10a PCO ordinations of samples with soil data based on the number of individuals per species. The pattern is unclear to be generalised for the different site categories.

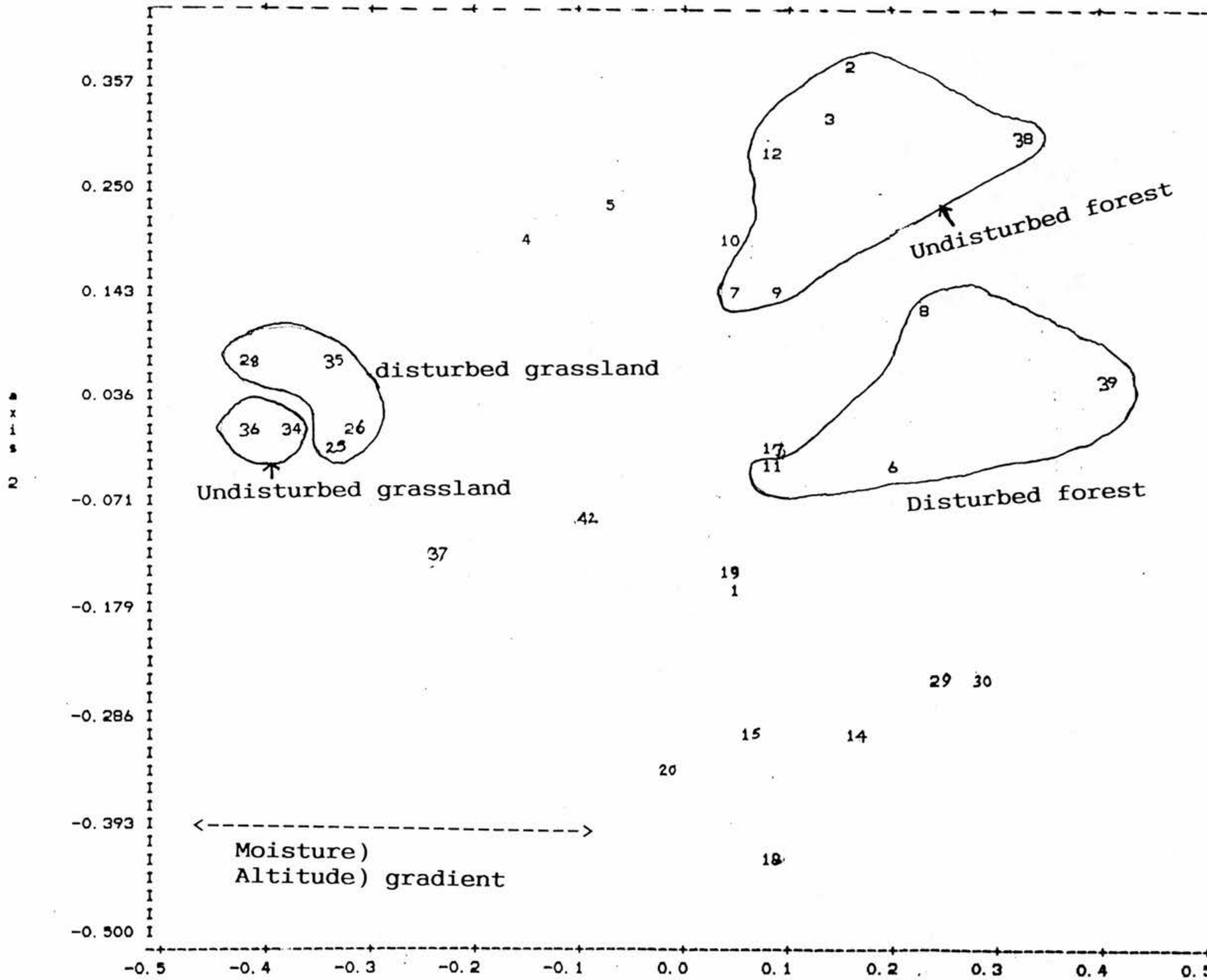


Fig. 7.10b PCO ordinations of samples with soil data based on species presence-absence. Grassland and forest disturbed sites are isolated from undisturbed ones.

with both vegetation and soil data. Using Figures 7.4 and 7.5, samples are fused on the basis of two factors. At the initial stages, proximity appears to be the main factor of clustering. At later stages, the influence of human disturbance starts to emerge.

Generally, closely located samples such as 2 and 3, 4 and 5, 27 and 28, and 35 and 36, with compositionally similar species, are fused first. These are followed by those with less similar species composition and geographically far apart (Fig. 3.8 in Chapter 3). Subsequent clusters involve a combination of 'synthetic' and original samples. At the 8th computation eight and eleven clusters can be identified for average-linkage and furthest neighbour strategies, respectively. At this level, a number of samples from the same community, begin to cluster on the basis of either rainfall/soil moisture gradient or human disturbance. With reference to preliminary classifications of vegetation (Chapters 3 and 5), some samples appear misclassified (Figs. 7.4 and 7.5) and are treated as outliers in the analysis.

7.4 DISCUSSION

The purpose of this section is to suggest the factors determining the structure of vegetation data and to relate the findings to ecological concepts that are useful to this study. The findings are used in chapter 8 to suggest which human disturbances can be manipulated for the management of vegetation in the study area.

7.4.1 Vegetation Description

7.4.1.1 The Number of Species and the Individuals per species

The use of the mean number of species and of species diversity as estimates to distinguish between disturbed and undisturbed sites, is not effective. The results are inconsistent and they don't reveal extremities in data which are significant in understanding the impact of different disturbances on vegetation. Therefore, original data in Table 7.1a and Appendix A are used in this discussion.

The first observation is that samples such as 1, 22, 24 and 33, with a high number of species, are among the most diverse. These sites have fewer dominant species, structurally or sociologically. From chapter 5, these sites are identified as mediumly disturbed. For instance, they have small gaps *in situ* and large gaps including cultivated farms in the neighbourhood. As the sites become dominated with herbaceous species (see sites 14, 29 and 42), given the sampling method, diversity increases. The second observation is that some samples with fewer species are less diverse. One group in this category with sites such as 2 and 3 is dominated with late successional woody species. The other group with sites such as 4 and 13 is dominated by weedy plants. From chapter 5, disturbance in sites 2 and 3 is described as low while in sites 4 and 13 it is described as high. These two observations suggest that the status of a site, disturbed or undisturbed, is important in determining whether it is the number of species or diversity that has to be prominant. Therefore, both diversity and the number of species can act as estimates of site history/status. From this assumption emerges the aspect of space, seen as a resource. For instance, space supporting mature woody species cannot be highly diverse.

Detailed examination of the number of species and species diversity on sample basis (Table 7.1a and 7.4), suggest that the pattern of the number of species and species diversity cannot be readily generalized. However, the observed patterns can be explained on the basis of human disturbance characteristics (Chapter 5). Low disturbance or the lack of disturbance, for instance in sites 2 and 3, leads to resource monopolization through competitive exclusion or limited habitats for pioneer species, ensuring dominance of certain climax species (Denslow 1980; Goldsmith *et al.*,1986; Grubb 1977; Connell 1978). The observed low species diversity for most undisturbed woody sites, therefore, suggests dominance, physiologically or sociologically, of a few woody species. This assumption is supported by the relatively fewer, mainly woody, species in sites 2 and 3 (Table 7.1a; Appendix A) in the more than 1m class, but with a high number of individuals per species.

In contrast, high disturbance devastates site conditions limiting regeneration and establishment potential of late colonizers. Uhl (1987) and Adedeji (1984), for instance, argue that severe disturbances kill and/or remove biomass *in situ* and reduce regeneration by devastating site conditions including soil fertility (see also chapter 6), rootstocks and seeds. This situation may explain the small number of species and low diversity in disturbed forest site 13 which is under cultivation, and overgrazed shrubland site 4 and grassland sites 25 and 26 (Chapter 5).

Medium disturbance on the other hand, leads to high species diversity. As indicated earlier, mediumly disturbed sites such as 1, 6, 22, 23 and 32 with small ($3cm^2$-$4m^2$) gaps, common *in situ* or large gaps (>1/4ha) rare outside register the highest number of species and are somewhat diverse (Tables 7.2a and 7.5). This observation agrees with Connell and Slatyer's (1977) intermediate theory of species richness which states that medium disturbance leads to maximum species diversity because it attracts both successional and climax species. At intermediate levels of disturbance, all dynamic phases of a community are well represented by area (Connell 1978; Ashton 1989).

The creation of an evolutionary setting for specialization in regeneration niches (Grubb 1977; Lawton and Putz 1988), and the delay or relief of competitive exclusion (Pickett *et al.*,1987; Connell 1978; Goldsmith *et al.*,1986; Huston 1979) are some of the ways through which intermediate disturbances promote species diversity. Extreme disturbances (too low or too high) reduce the range of potential opportunities for species colonization and are detrimental to species richness and diversity.

High species diversity in site 23 (Masurura) which, over 20 years ago, was a mine, further demonstrates the influence of disturbance intensity on vegetation recovery. Mining like quarrying, is a large-scale disturbance (Chapter 5) which affects vegetation through total removal of plants *in situ* and by burying under others. However, subsequent abandonment of mining has attracted woody species to the extent that the site is characterized by high species diversity compared to the surrounding area. These include clumps of bushes, dominated with herbaceous species, protruding from abandoned mines and on residue deposits. The increase in soil moisture and soil depth following accumulation of soil and rock deposits and the creation of ecological niches are perhaps the factors behind the high species diversity. In the neighbourhood of the abandoned mines, the soils are shallow (in some cases they are less than 20cm) and poorly vegetated.

The effect of disturbance intensity on floristic characteristics, is also evident in site 6 which is an abandoned farm. The site which was selectively cleared for cultivation following encroachment of Sasimua forest (Chapter 2), has re-established itself within a period of about 8 years leading to high species diversity. From Appendix A out of 48 species recorded in this site, more than a third are indigenous woody species. Undoubtedly, trees spared during cultivation have served as sources of seedlings for rapid recolonization. Similarly, site 33 which lies on the foothills of Maasai Mau has been selectively cleared. Trees are extracted for domestic use in settlements surrounding this site. In the neighbourhood there are abandoned farms. Also, the ease of recolonization of this site supports the high number of seedling sources. Out of

65 species in site 33, 31 are woody (Appendix A). It was observed that the largest number of woody individuals lies between 2 and 5m high suggesting forest recovery. Species such as, *Olea africana, Rhus natalensis Teclea simpilis* and *T. nobilis* show highest recovery. These species have representatives in the mature stage *in situ* and/or in proximity.

The impact of cultivation on vegetation is different depending on whether or not it is continuous. *In situ* effects include a decrease in the number of species and/or the dominance of herbaceous species. To begin with, cultivation involves total or selective removal of vegetation. This means loss and/or contraction of the community involved. From Figures 5.3a and 5.3b in chapter 5, for instance, over the study period the area under natural vegetation decreased by 27 km^2. Although this figure is small, at the District level, vegetation loss to cultivation is very remarkable. For instance, the expansion of cultivation in Ngorengore-Loita is associated with widespread clearance of woody communities in Mau Narok and the destruction of grasslands for wheat and maize farms. Subsequent effects of the expansion of these farms include a decrease in grazing land and the concentration of animals in the plains. This situation leads to the loss of palatable plant species and bush encroachment (Chapter 4). Overally, cultivation reduces species diversity by attracting continuous germination gradually exhausting the seedbank. This effect accounts for the lack of woody species in sites 14 and 39 which are experiencing cultivation, on-going and abandoned, respectively.

The relatively high number of species in sites 27 and 37 compared to those in sites 26 and 35 (Table 7.1a) may be associated with heavy grazing in the latter (Chapter 5). This is because heavy grazing retards the potential recovery particularly of herbaceous plants by removing photosynthesizing and reproductive parts of the plant. From Table 7.6a and Appendix A, overgrazed sites have the least average grass heights. This means that seed production is hampered. A number of plant species are killed by trampling while some are uprooted. Overgrazing like cultivation is a continuous disturbance. Other than destroying the seedbank, at most, it attracts opportunistic less valuable species (Chapter 4).

The seriousness of overgrazing is the lack of selectivity. For along time, a host of domestic and wild herbivores through selective grazing maintained an ecological balance with herbaceous communities. For instance, nomadic pastoralism involved seasonal movement of livestock following fluctuations of pastures, among other factors (Chapter 2). Also, the grasslands have been characterized by seasonal migrations of wildlife (Chapter 5). Thus, the vegetation would recover from animals activities. However, the addition of both livestock and wildlife or the replacement of grazing land with cultivation has upset the ecological balance leading to continuous grazing of palatable species. Thus, the plants are not given chance to recover. This situation leads to the death of palatable plants, especially those without underground food storages. In sites 25 and 26 where these species have been reduced, the animals are forced to feed on less palatable species or to browse on trees and shrubs, which they normally avoid. This pressure is responsible for the low number of even woody weed species in the plains. As observed by Lamprey (1985:225) "continued overgrazing may completely eliminate several species from a community or may reduce them to a low density". In time, soils are exposed through long-term vegetative cover destruction. By affecting soil conditions, overgrazing induces edaphic drought so that the original plants are replaced by disturbance-tolerant species (Chapter 4, see also Grime 1979) or the ground is left bare.

Destruction of shrubby species at Eorekule (site 4)-Mosiro by browsing and trampling following overgrazing accounts for the few plant species and the spreading patches of desert-like conditions. For instance, 86 out of 172 woody plants recorded in site 4 are browsed (Table 7.6a). The high number of weedy species, mainly *Acacia drepanolobium* and *Tachonanthus camphoratus* (Appendix A) is evidence of overgrazing. Also, colonization by a number of opportunistic dwarf shrubs and annual herbs adapted to disturbed soils at Maji Moto (sites 25 and 26) is an indication of overgrazing and reduced fertility (Chapter 6). Other overgrazing indicator species include *Microchloa kunthii, Solanum incanum, Harpachne schimperi, A. drepanolobium* and *Aristida adoensis*. It is suggested that the large number of these species, is an indication of the replacement of a perennial grassland by an annual grassland or by a bushland community. For example, the dominance of woody weed species in site 4 is an indication of bush encroachment (Chapter 4, see also McNaughton 1983).

Other than low disturbance, it is further postulated that the small number of species in undisturbed forest sites 2 and 3 could be due to their isolation from seedling sources. Both sites, which are relatively intact, are located in private forests which are surrounded with settlements and farms. For instance, site 3 lies in a forest which supports *Olea africana* as the climax species and *Teclea nobilis* and *Rhus natalensis* occupying the third layer. *T. nobilis* appear suppressed, waiting for its time to take over from aging *O. africana*. Although the site experiences selective tree cutting and browsing (Chapter 5), the gaps created remain vacant. Therefore, it may be suggested that inhibition of seedling recruitment to these gaps is due to both *in situ* factors such as shade and proximity factors such as lack of seed sources or simply because the gaps are too small to allow recruitment of *in situ* colonizers. The influence of proximity on species composition, is well illustrated by indices of similarity (see below). Proximity factors such as patch specialized species, extension of canopy and seed source are important in determining gap recolonization (Bazzaz 1983, 1984; Begon *et al.*,1990). Although browsing is recorded in site 2 and 3, this study does not perceive it as the force behind lack of seedling recruitment since it is infrequent.

7.4.1.2 Samples Association

Indices of similarity offer further insights into the factors influencing species composition in the different site categories. Lack of similarity (Table 7.2) characteristic of sample pairs 2 and 11, 29 and 25, 28, and 35, and 14 and 40 may be explained in two different ways. Firstly, these sample pairs are geographically far apart (Fig. 3.8). This means that they offer apparently homogeneous but basically distinct ecological conditions which are therefore suited to different plant lifeforms (Chapter 3). Dissimilarities between sites 29 and 30, from the uplands, and the lowland grassland sites, for instance, support the view that distance and climatic factors have an overriding influence on floristic characteristics over most environmental factors including human disturbance.

Secondly, on the whole these sample pairs represent the opposite ends of a disturbance continuum (Chapter 5). Except for site 28 paired with 35, the first site in each pair is undisturbed while the second is disturbed. This suggests that they offer niches suited to different successional plants. Undisturbed sites are dominated, mainly, by late successional species whilst those disturbed are dominated by pioneer or opportunist species (Appendix A).

Intermediate similarity between and among most sample categories is an indication that the vegetation in the different sites is highly diverse, with only a few species regionally represented. Therefore, there are many rare species making up most of the sample populations. This assumption is supported by edaphic and climatic heterogeneity in Narok District (Chapters 3 and 6) and differences in temporal and spatial patterns of human and natural disturbances (Chapters 2 and 5).

Highest similarity characteristics of closely located sample pairs suggest the influence of proximity in floristic characteristics. For instance, sample pairs 2 and 3, 4 and 5, 25 and 28, and 14 and 15 are (geographically) closer to each other (see Tables 7.2 and 7.3, Fig. 3.8 in Chapter 3). It may be assumed that closely associated species interact by sharing niches in space. This observation may also suggest the possibility of a previously or otherwise continuous plant assemblage. This is true for sites 2 and 3 which are from adjacent private forests at Nairagie-Ngare which until 1960s was a single forest (Ole Leposo and Ole Munte pers. comm.). Also, sites 4 and 5 are from adjacent shrubland communities at Eorekule.

Although percentage similarity between some site categories is very close, examination of floristic composition (Appendix A), reveals that the species shared are physioecologically different. For instance, sites 2 and 3 share, mainly, late successional woody species such as *Olea africana* and *Teclea nobilis* while sites 4 and 5 share, mainly, weedy species such as *A. drepanolobium, T. camphoratus* and *Asparagus africana.* This observation, firstly, presupposes that the factors affecting plant species in the different samples overlap suggesting continuous rather than discrete distribution of plant species. Secondly, with reference to sites 4 and 5, it may be suggested that some disturbed sites are quite similar in microconditions to undisturbed ones. However, we can see that the gaps in these sites are selective of the quality of species they support. Further, with regard to the second suggestion, it may be assumed that taxa for the specific sites have only been little changed but not eliminated. This assumption may be supported by the relatively recent large-scale human influence in Narok District. This observation helps this study to reject proximity as the only factor influencing floristic characteristics and, supports the contribution of human disturbance.

Detailed examination of the frequency distribution of species in sample pairs tends to suggest that disturbed sites offer a wider niche for the colonization of weedy species than undisturbed sites (Table 7.8). Some of the ruderals and/or commensals are recorded only in disturbed sites. Dominant colonizers such as *Indigofera spp, Erlangea cordifolia, Commelina benghalensis, Achyranthes aspera, Cynodon dactylon, Euclea spp, Solanum incanum S. nigrum* and *Asparagus africana,* occur across disturbed and undisturbed sites. Most of these are among the common weeds of East Africa (Ivens 1967; Belsky 1987), which grow on disturbed soils. Their widespread distribution tends to overrule the influence of mainly environmental factors. Instead, it pressupposes the influence of disturbance, natural and/or human. Some ruderal species such as *S. incanum* and *C. dactylon* have been identified in climax vegetation and on naturally as well as on human disturbed sites (Belsky 1987). It may be suggested that for these species, disturbance source is not significant for their distribution.

Species	Disturbed sites	Undisturbed sites
Tagetes minuta	9	0
Eragrostis tenuifolia	9	5
Commelina benghalensis	13	3
Pennisetum clandestinum	13	1
Solanum incanum	16	5
Cynadon dacylon	10	7
Acacia drepanolobium	5	1
Aristida adoensis	8	3
Asparagus africana	7	10
Pennisetum schimperi	7	4
Rhus natalensis	9	8

Table 7.8: Some species associated with disturbance in different samples, and their relative frequency of occurrence.

Although disturbed and undisturbed woody sites register more or less the same number of species, they share only a few species. This is particularly in the greater than 1m class (Appendix A). This is because the original canopy species in disturbed sites have been removed except those poor or fluted trees left during past selective clearing. For instance, although site 38 paired with sites 8 and 39 have SI>30% and JI>14%, the common species are mainly ruderals (Appendix A).

Similarity between most disturbed forest sites and the other woody community sites (Tables 7.2 and 7.3) may suggest that the former are at a transitional stage of development closer to most sites from intermediate communities, having moved down the successional scale. This movement simply involves a release of space which supports secondary successors and pioneer species.

In this section the fewer species and low diversity in undisturbed and highly disturbed sites have been explained on the basis of resource availability. Undisturbed sites monopolize resources while highly disturbed sites impoverish resources and seedbanks. Conversely, the large number of species and the high diversity in mediumly disturbed sites has been attributed to the release of resources for recolonization by both late and secondary successional species. Also, similarity between and among sample categories has been explained on the basis of proximity. This means that environmental factors in the sample pairs are similar and/or the site history has not changed much following human disturbance. The following section discusses the factors attributed to plant structural variations.

7.4.2 Size Structure and Recruitment Trends of Woody species, and the Height of Herbaceous Plants

The observed variation in species size distribution in class heights (section 7.3.1.3, see also Appendix A) is attributed to different factors. For undisturbed woodland and bushland sites variation in the number of species in the greater than 1m class may be due to past selective cutting of the best mature species. For instance, only four out of 14 samples in these community types do not register selective tree cutting (Chapter 5). A majority of these sites (e.g., sites 10, 19 and 40) are located in semi-pastoral areas where high species diversity allows selective wood harvesting. On the other hand, sites such as 14, 18 and 20, particularly in permanently settled areas, have lost most of their trees to cultivation and/or excessive harvesting (Chapter 4) such that they are characterized by open canopies. Sites 14 and 18 have limited or lack undershrub layer because of total clearing for cultivation. These sites hardly register any plants in the greater than 1m class. Thus, vegetation recovery is being inhibited by continuous disturbance (Chapter 5, section 7.4.1.1). This explanation also applies for the observed species size variation in disturbed forest site 39.

Further, differences in size structure distribution may be associated with on-going recovery following the exclusion of large herbivores, mainly buffaloes and elephants (Chapter 5) or the withdrawal of livestock due to tse-tse invasion.

Structural variation due to vegetation recovery is well illustrated by the high regeneration in bushland sites 16 and 23 and woodland site 10 (Appendix A) because of reduced browsing by elephants or reduced burning, grazing and trampling following the withdrawal of livestock from tse-tse infested areas (Chapter 4). The density distribution of animals in bushland and woodland communities is generally low (Chapter 5). In addition, it will be recalled that woody regeneration in site 23 is associated with abandonment of mining. This means a release of resources for woody species. These findings explain why the data for these sites have a size distribution heavily biased towards the under 1m height class. Suffice it to say that subsidence or withdrawal of disturbance is partly responsible for the recovery of woody species. This hypothesis does not hold for sites 4, 26 and 35 which are experiencing overgrazing and trampling because of the high numbers of animals (Chapter 5). Consequently, woody re-invasion in these sites is associated with reduced competition (from herbaceous species) for water and soil nutrients (Chapter 4).

It needs to be understood, however, that a high number of seedlings is not in itself evidence of vegetation recovery. Although seedlings are not removed or killed, their growth is severely inhibited by extensive utilization. Thus, the seedlings are effectively kept below 1m height through the combined impacts of browsing and trampling. In intermediate woody communities (sites 1, 5, 10 and 24), seedlings were observed to have a lot of scars suggesting that they are repeatedly disturbed. These sites are frequented by mediumly sized and small wild herbivores, and domestic herbivores mainly goats and cattle (Chapter 5) which, mainly, clip newly formed shoots. Except for site 1, the rest are located in undemarcated parts of the District where free range grazing is common. Thus, the sites are selectively and seasonally grazed many times allowing vegetation recovery. Also, most of these sites lie in the semi-nomadic pastoral areas where shifting cultivation is, at most, in the inception. Therefore, it may be argued that while animal activities allow germination and recruitment of seedlings into the browse class (<1m), seasonal or continuous browsing keeps them from advancing to maturity. For instance, animal foot prints and dung are suitable habitats for seedling recolonization. In different communities, microsites associated with mammal diggings support woody species, perhaps, because of accumulation of water, detritus and nutrients following sheet wash. These sites are significant in the semi arid plains where surface cappings are common. Also, animals disperse propagules from place to place (Begon *et al.*, 1990).

Therefore, the below 1m browsed trees/shrubs do not necessarily die, but they are delayed or prevented from being recruited into the next higher class. For instance, disturbed bushland sites 18 and 22, and shrubland site 1 which register highest number of browsed plants (Table 7.5) have relatively small volumes of wood (Table 7.6), suggesting that they have fewer taller plants. Increasingly short 'grazing and/or browsing rotations' due to contracting rangelands are responsible for reduced recruitment of seedlings to mature stage.

Repeated browsing not only inhibits plants to the next stage, but it also leads to structural deformation. Within the reserve, off Sekenani-Talek gates, vegetation consisting of *Acacia gerrardii, A. hockii* and *Solanum incanum* (mostly less than 1m high) has been suppressed by wildlife and livestock browsing. In particular, shrubby growth forms in the *Acacia drepanolobium* community are attributed to continuous browsing by Giraffe Dublin (1986) observed elephant browsing in the MMGR which was concentrated on less than 1m height to have suppressed seedlings. Mortality of trees and seedlings in the next higher class associated with animal activities, has been reported by Dublin (1986), Mwalyosi (1990) and Belsky (1983). These authors, associate seedling and tree mortality with browsing and trampling, and tree felling and debarking, respectively. In the MMGR and the surrounding woody communities, browsing has intensified within the last 10 to 30 years following animal compression (Chapter 5). In overgrazed parts of Loita, browsed vegetation exist as contagious coppicing rootstocks and seedlings or as standing dead trunks.

Furthermore, the unproportional representation of species type in the class categories may be attributed, specifically, to browsing preference. In bushland sites 16, 22 and 24, and woodland sites 10 and 41 and shrubland sites 4 and 5 the seedlings were selectively browsed. The plants involved include *Rhus natalensis, Sida cuneifolia, Tachonanthus camphoratus, Croton dichogamus, Olea africana* and *Indigofera spp.* Animal food preference has been reported in different parts of East Africa (Chapter 5), and it is generally associated with qualitative differences in forage and the availability of food. In this situation, the plant species subjected to specific disturbances may occasionally be uprooted reducing plant density and diversity in the mature stage (Dublin 1986).

Plant structural variations for grassland sites which are characterized by low woody species may be associated with physical factors. In the plains, average rainfall is low (Chapter 3) while the soils have relatively low amounts of carbon and nitrogen (Chapter 6). Therefore, the sites involved can only support a small amount of seedlings. At 'mature' stage, the plants are kept short due to combined effects of browsing and seasonal fluctuation of resources. From Appendix A, it is evident that the average height of plants from the plains is predominantly below 2m. The regulation of the height of rangeland plants in eastern Africa by rainfall variations, has been reported by Belsky (1983), Boutton *et al.*(1988) and Ross (1985).

Differences in average grass heights between disturbed and undisturbed grassland sites (Table 7.7a, Appendix A), is attributed to differences in animal grazing intensity. In settled areas and parts of the plains, for instance, short grass is attributed to year-round grazing (Chapter 5). The impact of grazing on plant structure in the Serengeti-Mara ecosystem, has been reported by Lamprey (1984), Dublin (1986), Olang (1985) and Karime (1990). Belsky (1983) reports that heavy grazing in the short-grass plains of the Serengeti National Park during the rainy season, keeps most of the herb layer below 5cm while less intense grazing in mid- and tall-grass savannas allows the vegetation to grow to 0.5-2.0m high. Observations made over a four year period by Olang (1985) in the Mara confirmed seasonal fluctuations in grass heights of between 1m in the wet season and 0.5m in the dry season due to a combination of rainfall and grazing. Also, Lamprey's (1984) findings of Landsat digital analysis in Maasai settled areas indicated a decrease in grass height along a gradient of cattle density. Generally, following the expansion of cultivation, grazing and the reduction in grass height in Narok's plains are continuous, increasingly involving both wildlife and livestock.

The influence of grazing on plants is being exacerbated by recent confinement of animals which has led to overuse of pastures (Chapter 5). The initial pattern whereby grazing pressure was spatially and temporarily distributed, that is, accumulation of animals in the plains during the wet season and in the surrounding hills during the dry season (Chapter 2) has become limited or has been replaced by year-round grazing. This is true of livestock in demarcated areas, and livestock and resident wildebeest in the Loita plains. Subsequent ecological imbalance called overgrazing has attracted bush encroachment (Chapter 4), reducing the number of herbaceous species and/or leading to their loss *in situ*. From Table 7.1a, also Appendix A, the higher number of woody species in disturbed than undisturbed grassland sites is therefore attributed to bush encroachment. In management terms, the latter may be seen in two different ways. Firstly, as a way of increasing wood resources which are highly needed (see section 7.4.1.4). Secondly, as a problem in the management of rangelands, because it reduces the amount of available grazing land and attracts tse-tse infestation, posing a problem to the livestock industry (Chapter 4).

Grass height differences may further be explained on the basis of plant association. For instance, the grasses from undisturbed, and even disturbed, woody community sites are tall although scanty. These grasses are confined within tree stands or they occur as patches in open spaces between clumps of woody species. Many of them are supported by woody and other herbaceous plants.

The change in fire regime (Chapter 5) is also affecting plant structure. Some shrubby structures characteristic of grassland and shrubland communities are associated with frequent fires. For instance, at site 26 burning is an historical disturbance. This is supported by fire dependent communities dominated with *Acacia-Tachonanthus* communities. In spite of reduced burning, the wide ecological tolerance of these communities has maintained their widespread distribution. While most woody species are also tolerant to overgrazing, the dominance of herbaceous cover has greatly been affected. This evidence is further supported with the small number of herbaceous species following a decline in burning (Chapters 4 and 5). Therefore, reduced burning implies that in the absence of repeated browsing (Dublin 1984), woody species are likely to be recruited into the next higher stage. Where fires have been frequent (e.g., sites 26 and 34), most of the woody species are kept below the 1m height. Suffice it to say that the role of fire in vegetation dynamics is very controversial (Dublin 1986; Werger 1983). What is clear, however, is that it is very difficult to isolate the effect of fire on woody species from that of large herbivore activities. This is because, first, many times, burning and browsing occur together (Chapter 5, see also Dublin 1986) and the indicator species for both disturbances are sometimes the same. However, by considering the amount of specific species, the problem can partly be solved. The predominance of herbaceous species presupposes the influence of fire. This is because, fire can only be supported by a large amount of herbaceous layer. The situation becomes complicated when edaphic factors have a prime role in species composition.

Historical records (e.g., Vollensen 1980; Dublin 1986; Pellew 1983; Glover 1968; see also Chapter 2) support that fire has been a significant tool, mainly, in reducing woody communities. Vollensen (1980) associates the disappearance of the forest and bushland communities of the Selous game reserve in Tanzania with frequent fires. In Lake Manyara basin of Tanzania, Greenway and Vesey-Fitzgerald (1969) attributed the decline in riverine forest to frequent severe burning. Also, it should be recalled (Chapter 2) that the greatest losses of woodland cover in the Mara between 1957 and 1974 were due to severe burning. Withdrawal of fire and/or reduced incidents of fire (Dublin 1986; Chapters 4 and 5) has been associated with the regeneration of woody communities. In some parts of Moita-Masurura, reduced burning over the last 20 to 30 years, for instance, has attracted regeneration of clumped bushlands.

In this section, species size and structural variations in class heights have been explained on the basis of selective wood harvesting, browsing preferences and differences in grazing intensity and changes in fire regime. Generally these disturbance characteristics directly remove individual plants or deform plant structures or they affect plant size and structural characteristics through seedling germination and recruitment into the next stage. Also, physical factors influence plant lifeforms and plant height through soil moisture and nutrients. In the next section, detailed examination of wood resources obtained using the structural parameters is discussed.

7.4.1.4 The Situation of Wood Resources

The higher volume of wood in undisturbed than disturbed sites (Table 7.7a), is an indication that human disturbance predominantly involve direct removal of wood resources. However, higher mean volumes of wood in disturbed than undisturbed grassland sites (Table 7.7b), suggests that human disturbance appears to be promoting wood resources through bush encroachment.

The low amount or lack of wood in disturbed forest sites 11 and 39, disturbed woodland sites 14 and 20, and disturbed bushland site 18 (Table 7.7a) is attributed to increasing demand versus its diminishing supply as vegetation is cleared for cultivation and settlements. Also, these areas which are located along the borders export wood products to neighbouring Districts (Chapter 4). The direct loss of wood due to human disturbance in some of the sites is historical. The border areas have had the greatest influence from cultivator immigrants since the 1960s (Chapter 2). Human influence on vegetation has since then continued due to increasing population. Therefore, wood shortages in disturbed woody sites are attributed to temporal increase in the intensity and frequency of human disturbance. For instance, sites 14 and 18 which have had high disturbance over a period of more than 20 years register no wood (Table 7.7a). These sites which are located in settled/cultivated areas of Nkararo and Nyangusu-Kilgoris, respectively, lost most of their woody resources to clearing in 1976 during the wheat and barley experimental projects (Chapter 4). Since then further reduction of wood resources has been mantained by the expansion of cultivation, increasing domestic use of wood products by the local people and the export of wood products into neighbouring Districts.

Wood scarcity in the grassland sites is generally associated with low tree growth potential. This is due to low amounts of rainfall (Chapter 3) and low nutrient potential (Chapter 6). Accordingly, weedy species are dominant. While most of these species are of little demand for domestic use, many of them are retarded from growing into the next stage by increasing browsing and trampling. Availability of wood depends upon recruitment of seedlings into the mature class. This cannot be possible in the presence of high rates of browsing and trampling (Chapter 5). Woody scarcity, further, follows its increasing use in lodges. The area bordering the MMGR is loosing wood to tourist camps and lodges. Here, wood is used to warm water and for cooking. In these relatively newly settled areas, the demand for woodfuel and the general "damage on vegetation is unmatched" (NER 1986:133). In chapter 4, it was indicated that in the recent past, Maasai consumption of wood has increased due to a change in cooking habits. Therefore, the small volume of wood recorded for sites in the plains is attributed to the initial small amount of wood resources associated with a multitude of human factors and the low rate of recovery.

In this section, the small amount of wood in disturbed sites has served as an indicator of direct human impact on vegetation. Differences among site categories have been explained on the basis of human disturbance duration and intensity, and the differences in site potential to support woody species and to recover from disturbance. The following section attempts to generalize the factors underlying the observed floristic and structural patterns.

7.4.2 Ordination and Classification of Vegetation

7.4.2.1 Vegetation Ordination

Two explanations are offered for the pattern of samples displayed in Figure 7.2. Firstly, samples ordination in axis 1 shows that a complex moisture gradient is an overriding environmental control on vegetation. This axis shows from the left bottom corner xeric community sites to the right mesic community sites. The influence of moisture gradient on vegetation is supported by a high correlation coefficient (r=0.51) between vegetation vectors and average rainfall. Further, the isolines of average rainfall (Fig. 7.6) on the samples ordination space display a moisture gradient. The significance of rainfall on plants, and particularly the distribution of lifeforms cannot be disputed. It should be recalled from chapter 3 that woody communities predominantly occupy wetter areas whereas the drier plains support the grassland community. The significance of soil moisture on the vegetation of the study area is further supported by the invasion of woody species in overgrazed sites (Chapter 4) where plant competition for moisture is common.

The preceding findings agree with previous studies done in the Serengeti-Mara ecosystem. Belsky (1983,1987), McNaughton (1983,1985), Boutton *et al.*,(1988) and Jensen and Belsky (1989) associate floristic and somehow structural characteristics in eastern Africa with the amount of rainfall. In Narok District, the moisture regime is linked with altitude and topography (Chapter 3). Therefore, the relationship between these two, and particularly their influence on soil and vegetation, accounts for the similar pattern of vegetation and soil data on the ordination space (Figs. 7.10a and 7.10b). Basically, topography and altitude have interactive effects on soils and vegetation.

The overriding role of soil moisture on floristic composition in Narok District has been suggested by Taiti (1973) and Mwichabe (1986). Taiti established that moisture availability determines the establishment of species such as *T. camphoratus, A. gerardii, A. drepanolobium* and *A. hockii*. With reference to *T. camphoratus*, Taiti (1973) associates its distribution to 1800m altitude with soil moisture and not the mere degree of grazing. Also, Talbot (1973) identified a vegetation gradient from grassland through bushland to evergreen thicket which he recognised was dependent on climatic and topographic factors, and fire and animal impact. The influence of the amount of rainfall on the distribution of weeds has been confirmed in Trans-mara (Mwichabe 1986).

The influence of soil on vegetation can be inferred by using Figures 7.10a and 7.10b. These ordinations are based on species presence-absence and the number of individuals per species, respectively. When they are compared with vegetation data ordinations (Figs. 7.2 and 7.3), they show a similar pattern.

Also, average amount of soil elements, which depend on organic matter as their source, display an ecologically meaningful pattern in the samples ordination (see Figs. 7.6 to 7.9). This pattern suggests a gradient from grassland sites to upland, woody, sites.

The interdependence between soil and vegetation was demonstrated in chapters 3 and 6. It became evident that phosphorus, carbon, nitrogen, zinc and copper are strongly correlated to vegetation latent vectors of the present ordination (Table 6.3). It was also evident that elements which are supplied by organic matter such as carbon, nitrogen, P and base cations were lower in disturbed than in undisturbed woody sites (Table 6.2b). Therefore, other than removing plants directly (section 7.4.1.4), human disturbances affect vegetation through soil fertility.

Secondly, the ordination in axis 2 is partially obscured such that a secondary ecological gradient, human disturbance in this case, appears hidden. The influence of human disturbance is evident mainly among mesic forest and bushland sites (see Fig. 7.2). This observation suggest that disturbed and undisturbed site categories in these communities are revegetated by different floras. From Tables 7.2 and 7.3, the association within sample pair categories is consistently higher than between sample pair categories. Implicit in this observation are differences in plant resilience, that is, their ability to resist and/or tolerate perturbations. It is suggested that plants from these two communities are more responsive to disturbance than those from other communities. One reason could be the recent exposure of the communities to large-scale human disturbance, meaning that they haven't acquired disturbance recovery mechanism. Burning and overgrazing, for instance, have been common in the drier bushland and shrubland communities, predominantly on a seasonal basis. Most fires lit in the grasslands usually extended into these neighbouring communities (Chapter 2). Therefore, the species, therein, have obviously developed varied mechanisms to occupy areas differently disturbed. Therefore, diffuse ordination of disturbed and undisturbed samples from the woody and herbaceous communities is an indication of weak association (see Tables 7.2 and 7.3) and the lack of plant sensitivity to disturbance because of their long exposure to different disturbances. Belsky (1987), and Jensen and Belsky (1989), for instance, found distinct samples ordination. They associated this to the vegetation which was homogeneous.

The use of the Manhattan metric to eliminate the arch was effective. However, the results have been excluded from the discussion because of the difficulties in interpreting them. Therefore, given sampling limitations associated with non-individual plants (Chapter 3), it is suggested that the samples could best be separated on the basis of presence-absence of species type rather than the relative abundance of the species.

The arch effect is associated with the presence of a wide range of species composition in different samples such that some pairs share no species (Orloci 1978; Williams 1987). This assumption is supported by the observed diffuse similarity between sample pairs (see Section 7.4.1.2).

7.4.2.2 Classification of Vegetation

Classification results agree with those of samples association based on indices of similarity (section 7.4.1.2). Most samples fuse on the basis of closeness to each other (Figs. 7.4 and 7.5). The strong association between closely located sites is, firstly, associated with the sharing of recolonization sources. Adjacent sites offer establishment potential that suit similar plant lifeforms and plant history. High similarity in these (two) plant aspects and environmental conditions therefore explains the fusing of closely located samples. The influence of plant life history is evident in the fusing of disturbed and undisturbed sites from the same community. Accordingly, some plants therein are resisting changes associated with recent human disturbance. These are mainly weedy species (section 7.4.1.1). Therefore, it may be suggested that, although human disturbance plays a role in determining vegetation patterns, it has had little effect in altering species composition in some sites which this study perceived as disturbed. However, late fusing of disturbed and undisturbed bushland and forest site categories, supports the influence of human disturbance on floristic composition. The forest site categories do not fuse until step five whilst the bushland site categories fuse at step six (Fig. 7.4 and 7.5).

Whereas we may accept that plant establishment and growth in disturbed sites is being affected by different forces including human activities, the plant's ability to resist or return to its initial state is therefore as important as the disturbance regime (Reiners 1983; Bazzaz 1983). The significance of these properties is evident in high species similarity between disturbed and undisturbed sites from the same community, hence the earlier clustering of closely located sites.

Therefore, it must be admitted that the influence of human disturbance on vegetation cannot be simply generalized. It depends on a number of factors, but mainly plant lifeform and plant history. These factors determine a community's ability to resist or tolerate disturbances. This observation is supported by previous investigations of vegetation dynamics in East Africa (see Belsky 1987; Jensen and Belsky 1989). Both physical and biotic factors have been identified as significant in determining vegetation dynamics. Also, ecological studies (e.g., Grubb 1977; Connell and Slatyer 1977) acknowledge the importance of life history of individual plants, the environment and historical factors in determining the trend of succession.

In this section proximity, plant lifeforms, plant history, soil moisture and soil nutrients associated with organic matter and human disturbance have been used to explain the results of multivariate analysis. It is suggested that low plant resilience accounts for distinguished pattern between disturbed and undisturbed forest and bushland sites. The following section uses the findings in section 7.3.1.2 to infer successional trends in the study area.

7.4.3 Implications of these Findings to Theories of Succession

Using size structure, this study offers the following insights into successional trends in the different sites. Plant stratification of undisturbed woody sites such as 7, 9 and 19 suggests plant replacement which depends on the availability of seedlings of different species below the existing adult tree canopy and/or in proximity. Some species occur in both less and more than 1m classes, suggesting that these sites are regenerating and that the seedlings are from seedbanks generally within or several metres from the sampling sites or are simply resprouts. Also these sites, by being characterized by an emergent canopy of widely spaced individuals of great size in a matrix of other species, suggest that succession is in progress (Jones 1945; Whittaker 1974; Karime 1990). Therefore, the structure of the plants in these sites is consistent with the hypothesis that in the absence of large-scale human disturbance, undergrowth (mainy late succession) species would replace the main canopy species as the emergents become senile loosing their canopy dominance. Eventually, they would become the next generation of canopy dominants.

For sites such as 2 and 3 which appear to be at a late successional stage, deep shade created by upper canopies means a decline in the heterogeneity of microhabitats at the forest floor, narrowing options for specialization in the regeneration niche. Therefore, regeneration will only occur when a gap is created by the removal of existing plants. The gap will allow seed germination or growth of suppressed seedlings, particularly in the absence of further large-scale disturbances. In highly disturbed sites such as 4, 26 and 35 suppression and/or killing of seedlings by repeated browsing and trampling tend to suggest that regeneration is retarded. In sites 14, 18 and 39, inhibition of regenera tion is associated with delayed or suppressed recovery due to weeding and, eventually, the impoverishment and/or exhaustion of the seedbank.

Therefore, the preceding site categories, appear to be following Connell and Slatyer's (1977) inhibition model of succession. In this model, late successional species can invade a site only after early species are damaged by a disturbance. Also, growth and regeneration of inhibited plants to the next stage will follow relief from the underlying forces, that is the removal of a disturbance. On the basis of predominance of this model in most sites, there is room to suggest that most communities in Narok District are likely to stay unchanged for some time unless they are exposed to large-scale disturbances such as cultivation. Also the presence of species in different height classes could mean that the plants which have established themselves have modified the environment so that it is less suitable for the recruitment of individuals of any species, a pattern which further supports the inhibition model.

The other models of succession are facilitation and tolerance. In the former early occupants modify the environment so that it is unsuitable for their further recruitment. In tolerance model, the species can invade an occupied site, and grow to maturity by utilizing an alternative niche or using low resources (Connell and Slayter 1977; Kershaw and Looney 1985; Goldsmith *et al.*,1986).

7.5 CONCLUSION

In this chapter variations in samples association have been explained on the basis of proximity, plant lifeform and plant history and human disturbance characteristics. Adjacent samples offer microhabitats that suit plants with similar growth requirements and adaptation to different environmental forces. Extreme disturbances are associated with low diversity, a small number of species and a small amount of wood. The lack or low disturbance is associated with low diversity and a large amount of wood due the dominance of woody species. High disturbance is associated with low diversity and a small volume of wood, because it reduces the potential of plant establishment and growth to maturity. Conversely, a medium level of disturbance is associated with high species diversity, non-dominance of specific successional species and a substantial amount of wood.

Details in plant (size) structure variation have been shown to relate to differences in methods of wood harvesting, browsing preference, differences in grazing intensity, changes in fire regime and variations in soil moisture and nutrients.

It has also been demonstrated that large-scale and long-term disturbances such as overgrazing and cultivation override the significance of plant resilience to disturbances. Thus, they interrupt successional processes through the destruction of site conditions or simply by keeping seral stages at zero by lowering soil fertility and destroying recolonization sources *in situ* and in proximity. Lastly, these disturbances create niches which favour opportunist, less valuable species.

CHAPTER 8 HUMAN DISTURBANCES, THEIR MANAGEMENT AND THE EXPLOITATION OF VEGETATION

8.1 INTRODUCTION

The preceding chapters have supported the view that vegetation change in Narok District has been dynamic, and that the disturbances influencing them have operated collectively or singly over a wide range of spatial and temporal scales. Until the introduction of cultivation, mild, small-scale disturbances such as light grazing and selective tree cutting were frequent and localised (Chapter 2). While these disturbances are significant for the relative selection and persistence of plant species, recent disturbances are comprehensively destructive. Consequently, vegetation loss/destruction is accelerating and will continue to do so unless some of the present human activities are modified.

Whereas intensive human disturbances are mainly destructive, it is partly established (Chapter 7) that they are significant in maintaining the structure and functioning of vegetation. This chapter, therefore, attempts to point out some of the ways human disturbance characteristics in Narok District could be manipulated for the pertinent management of vegetation. It is argued that the once unforeseeable side effects of human influence on vegetation tend to suggest that something more than we previously knew or intended has gone wrong. With this realization, recommendations are made towards encouraging medium disturbance. The aim is to reduce negative effects of human impact on vegetation so as to reconcile wildlife conservation, wood consumption, cultivation and livestock activities. The recommendations offered, are contrary to the traditional view that vegetation change of any sort is undesirable and less beneficial.

Given the limitations of data collection, together with previous research (e.g Lamprey 1984; Olang 1985; Dublin 1986) which concentrated on individual or a number of communities, it is difficult for this study to suggest a wide range of alternative landuse strategies for the different plant communities. It is also difficult to direct activities to sites that will be least damaged over the long-term. Therefore, general rather than specific recommendations are offered. It is, however, assumed that such framework will enable more site-specific studies to be undertaken in the future. Despite this limitation, the significance of disturbance-recovery models in the management of Narok's vegetation, is unquestionable.

In order to decide on these recommendations, the following section attempts to answer the question : What is unique about present human disturbances in Narok District?

8.2 CHARACTERISTICS OF PRESENT HUMAN DISTURBANCES

It will be recalled from chapter 2 that the pre-independence Maasai and the shifting cultivators only influenced vegetation seasonally and at a small-scale. Except for burning, human disturbances mimicked natural openings in terms of their size and in their intensity of effect on plants. It was argued that to some extent, these people lived in harmony with their environment. In the post-independence period, human influence on vegetation has changed. There have been remarkable changes in type, size, frequency and intensity of disturbances. Therefore, these are disturbance characteristics that have to be manipulated so as to reduce the growing gap between the influence of traditional and modern human practices on vegetation. The greatest cause of this gap is the introduction and/or the intensification of disturbance types, particularly cultivation.

Disturbance size is being influenced to different degrees by different immigrant cultivators; it ranges from less than $1m^2$ to more than 1ha (Chapter 5). Since gap size is one of the major characteristics of human disturbance which determines the number of plants killed and the rate of site recovery (Chapter 7, see also Denslow 1980; Coffin and Leunroth 1988), its consideration for the management of vegetation is significant. Small gaps are short-lived and kill fewer plants. Obviously, bigger gaps kill more plants for the same area affected because of their relatively large surface area. Another crucial aspect of disturbance size is its effect on the rate of natural regeneration of disturbed sites. Large-scale disturbances are long lived, usually destroying the potential recovery of the sites involved (Chapter 7).

A second quality to the present human disturbances in Narok District is a change in their rate of occurrence. Seasonal influence of vegetation which is characteristic of the traditional Maasai way of life is disappearing following increasing cultivator immigrant influence, changes in modes of wood consumption, sedentarisation and land demarcation (Chapters 4 and 5). Most areas are now either permanently under cultivation or are experiencing year-round grazing and trampling. Therefore, disturbances such as seasonal burning and seasonal grazing have been greatly reduced or are disappearing.

The change in the rate of occurrence of a disturbance obviously interrupts acquired plant survival and recovery mechanisms. Ephemerals, for instance, live and cope with a disturbance because of its predictability. An abrupt change in disturbance regime presents a high level of unpredictability of resource change to most species affecting the potential recovery of a community (Yarranton and Morrison 1974; Bazzaz 1983). In contrast, regular disturbances select plant species whose germination and growth requirements take advantage of the resources they make available (Bazzaz 1983; Reiners 1983; Christensen 1985). The change in frequency of a disturbance means an acquisition of new tactics by plants which have to benefit from the change. This is an evolutionary process which cannot now happen in Narok District given the rate at which human disturbance types and frequencies are changing. Consequently, continuous cultivation in woody communities has favoured the invasion of herbaceous species (Chapter 7) while a combination of overgrazing and trampling has attracted the invasion of woody species in the formerly herbaceous communities

(Chapter 4).

A third unique characteristic of present human disturbances in Narok District is an increase in their intensity following, mainly, increasing and continuous compression of animal grazing space and cultivation (Chapter 5). Disturbances such as wood cutting, cultivation and charcoal burning are increasing in space, amount and frequency so as to cope with the demand for food, building and fuel resources. The use of fertilizers and decreasing arable land has ensured continuous cultivation in medium to high potential areas and reduced animal movements (Chapter 4), compounding the impact of human disturbance on vegetation by their long duration in a site. As such, they kill and/or remove biomass and reduce regeneration potential by devastating favourable soil properties, including destruction of rootstocks and seedbanks (Chapter 7). On the contrary, small-scale, short-lived disturbances fill up more quickly, once abandoned, via the extension of crown of adjacent plants or by regrowth of rootstocks or seedlings resulting from propagules from remaining plants and the seedbanks *in situ*. The rapid recovery of this gap size category is also associated with rapid build up of organic matter and nutrient conserving mechanisms associated with mycorrhizae. A similar contrasting influence of the intensity of human disturbance on vegetation is associated with cattle ranchers and semi-nomadic pastoralists. The former confines his animals, thus increasing grazing and trampling pressure while the latter moves his animals with fluctuations in grazing resources, thus ensuring environmental recovery.

What can then be done, concerning the management of vegetation, with present human disturbance characteristics in Narok District? In answering this question, see also below, an attempt is made to examine the hypothesis that 'human disturbances can be significantly more beneficial to the management of vegetation than is normally thought'.

8.3 A CRITICAL APPRAISAL OF HUMAN DISTURBANCE MANAGEMENT AND VEGETATION EXPLOITATION.

8.3.1 Introduction

In chapter 7, it was evident that human disturbances are not wholly destructive for the development of vegetation. For instance, high species diversity was associated with medium disturbance. This is accomplished by the creation of openings which serve as recolonization microsites for shade intolerant species. Conversely, low fires and/or overgrazing attract the development of woody species in a herbaceous community (Chapter 4). Thus, direct manipulation of human disturbance characteristics can lead to the establishment of either woody or herbaceous or a combination of both communities.

Further, in Chapter 5, it was indicated that while browsing and tree felling by zebra deforms plant structure, by removing coarse top stems of trees, they make more nutritious plant components available for the wildebeest. Also, grazing to the extent that grass is reduced to a short sward is necessary for making available the scattered herbs preferred by gazelle. Similarly, zebra grazing keeps the grass canopy low, permitting shorter herbaceous species such as *Eragrostis tenuifolia* and *E. racemosa* to grow and flower. Thus, it reduces competitive effects over less successful plants.

Therefore, it can be inferred that human disturbances have mixed effects on plant communities. They are simultaneously a source of mortality for some plants and a source of establishment for others. Even total clearing which kills dozens of trees/shrubs, provides establishment and growth potential for new arrivals. The gap created, if later abandoned offers an opportunity for suppressed undergrowths to be recruited into the upper storey. It should be recalled (Chapter 7), for instance, that disturbed sites support a majority of the pioneer and secondary succession species. Seasonal burning which attracts palatable grasses and reduces dominance by a few species, adds to this list. It is on the basis of these findings that the present study discards the traditional belief that disturbances are wholly destructive (Grime 1979; NDER 1986; Runkle 1985).

Begon *et al.*,(1990), and Begon and Townsend (1986) in their non-equilibrium theory, support the idea that human disturbance should be manipulated for the betterment of plant components. Indeed, they maintain that vegetation disturbance is the most powerful way of generating community diversity. Also, Lal (1987) supports the proposition that vegetation disturbance should be seen as a management tool, but within acceptable levels of instability. He, however, fails to define these levels in quantitative terms. The method of quantifying disturbance characteristics is an issue that the current ecologists have to unfold.

In view of the preceding arguments, it is suggested that a disturbance regime should be incorporated into management practices if it somehow contributes to the functioning and maintenance of certain components of a vegetation community. But in so doing, accompanying negative effects must be accepted. It should be recalled from chapter 7, for instance, that high species diversity can be maintained only at the expense of plant structural dominance and, therefore, at the expense of the amount of wood volume. This situation is in accordance with the second law of thermodynamics - in effect, that no transformation is perfect. This paradigm accords better with today's options of viable developments and vegetation management. Despite this limitation, as will be seen, this study strongly discourages the creation of short-term excessive disturbance for economic gains. Working solely to this end is being short sighted. Instead, it recommends that vegetation management should aim at disturbances that may lead to favourable ecological conditions, which in the end will allow the communities to increase productivity at minimum or acceptable levels of negative effects. Human disturbances of intermediate level are recommended because they make positive contributions to ecosystem functioning (Chapter 7). Accordingly, possible management and exploitation strategies of the vegetation should aim at controlling extreme disturbance characteristics which reduce the range of potential opportunities for species recolonization.

In the following five sections, different ways of manipulating human disturbances consisting mainly of cultivation, animal activities, wood cutting, landuse practices and burning, are suggested.

8.3.2 Manipulation of Cultivation

Cultivation is the type of extreme disturbance which requires necessary manipulation. So when we are deciding on suitable landuse practices for the management of vegetation, by and large, we are deciding on how to accommodate cultivation practices. The crux with cultivation is that it is occurring at a large-scale and expanding at a fast rate (Chapter 5) whilst retrogressing vegetation from one successional stage to another (Chapter 7). Since Narok District holds one of Kenya's greatest agricultural potential for large-scale farming in terms of existing and improvable land (NDDP 1984;1989), vegetation conservation will need to conduct cultivation in such a way that it allows part of a community type to mature to the next so as to maintain the inherent diverse communities in the District. The issue is how efficiently this can be acomplished and, particularly, where cultivation should be practiced. Figure 8.1 is a summary of proposed landuse strategies for cultivation of any given area.

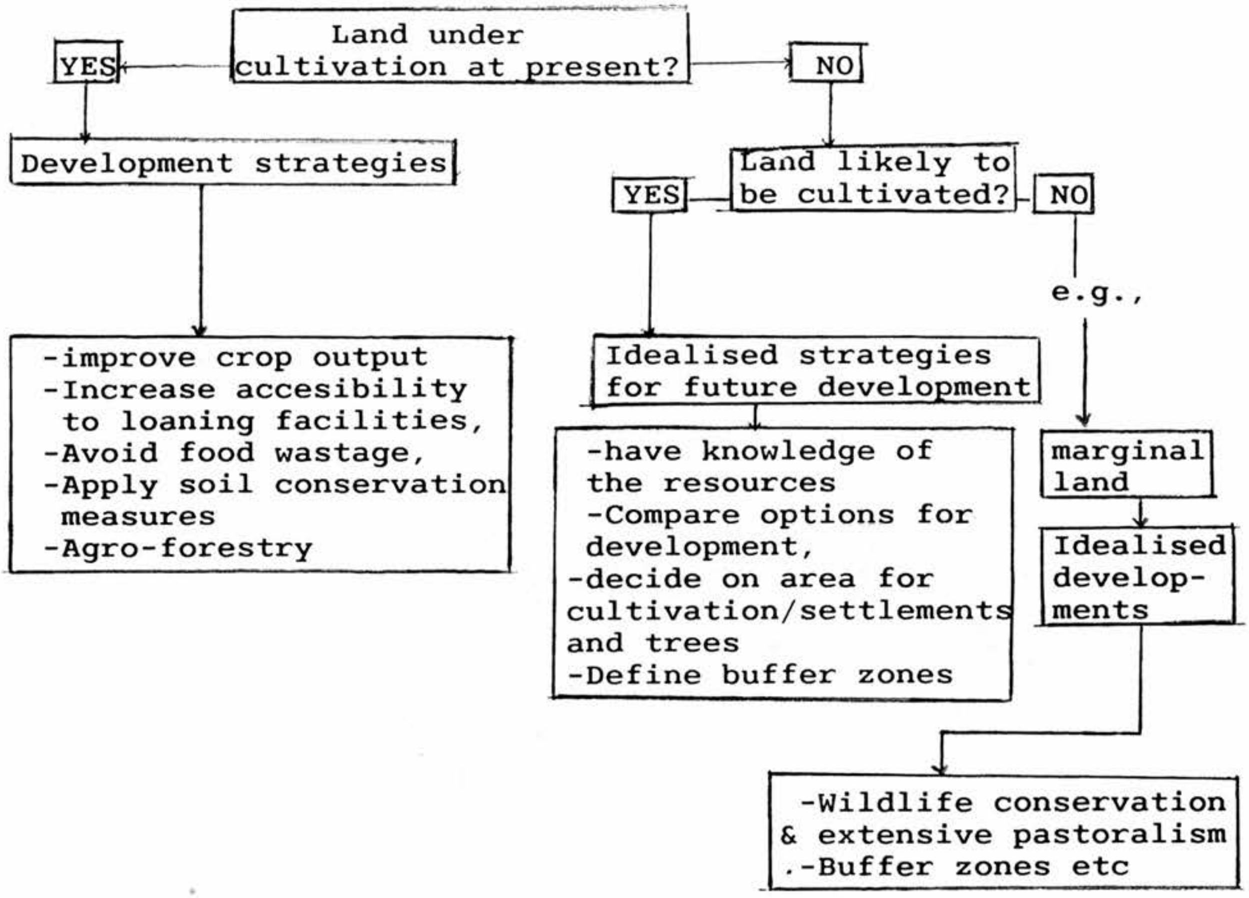


Fig. 8.1. Idealised cultivation strategies in arable lands

The first step to reducing further destruction of the remaining vegetation should be to discourage bringing more land under cultivation each year. Instead, emphasis should be, firstly, on improving crop output per hactare of the area already under cultivation. This can satisfactorily be achieved by instituting soil conservation measures and by the use of agricultural inputs. To meet the second recommendation, access to farm chemicals and a wider use of crop varieties must be addressed. This can be achieved by providing title deeds to the farmers to enable them obtain credit facilities. Title dees will also provide them with economic security which is necessary for resource management (Chapter 4). Essentially, this proposal requires land demarcation and registration.

While addressing land tenure questions, it has to be decided which land should be demarcated and/or cultivated. When raising this concern (see also below), the author is not opposed to land adjudication policy and the intended expansion of cultivation. On the contrary. Rather, it is felt that certain vegetation communities should be spared because of their inherent low potential or their contributions to wildlife conservation or their biodiversity or the endangered species they support. These include group ranches bordering the MMGR which serve as wildlife dispersal areas. Demarcation of these areas will interfere with free movement of wildlife which is necessary for vegetation recovery. Also, the establishment of boundaries and the raising of fences once this land is demarcated, will conflict with tourism and wildlife management. Therefore, in areas suitable for cultivation that should not be demarcated for the provision of title deeds, different criteria should be designed to enable the people to have access to loaning facilities. For, instance, cattle can be used as a security.

The local people have to be convinced of the need for land demarcation. As was indicated in chapter 4, this exercise is receiving mixed reactions with only a few residents in semi-pastoral areas responding enthusiastically. This is either because it is seen to secure the claims of Maasai pastoralism to land in danger of encroachment by cultivators or because it enables them to lease it freely, or the people find individual land profitable to commercialise by constructing lodges and camping sites.

The development of cultivation may require intervention of, further, land division even in high potential areas because of its impact on productivity. In Mulot and Kilgoris, demarcated land is already lowering agricultural production (NDER 1986). It must, however, be admitted this intervention is very difficult to conceive in the contemporary Kenya where land is passed from father to sons. But the proposal is a challenge that must be thought about. The idea should be to introduced it at this early stage of land demarcation, by educating the people about the advantages of large farms.

Expansion of cultivation (Chapter 5) can be discouraged, secondly, by the intervention of frequent border skirmishes (Chapter 4) that bring about underproduction and wastage of food.

Inevitable expansion of cropland will require, firstly, detailed information on natural resources and human ecology; which in the past have hardly received due attention (Chapter 1). Potential areas for cultivation should then be decided on the basis of this information. Secondly, it will be necessary to introduce and/or promote agroforestry practices and soil conservation measures in advance. Deep rooted plant species such as *Markhamia platycalx* and less shade species such as *Acacia spp* and *Dombeya* *goetzenii* should be spared during clearing of land. Also, rare native species such as *Croton dichogamus* should be conserved because of their wide traditional uses as medical plants (Chapter 4). Indigenous windbreak trees and a few quick growing exotic species should be planted as hedges or clusters within croplands. The objective is to increase and maintain wood sources whilst having no adverse effects on cropland. This approach is in line with Kenya's philosophy of vegetation conservation - 'plant two trees for every one cut'. Such a timely move could reduce potential wood shortages and save the time spent in looking for poles and fuelwood, and ensure a degree of protection for the environment. Thirdly, deferred grazing (after crop harvest) should be controlled to avoid excess utilization of plant remains, so that the soil remains protected throughout the year.

Extension of cultivation should be accompanied with the provision of a 'buffer zone'[1] between cultivated areas and a mildly disturbed community (Fig. 8.2). This zone would provide room for multiple uses depending on the land potential and the human ecology of the occupants whist supporting vegetation cover. For instance, in semi-pastoral areas, light grazing and selective extraction of trees for domestic use could be allowed. The establishment of the buffer zone should be a priority in

[1] Defined as an area adjacent to protected areas on which landuse is partially restricted to give an added layer of protection to the protected area itself while proving valued benefits to neighbouring rural communities..IUCN(1986:90).

riverine vegetation in the plains and parts of Trans-mara where horticultural activities are being conducted (Chapter 4) and, the woody communities on hilltops and hillslopes. These communities support specific biota, support wildlife populations that attract tourism and they include the catchment areas of the streams and rivers in the District.

A buffer zone concept is not a new phenomenon in Narok District. Mbuvi and Njeru's (1977) study in the Mau Narok, for instance, suggested the creation of a buffer zone between cultivated areas and the forest/bushland communities on the footslopes. The concept is also implied by Lamprey (1984) while referring to the need for the protection of woody communities on the Lemek hills. Introduction of buffer zones, which presupposes 'selective farming', is a type of landuse strategy that will lead to conservation of indigenous communities. The landscape will be characterised by pockets or rings of cultivation between more or less intact communities (Fig 8.2).

Introduction of buffer zones could be extended into the rangelands bordering the MMGR. Figure 8.3 is an idealised strategy of the buffer zone in the plains, including the MMGR. A broad area has been defined so as to include wildlife dispersal and the semi-pastoral areas in the Loita plains. Due to increasing shortages of land, a narrow strip of land can be used as the buffer zone. With, mainly, communally owned land in the neighbourhood of the MMGR, it is much easier to find room for this zone. Establishment of a buffer zone should be a priority in areas where land demarcation is going on. Once suitable land is identified, both human and natural resources should be mapped and the multiple landuse practice options decided for implementation without interfering with the residents. The objective should be to incorporate local activities such as traditional pastoralism, deemed less destructive.

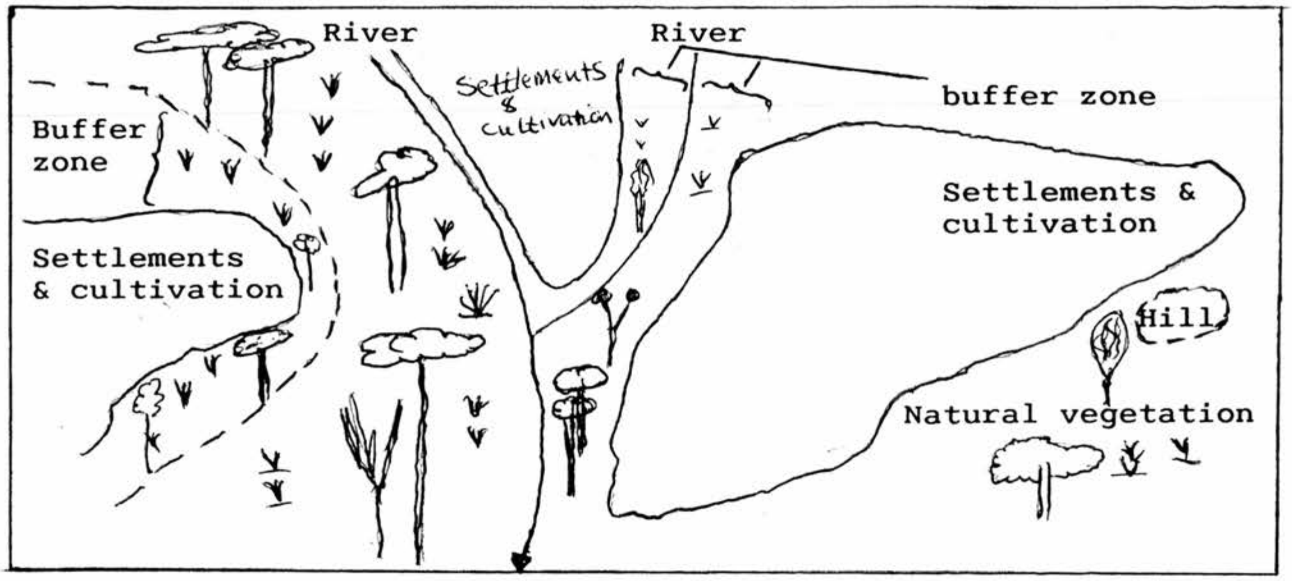


Fig 8.2: A buffer zone landuse strategy

The development of buffer zones in the plains must be geared towards assisting the residents to adopt extensive pastoralism so as to allow wildlife to move freely. The creation of these zones will mean a loss or limited use of a given piece of land. Extra earnings must therefore be generated to avoid subsequent impact on the human ecology. This can be achieved, firstly, by increasing the number of camping sites and lodges in this area so as to provide supplementary earnings from pastoralism. Currently, there are six tented camps, at Talek and north-east of Sekenani gate located on land. Thus, levies and fees are paid directly to the landowners. Appropriate places for establishing camping sites include Megwara, Aitong, Maji-moto and Lolgorein which are within wildlife dispersal areas. These places are served with tracks and are close to water points. Also, they are endowed with abundance and a variety of wildlife and birds. Other than supplementing earnings, wide distribution and an addition of more camps will reduce human pressure in the MMGR (Chapter 5) and encourage wildlife conservation.

For group ranches which are receiving rent from tourist lodges located on their land (Chapter 4), for instance, there is no reason why they cannot accept a wildlife conservation promoting landuse through the introduction of a buffer zone. However, direct remissions of cash from NCC and the Ministry of Tourism and Wildlife (hereafter, MTW) which benefit from the MMGR may be necessary (see Lamprey 1984; Sindiga 1984), especially if this land is to be maintained as a wildlife dispersal area.

Therefore, establishment of buffer zones requires the central government and the NCC ensuring survival of the Maasai who will lose their land or yield to destocking or both at the expense of wildlife dispersal areas. It is in respect of this economy that the needs of the local people must be a priority for the accomplishment of long-term objectives of wildlife conservation.

Lamprey (1984:288) maintains that

"in order for tourism and conservation to continue the Maasai have to be fully compensated for the use of their rangelands by wildlife".

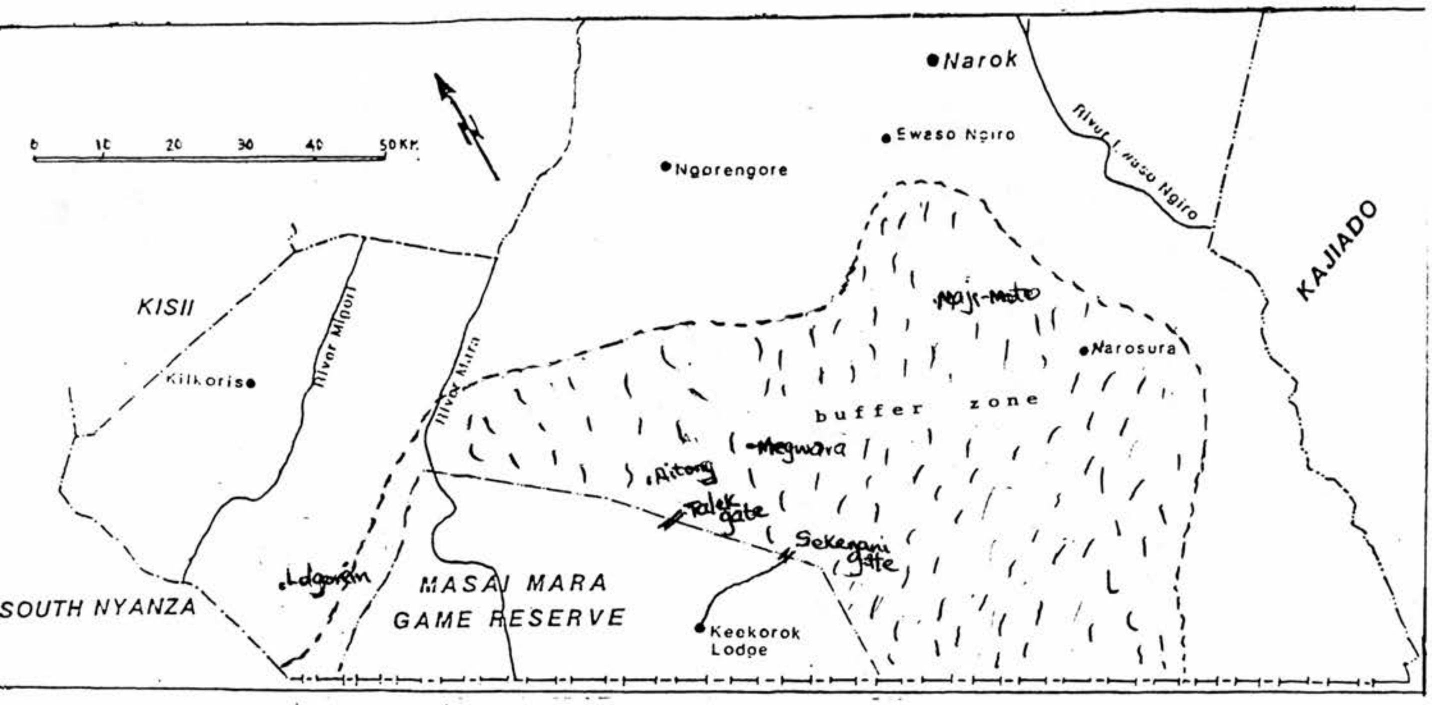


Figure 8.3. Idealised buffer zone landuse strategy in the neighbourhood of the MMGR.

The way this can be achieved has raised a lot of concern (see Sindiga 1984; Simon 1963). It should extend beyond using the Maasai as watchmen in camping sites or objects for the tourists' camera. Group ranchers in the woodlands of Megwara-Naikara should be assisted to develop bee keeping so as to improve dry season food shortages. Extra earnings can also be generated by increasing local handcraft and beadwork which have ready market in tourist centres, and during traditional Maasai ceremonies.

Assistance should be in the form of funds to buy materials needed for these industries and the marketing of the products. The Maasai should also be encouraged to conduct some small-scale cropping. Growing cereals will be an added advantage for their survival during droughts (Chapter 4). This move if accompaned by channelling of some earnings from wildlife conservation/tourism towards local people's welfare, destocking may be a possibility.

Another problem facing cultivation is crop damage by wildlife (Chapter 4). Its intervention is becoming increasingly significant because of animal compression and further loss of grazing land to cultivation. The idea of keeping wildlife away by the use of game proof fences may be restricted to croplands. Its wide use, however, somehow ecologically unviable — for wildlife conservation and the management of vegetation is not attractive in pastoral areas. This is why the establishment of buffer zones should be a priority.

The buffer zone, also, has other ecological advantages. For instance, it could be used for dry season separation of smallstock from cattle. In this way, modern livestock industry will be advanced along with traditional Maasai pastoralism which is very useful for the management of vegetation (Chapter 2). Such grazing strategy will temporarily reduce grazing pressure. Developments in the rangeland buffer zones such as the provision of roads, veterinary and water services, destocking, improvement of grazing resources by bush clearing, may be necessary. The objective will be to reduce trampling pressure resulting from animal concentration and unnecessary movements. In this way, trampling caused by multiple tracks formed due to off-road driving (Chapter 5) could be discouraged.

Where land is not readily available for the buffer zone and where the people cannot be permanently incorporated in the zone, the NCC and the MTW should arrange and purchase some from the people within the area to be involved. Funds for these developments would come, mainly, from the NCC and the MTW. More financial contributions should be provided by tour companies, lodges and camps. Alternatively, the NCC and the MTW should arrange to transfer and resettle the people in one of the NCC forest or one of the woody private communities which is likely to be bought by the wealthy immigrants. Once resettled, the people will have to be assisted to adapt new lifestyles and/or allowed to transfer their lifestyles without necessarily interfering with vegetation resources.

8.3.3 Manipulation of Animal Activities

Table 8.1 is a summary of wildlife and livestock activities that should be manipulated for the management of vegetation in the study area. Two strategies, prevention of further vegetation destruction and rehabilitation of degraded land are proposed.

Manipulation of pastoral activities could be useful in avoiding unnecessary reduction and modification of plant species composition. Animal activities should be reduced in overgrazed areas which are experiecing bush encroachment (Chapter 4). These include drier parts of the Loita plains and the surrounding high density Maasai grazing lands. Where conditions have not reached the level of bush encroachment, overgrazing should be discouraged through destocking or otherwise. Afforestation programmes could be instituted to supplement natural regeneration of disturbed sites.

Animal activities	Problems	Ways of soilving the problems
(1) Overgrazing	-land degradation	-Rehabilitation programmes involving afforestation and other soil conservation measures, destocking, and game cropping -encourage selective grazing -opening up tse-tse infested areas
	-bush encroachment	-reduce land degradation -practice destocking & game cropping
(2) Browsing and trampling of seedlings	-Reduced tree recruitment	-reduce compression of grazing land, destocking and game cropping -physical protection of seedlings following agroforestry & afforestation practices

Table 8.1. Proposed strategies of Manipulating animal activities.

Although bush encroachment could be a source of wood, which is greatly needed in the plains (Chapter 7), its overall effects are a threat to the extent and status of the grassland communities. Also, it affects the development of tourism and the livestock industries (Chapter 4) through reduced grassland productivity. Dense tree cover associated with bush encroachment, sometimes, obscures game viewing by tourists. At the very worst, bush encroachment attracts tse-tse fly (Chapters 2 and 4). In view of these reasons, it is suggested that tse-tse invasion, which leads to exclusive use of certain vegetation communities, has been a major cause of pressure on grazing resources in the plains since the turn of this century. Tse-tse free habitats are preferred by wildlife but mostly by livestock, especially because of their openness (Chapter 5).

Given different effects of bush encroachment, improvement of the affected land for livestock development requires, firstly, knowledge of the spatial distribution and the nature of bush encroachment. Secondly, designing landuse practices which are less destructive to the environment. Tse-tse eradication programmes, for instance, could be intensified by clearing invaded bushlands not only to allow movement of livestock and wildlife, but also to reduce burning which has to be done to reduce tall and coarse grasses. The opening up of tse-tse infested areas for livestock activity will reduce animal pressure on grazing lands since the grasses therein which are virtually underutilized and many times attract fires, will be made available to grazers. Presently, bushlands have low livestock densities for fear of tse-tse and wildlife attack (Chapter 5).

Also, manipulation of animal activities may have to involve game cropping. Although game cropping has failed in the Serengeti (Lamprey 1984), it should be tried in Narok District, particularly with the Loita and MMGR residents, mainly wildebeest and elephants, respectively. Game cropping may be extended to include zebra and buffaloes. The move will require, firstly, settling international border skirmishes as game is a common resource between Kenya and Tanzania. Secondly, stringent rules in licensing game cropping will have to be laid down and enforced by both governments to avoid over-exploitation.

Game cropping in the Serengeti failed, firstly, because it was found to be uneconomical to conduct meat inspection and veterinary services. Secondly, because it was difficulty to run refrigerated trucks on poor roads (Lamprey 1984). The high demand for meat in Kenya (Evangelou 1984), increasing veterinary services, the relatively good road network in wildlife occupied parts of Narok District and the increasing ungulate populations (Chapter 5) are major attractions to this recommendation. A move against anti-wildlife protection option may be necessary in degrading parts in the MMGR and the neighbouring plains for the conservation of vegetation upon which wildlife populations depend and, for maintaining and/or creating a sound environment. In doing so, we will be responding to present resource dynamics in the Serengeti-Mara ecosystem following reduced grazing land.

Proper utilization of rangelands should also involve differential grazing by encouraging different animals. This practice which will allow selective grazing will also encourage differential pressure on plants leading to tall and short plains. This vegetation pattern that is being lost to increasing year-round grazing, can be achieved by different grazing height strategy involving rotation grazing.

8.3.4 Manipulation of Methods of Wood Harvesting

Direct wood cutting is another form of human disturbance which calls for re-examination. Three issues identified with this disturbance are

- -firstly, whether charcoal burning should be allowed.
- -secondly, the method of harvesting which is environmentally conservative and
- -thirdly, how to reduce pressure on decreasing wood resources.

Table 8.2 is a summary of the proposed alternative strategies of human disturbances associated with wood harvesting.

Although charcoal burning is illegally conducted (Chapter 4), the present research proposes that it should not be banned. The intervention to raise the ban is necessary because charcoal burning is becoming a thriving business in the District. Re-examination of its ban is unquestionable given that it serves as a source of income in privately owned woody communities (Chapter 4). The alternative strategy is to improve the ways of conducting this industry, especially through reducing its impact on vegetation. One way of achieving this is by intensifying afforestation of open land, including marginal areas. Once a reasonable amount of wood is raised, a licence or some form of authority should be sought for selective tree cutting, ~~trees~~. The approach whereby Chiefs authorize tree cutting (Chapter 4) which has worked fairly well in settled and demarcated areas would be extended to privately owned woody communities.

Human disturbance	Problems	Alternative strategies
(1) Charcoal burning	-exhaustion of specific species -decrease in tree density -reduced regeneration sources	-Intensification of afforestation -promotion/introduction of agroforestry -controlling tree cutting
(2) Wood cutting for domestic use	-exhaustion of valuable spp (if selected) -exhaustion of regeration sources (if totally cut) -reduced wood resources	-encourage selective wood cutting -Using less valuable abundant spp -intensify afforestation and agroforestry -explore alternative sources of energy -encourage efficient use of woodfuel -reduce the number of meals cooked per day

Table 8.2. A summary of the proposed alternative strategies of manipulating human disturbances associated with wood harvesting

In the border areas where agricultural activities have reduced recovery of natural vegetation (Chapter 7), a satisfactory afforestation programme could be instituted. This can be supplemented with agroforestry practices (section 8.3.2) which are in an early stage of development (NDDP 1984,1989; NDER 1986). The objective will be to improve increasing wood shortages (Chapter 7). Other than being assisted to establish seedling nurseries, the people must be provided with seedlings from the nurseries already established in the District (NDER 1986). Once the seedlings are planted, they must be protected against destruction by animals. Seedling damage by animals is expected. This is because as indigenous vegetation is decreasing due to increasing settlements, browsing pressure on the remaining vegetation is increasing; contributing to shrubby structures or simply destroying seedlings (Chapters 4 and 7, see also Hughes 1986; Kokwaro 1985). Watering of the seedlings during the dry season may be a necessary treatment in the semi-arid plains. Since rainfall is scarce and the rivers seasonal (Chapter 3), more water can be obtained using 'rain harvesting' water conservation methods.

Afforestation may require the local people because of the shortage of government personnel (Chapter 4; NDER 1986) for such a wide-scale exercise. Abandoned disturbed areas should be planted with indigenous fast growing multi-purpose trees. For arable land where subdivision is yet to be done, afforestation should be encouraged so that the people who will settle there will have trees to start with. Priority areas include Sogo, Masurura-Sikawa-Olenkasorai and Ndulele which are experiencing spontaneous settlements. Trees can be planted as woodlots or otherwise along the edges of the farms, or near homesteads or within pieces of land set a side (section 8.3.2).

In order to decide on the methods of wood harvesting, current ones (e.g., debranching, selective and total tree cutting) should be re-examined and weighted against available options. Due to increasing demand for food, the woody communities in medium and high potential agricultural areas will, however, have to be reduced to create room for cultivation. Also, wood harvesting cannot be avoided since the rural population depend on locally available trees/shrubs for building and fuelwood (Chapter 4). However, the emphasis should be on selective and not total tree/shrub harvesting so as to allow continuous regeneration of disturbed communities and maintain productivity of remnant communities. Selective wood harvesting should, however, not aim at creaming the best individuals leaving only less valuable species. On the contrary, it should sieve all components of a community depending on their quantity or availability and the regeneration potentials. Thus, harvesting wood resources should be regulated with respect to their availability ~~and substitutity~~. Controlled wood harvesting should be practised in all communities, including those where the tree density is high. Using less valuable, abundant, species for certain purposes (see Chapter 4) is a better way to allow regeneration of over-exploited species. This is why selective tree harvesting is a better strategy for vegetation management. Selective tree harvesting which is confined to and is responsible for the maintenance of woody communities in Maasai settled areas of Megwara and Moita-Sikawa-Masurura should be encouraged as sedentarisation advances.

Selective wood cutting spares trees which serve as sources of seeds or rootstocks leading to rapid regeneration. These trees, also, protect the soil against physical forces and ensure nutrient nourishment (Chapter 3). Thus, selective tree harvesting strategy makes the plant-soil system more closed.

Also, it takes into account tomorrow's need of tree resources. Since selective tree harvesting is familiar in the District, it should be easy to reinforce. All that is required is widening people's awareness on its ecological significance.

Further, pressure on wood resources can be reduced by encouraging importation of poles, which is becoming prevalent in both Maasai and non-Maasai occupied areas, for the construction of *bomas* and farm fences. Poles can be obtained from government exotic forest plantations in Nakuru and Kericho Districts.

Development of wood resources shouldn't stop at the mere provision of more trees. Instead, it should venture into the possibility of utilizing other sources of energy, mainly solar and wind energy. It should also address the issue of efficient use of woodfuel and the implications of continued dependance of neighbouring Districts on Narok for wood resources (Chapter 4). The use of saving stoves (*Jikos*) and the regulation of meals are ways of circumventing future fuelwood shortages. Also, there is need to create awareness of the fuelwood issue as a growing problem in the District that needs urgent attention. This is true of settled areas which are already experiencing wood shortages (Chapter 7). This awareness is expected to increase the scope of afforestation and agroforestry programmes. The agents required to participate in creating this awareness include the forest department, International Council for Research and Agro-forestry (ICRAF), Beijur institute, the Ministry of Agriculture, *Maendeleo ya wanawake* (Women's groups), NGOs, Schools and Youth wingers.

8.3.5 Manipulation of Burning

The historical significance of fire in Narok District (Chapter 2) raises two issues. These are:

-whether its use should continue or be banned. If so,

-where and when it can be used.

The scarcity of huge grass biomass, to support fire, characteristic of historical Narok (Chapter 5) is perhaps the critical factor which calls for re-examination of the use of fire as a management tool.

The use of fire for the management of vegetation must first understand its impact on vegetation. This one of the unfolded ecological aspects in the tropical savannas (Werger 1983, Cole 1986). Part of the drama is difficult to isolate the impact of fire on vegetation since it doesn't occur in isolation from the other disturbances (Chapter 5). What is clear, however, is that reduced and less hot fires promote tree regeneration because of the availability of water and nutrients as competition from herbaceous plants is reduced (Chapter 4).

The current trend of human activities in the plains, which is characterized by excessive use of grasslands implies that the use of frequent fires may not be ecologically viable. Fire should therefore be reduced or even excluded in these areas and in elephant frequented communities so as to allow regeneration of damaged trees/shrubs (see Dublin 1986, NDER 1986). Frequent fires which are converting the Olive wooded bushlands of SW

Narok into wooded grasslands, and reducing the grouped woody communities north of Lolgorein-Narok road need to be prevented to stop further destruction of woodlands which are highly needed for the supply of woody resources (Chapter 7). The build-up of litter in this areas, after the withdrawal of fire is unlikely due to the large ungulate population. Also, since there will be recruitment of woody species due to cessation of burning severe fires are not foreseable.

The use of fire to promote palatable pastures can be achieved by increasing animal activities following intensification of tse-tse fly eradication programme (section 8.3.3). This would be an ecologically viable way of reducing the use of fire in bushed grasslands and bushlands. Animal activities such as grazing and associated small-scale disturbances (Chapter 5), will keep herbaceous plants productive and palatable. However, the activities must be monitored so as not to exceed a level where they may attract tse-tse fly invasion through bush encroachment (Chapter 4). The use of fire to reduce the spread of weedy species can be replaced by direct uprooting of the species or by cultivating the area they occupy (Chapter 4). This is true of *P. schimperi* whose regeneration tends to be encouraged by burning.

In the light of declining woody resources in the plains (Chapter 7), temporary suppression of fire is inevitable. Otherwise grazing productivity will be hampered due to dominance of weedy species. For instance, the susceptibility to burn and the ease to be spread by animals and the resistance to grazing have led weedy species, mainly *Pennisetum schimperi*, *Solanum incanum*, *Croton dichogamus* and *Acacia spp* to spread very fast in settled areas at the expense of valuable grasses such as *Lodea kagerensis* and *Themeda triandra* (Chapters 4 and 7). Thus, burning for specific objectives should be weighed against the resistance of a community and the alternatives available. Ecological research being undertaken in the MMGR (Chala pers. comm.) should help in identifying the amount of herbivore impact woody resources can withstand at different browsing and trampling levels, and fire frequency and intensity. Similar disturbance-plant recovery studies are required in settled areas. The information obtained will be important in making vegetation management decisions. Consistent monitoring of the status of the herb layer in the woody communities and wooded grasslands will also be required so as to help decide whether and when to burn. The idea is to discourage (historical) spontaneous burning at the end of each dry season.

Despite the destructive effect of fire on woody communities, light burning may be necessary in rangelands. However, its timing is crucial. As was indicated in chapter 5 (see also Ross 1985), light burning is necessary for the maintenance of palatable forage. Management of fire dependent communities should allow burning when the plants are best able to recover. With reference to different studies in eastern Africa (e.g., Pratt and Gywnne 1977; Ross 1985), the burnt communities should be grazed so as to discourage development of a poorer quality habitat. According to Ross (1985), burning but no grazing results in the effective loss of grassland habitat for most grazers. Close and early grazing after burning should be discouraged to allow grass recovery (Pratt and Gwynne 1977). A cool burn early in the dry season could be the best for regrowth of woody plants (Versey-Fitzegerald 1973) and it will enable grasses to survive repeated fires while providing quality pastures. Therefore, burning should be done at the right time and the right frequency. It should be excluded in areas, where grazing intensity is moderate to severe, which may not need fire for regrowth of pastures and reducing dominance of unpalatable species.

In summary, the following sections have highlighted the possible ways of manipulating cultivation, animal activities, methods of wood harvesting, landuse practices and burning for the management of vegetation. It is clear that there is need to monitor the different human disturbances and their impact on vegetation. A methodology is therefore needed to establish the various indicators and evidence on whether changes are occurring and whether the change in direction is acceptable. These should however be preceded by feasibility studies to determine appropriate landuse practices, particularly in areas undergoing landuse transformation.

8.3.6 Manipulation of Landuse Practices

Table 8.3 summarises the problems associated with landuse practices in the study area. Alternative manipulation strategies are also offered.

Limitations	Problems	Solutions
(1) Lack of a landuse policy	-illegal encroachment into plant communities	-define the landuse policy -define forest boundaries -intercept encroachment in time
	-spontaneous human migrations and expansion of cultivation	-encourage sedentarisation and define landuse type
	-incompatible landuse -loss of privately owned woody communities	-define landuse type -control landuse -include buffer zone or offer alternative sources of wood products
(2) lack of land leasing and hiring terms	-border skirmishes -accumulation of wealth by a few in group ranches	-define leasing and hiring terms
(3) Unsatisfactory sedentarisation	-inaccessibility to common resources	-allow accessibility otherwise don't demarcate the land

Table 8.3. Limitations of landuse practices and alternative strategies for the management of vegetation.

Satisfactory manipulation of the different human disturbances, and planning and management of vegetation can be accomplished by the introduction of a landuse policy which is lacking at present (Chapter 1). The policy is needed to

- -define the viable activities for different vegetation communities
- - decide access to these communities.
- -decide on the type and extent of vegetation encroachment that is permissible in a given area together with, where

necessary, the displacement of squatters and forest dwellers (the Dorobos) from threatened communities.

-decide the future of immigrant cultivators in agricultural development.

The need for a landuse policy in Narok District has been raised by Sindiga (1984) and Lamprey (1984), see also Chapter 1, yet the suggestion remains unheeded in spite of its significance in safeguarding against the utilization of land for incompatible activities. Agricultural development is therefore advancing without central planning and control of the resource base. The major gaps include undefined landownership and the unspecified type of landuse. For instance, it is not clear whether individuals and groups of people where land is privatized and communally owned, respectively, are at liberty to put their land into uses of their choice. These uncertainities need attention from the different institutions in the District which are involved in development. These are District, Divisional and Locational development committees.

On-going privatization of land and the sedentarisation of semi-nomadic groups are not progressing satisfactorily. Certain factors remain unattended. For instance, there is need to provide access to common resources, mainly, pastures and water (Chapter 4). Knowledge of the amount and distribution of these resources and the people involved are a prerequisite. Landownership in the semi-pastoral areas may be accomplished with adequate supply of water and salt licks. This is the best way, the individual pastoralist and his animals will be kept within a demarcated boundary. Different institutions such as the Ministry of Lands, Settlements and Physical Planning, the Ministry of Agriculture, the District development institutions and a council of elders should be involved in this exercise. These groups will have to define access to common resources or raise issues, concerning them, that may require the necessary attention. As indicated in section 8.3.2, land privatisation is important for agricultural development. It brings about some attachment to the land and ensures its proper use. In the rangelands, for instance, subdivision of group ranches is encouraging sedentarisation making it easier to carry out livestock census and estimates of animal carrying capacity of each ranch. This data base is necessary for vegetation management. Diseases, especially those transmitted by animals, can also be brought under control.

Also, landuse policy should decide on landuse types with respect to the human ecology and the land potential of a given area. Under no circumstances should decisions be made only on physical endowments criteria (Ogutu 1990). Cultural factors to be considered include,

-firstly, the amount of land set a side for livestock activities. This should be a priority because of Maasai attachment to cattle (Chapter 4). In order to decide on landuse type on the basis of land potential, existing information (e.g., Jaetzold and Schmidt 1982; Sombroek *et al.*,1980) should be consulted. The information needs to be supplemented with detailed mapping and description of the plant communities, especially on private land. This information will be useful for the assessment of the genetic value of each community, the amount of the community which remains 'undisturbed' and its carrying capacity.

-secondly, local people should be allowed to participate in deciding the possible landuse in their land. This is important in formulating appropriate strategies for the utilization and management of the different plant communities. It is also important for successful implementation of these strategies. It will be recalled from chapter 1 that lack of local participation contributed to the failure of developments in the District.

The government's attempt to withdraw people from forest areas wrongly allocated to them (Chapter 4) is commendable given that the vacated areas supply Narok with forest and water resources (Chapter 3). The objective is to discourage wanton destruction. Therefore, firstly, there is need to maintain the police posts which were set up in the middle of 1980s to protect forest encroachment. The posts should be served with proper transport and communication (e.g., radio-telephone) facilities. Secondly, inaccessible forest sites should be monitored regularly using remote sensing such as Landsat to establish their status and any human encroachment. For sometime, KREMU has been involved in assessing forest cover changes in the country. Currently, the exercise has been interrupted by inadequate funding. Financial support, of this institution is needed, mainly, from the government and different development agencies in the District.

Thirdly, forest encroachment can be discouraged by the definition of forest boundaries. The latter is most needed, particularly, due to forest encroachment by immigrant cultivators in the 1980s. Attempts by the forest department to supplement natural regeneration by replanting some of the cut trees should be accompanied by the protection of regenerating species against animal browsing and trampling (Chapter 7). The vulnerability of privately owned woody communities to encroachment (Chapter 4), demands urgent attention. The situation is compounded by communal land ownership which encourages indiscriminate tree cutting since none of the members is directly accountable. As was indicated in chapter 4, the control of forest destruction has been difficult in privately owned land. On-going subdivision of these forests for individual ownership, does not guarantee forest protection. Instead, destruction may continue at a fast rate under the pretext that the individual has the right to control the activities on his land. Although this is true to a certain extent, government intervention on the nature of landuse should be inevitable. Intervention could be particularly important where a landuse type is seen to be destructive. Consistent advice to owners of these communities is required, especially because during the last 10 to 20 years, these communities have experienced the greatest loss to cropland.

Fourthly, certain precautions should however be taken so that further forest encroachment is discouraged. In settled areas, gazettement of forested land should be preceded by the provision of alternative wood resources (section 8.3.2). Or, some controlled use of these forests by the local people, especially those whose survival partly depends upon these forests should be permitted. Although this situation would be difficult to manage, small-scale activities such as selective wood and bee harvesting would be allowed since they are beneficial for vegetation regeneration and maintenance of species diversity (Chapter 7). These activities should, however, be monitored consistently so that they don't retard vegetation productivity of a given community. On the contrary, disturbances such as tree stripping for bark (Chapter 4) should be banned as they affect the survival of the already threatened species such as *Juniperus procera* and *Olea africana.*

Therefore, the manipulation of landuse practices within the forest communities may not necessarily exclude the people whose lives are intricably linked with these communities. If need be the withdrawal of forest inhabitants should be gradual to avoid ecological displacement. Okiek of Olposumoru forest who practice honey hunting are an example.

Lastly, the landuse policy should address issues affecting immigrant cultivators. As was indicated in chapter 4, harassment of these people has alot of implications for the food situation and the status of the environment. Therefore, whilst defining the different landuse types and landownership, a landuse policy should cater for land leasing or purchasing systems so as to reduce frequent tenant-landlord conflicts and associated border skirmishes (Chapter 4). In order to achieve this, the policy should review the role of the local land-board committee and adjust it accordingly.

8.4 CONCLUDING REMARKS

This chapter has offered different ways of manipulating human disturbance for the management of vegetation. These recommendations are based on the assumption that certain disturbance conversions are beneficial for vegetation development. Three human disturbance characteristics, size, frequency and intensity were identified as crucial for making decisions concerning pertinent management of vegetation. The following manipulation strategies have been suggested:

-Agricultural development should aim at reducing the expansion of cultivation. This can be achieved by improving crop output and instituting soil conservation measures. Inevitable expansion of cultivation should introduce buffer zones.

-Wood consumption should involve selective tree harvesting; Agroforestry and afforestation practices should be introduced and/or promoted to increase and/or sustain production of wood products.

-Manipulation of animal activities should involve destocking, game cropping and improvement of grazing resources.

-The use of fire for the management of vegetation should be weighted against available management options and the amount and quality of ... fuel.

-Successful implementation of the proposed recommendations requires institution of a landuse policy. This will define the landuse type and landownership. It will also define terms of land leasing and hiring.

-It is also suggested that other than relying on physical factors, successful manipulation of human disturbance requires consideration of the interest of the local people when making landuse policies. For instance, there is need to provide them with alternative earnings in return of the landuse types that they will be required to support.

CHAPTER 9 : CONCLUSIONS AND VEGETATION MANAGEMENT RECOMMENDATIONS

9.1 INTRODUCTION

In this thesis a variety of approaches have been used in data collection, description and statistical analysis in an effort to understand the impact of human disturbance on vegetation. Vegetation is an important resource which is associated with virtually all developments in Narok District. Appropriate management of this resource is required;

firstly, so as to conserve a variety of different vegetation assemblages, including rare and valuable species.

secondly, because of the role of vegetation in environmental protection.

thirdly, because of its cultural values to local inhabitants and,

fourthly, because of the large wild and domestic animals it supports.

Yet the vegetation is now undergoing rapid changes the consequences of which cannot be fully predicted.

During the course of the study a number of problems were encountered, presenting constraints on the gathering of data. These were:

-existing soil and vegetation data were either non-existing, incomplete or obsolete and were confined to a few communities, limiting generalization.

-the Maasai were reluctant to release information associated with vegetation and soil. They believed that such may lead to the death of livestock or the loss of their land.

-the use of Landsat data was hindered by delays in the purchase of images, the poor quality of the 1984 scene, which was the best available for the area, and lack of time for fieldchecks. This limited remote sensing to general interpretation and to a cloud free part of the 1984 scene.

Despite these difficulties, this study managed to:

- administer 132 questionnaires
- gather vegetation data in 42 sites
- gather soil data in 30 sites

which have proved useful in drawing a number of conclusions and making some recommendations

9.2 CONCLUSIONS

1. Vegetation changes were associated with

    - population changes due to
        - seasonal migration of humans and wildlife following fluctuations in pastures and water due to changes in rainfall, disease outbreak and internecine wars.
        - immigrants together with increased local fertility

    - loss of grazing land to *white* highland development and to immigrant cultivators. The influence of the latter was compounded by spontaneous expansion of cultivation.

    - livestock development which was characterized by inadequate knowledge of both the natural and human resources

    - increasing dependence of neighbouring Districts on Narok District for wood resources

    - destruction of plant habitats and changes in Maasai ways of wood consumption

    - increasing impact of human disturbance on soil chemistry through processes of decomposition, leaching, nutrient replenishment and biomass production.

    - variation in life form, plant life history and size of the community.

2. The inhibition model was suggested as the most appropriate to the communities' pattern of succession. Therefore, vegetation recovery will depend on the release of resources to plants which are either suppressed or have been excluded by continuous human disturbance

3. Vegetation changes resulted in

    - contraction of natural communities at the expense of agricultural communities

-decline in valuable plants, bush encroachment and, decrease in plant heights.

-increasing shortages of wood resources

-decreasing species diversity

4. Human disturbances showed a number of different patterns. They:

-differed from one plant community to another
  -due to differences in human ecology and rainfall patterns

-showed synergism

-were becoming increasingly continuous and large-scale

-were increasing in number and type

It can be concluded therefore, that knowledge of observed vegetation changes and underlying human disturbance characteristics should provide a very useful guide to decisions on the management of vegetation resources.

9.3 RECOMMENDATIONS

With reference to appraised management strategies, it is recommended that:

-agroforestry and afforestation practices be promoted for improving wood resources whilst selective tree cutting should be encouraged for wood harvesting.

-expansion of cultivation should be replaced by improved crop output through fertilization and reduction of food wastage. Accomplishment of the latter requires prevention of border skirmishes and growing of tension from the local people together with infrastructural improvement such as improved transport and marketing facilities

-cultivation should be preceded by detailed assessment of human and natural resources and identification of buffer zones, and accompanied by soil conservation measures, agro-forestry and afforestation practices.

-a move to a mixed economy be encouraged because pure pastoralism subjects the local population to seasonal food shortages and degrades the natural environment.

-manipulation of animal activities should involve destocking, game cropping, improvement of grazing resources through bush clearing and provision of marketing and transport facilities and, alternative sources of income.

When suggesting these recommendations, it must be admitted that they cannot be accommodated without a degree of negative effect on the human and natural environment. This however gives us no reason to sit back or relax hoping that somehow vegetation destruction in Narok District will be resolved by sheer chance of wisdom of the political leaders. Specific guidelines arising from detailed field studies are required to enable them decide objectively and effectively on management strategies.

9.4 IMPLICATIONS OF THE STUDY

The findings of this research have several important implications for development planning in Narok District and implications for future research.

9.4.1 Implications for Development Planning in Narok District

Future developments should

1. address landuse policy, particularly, issues of land ownership and the type of landuse, with respect to physical and human ecology.

2. protect certain areas from demarcation either because of their low potential and high susceptibility to disturbance or due to the unique biota they support or on both counts.

3. involve local participation and assist the people to cope with changes accompanying development so as to reduce environmental degradation and rural poverty which development is geared to eliminate.

4. provide adequate investment and funding of projects. Government funding and foreign aid may be necessary. However, before seeking foreign assistance, local development agencies should be approached for some funding and clear stage-by-stage objectives established.

5. increase public awareness on the effect of the increasing

human and animal populations on vegetation management. This awareness should be country-wide because of increasing dependence on the District for food, water, wildlife and wood resources.

Population characteristics are important in determining the rate of implementation of development projects and the allocation of resources. It is maintained in this thesis that the present degradation of the resource base in Africa and, indeed, with other developing countries is as a result of population explosion in fragile environments. Consequently, implementation of development projects has often had to be carried out hurriedly, without due consideration of human and natural resources. This is the problem that developing nations have to confront. Narok District is no exception; otherwise, its meagre vegetation resources will be eroded within the next few decades. Failure to prevent further destruction of the vegetation of Narok District should be seen not only as a misfortune to the local people, but in a wider context, as a threat to the neighbouring Districts and Kenya of an environment which currently supports agriculture, wildlife, wood and water resources. It is on this basis that development of wood resources in the District must consider continued dependence of neighbouring Districts for wood products.

6. have some linkage within development agencies and, between themselves and the local people so as to increase their knowledge of the nature of resources involved in development projects.

7. re-examine the influence of both internal and external forces on cropland fluctuations. These forces bear a lot on Kenya's food situation, and the development of agriculture, tourism/wildlife conservation and the management of vegetation in Narok District.

8. give special attention to plant communities in marginal areas. Over-exploitation of specific species such as *Olea africana* and *Juniperus procera*, also, requires special attention. These species take a long time to mature and require specific ecological conditions for germination and growth.

9.2.2 Implications for Future research

Different aspects that require consideration are:

1. data on human ecology so as to establish past human impact on vegetation, and predict present and future human impact on the Narok environment. An interdisciplinary approach should be used so that each discipline contributes its knowledge and biases.

2. updating existing landuse, soil, vegetation and population surveys preferably at a large-scale (1:25,000 or 1:50,000). Priority should be given to compiling an accurate database of the state of plant communities on private land.

3. focusing on plant response to disturbance, regenerative capacity of different lifeforms, environmental triggers for reproduction, seed dormancy and mechanisms of seedling protection. Such knowledge would be useful for assessing different types of human disturbances and for selection of management strategies of specific species.

4. vegetation inventories with a focus on the quality and abundance of species and endangered species. Local knowledge of scarce plants or those disappearing should supplement scientific investigation of endangered species; and an understanding of the ecological conditions of these species.

This accomplishment will help us know what vegetation resources there are, how they are distributed and how much have been disturbed. It is on the basis of this knowledge that specific areas will be identified and given due attention.

Lastly, this study has demonstrated that Narok District has been until recently, a forgotten limb of Kenya's economy. The contemporary increases in population pressure on resources, render it certainity that the District can no longer escape the pattern of development elsewhere. Fortunately, there is still time, albeit short, to ensure that worst excess of land degradation are avoided in Narok.

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Appendix A List of Plant species per plot, a total of 42 plots considered. Species identification based on herbarium specimen.

Site No.	plant species	Number of plants /seedlings <1m	Number plants >1m	Average height(m)	dbh (m)
Undisturbed forest					
2.	*Olea africana*	0	8	32.5	0.9
	Pavernia patens	7	233	1.75	0.01
	Hibiscus aponeurus	0	4	1.40	0.02
	Leonotis nepetifolia	20	0	0.20	
	Dombeya dawei	12	112	3.10	0.01
	Urena lobata	0	26	1.85	0.01
	Cyanthula polycephala	1	0	0.24	
	Monechma subsessile	1	0	0.25	
	Tagetes minuta	1	0	0.09	
	Solanum indicum	1	0	0.51	
	Teclea nobilis	2	3	4.0	0.52
	Vigna spp	1	0	0.09	
	Capparis tomentosa	1	0	0.2	
	Asparagus africana	1	1	0.24	0.01
	Rhus na talensis	3	0	1.30	
	Hibiscus fusca	45	30	0.40	0.02
	Tachonanthus camphoratus	2	4	4.0	0.03
	Amaranthus angustifolia	1	0	1.20	
	Lippia carviodora	0	11	1.84	0.02
	Getenbergia fischeri	5	1	1.35	0.02
	Lippia javanica	3	1	1.75	0.01
	Isoglossa gregorii	1	0	0.24	
3.	*Olea africana*	0	34	32.2	1.3
	Abutilon mauritianum	1	121	3.0	0.14
	Cyanthula cylindrica	1	0	0.2	
	Urena lobata	19	0	0.6	
	Monechma subsessile	1	0	0.05	
	Asparagus africana	1	0	0.03	
	Solanum indicum	1	0	0.64	
	Teclea nobilis	6	8	1.4	0.26
	Solanum incanum	1	0	0.3	
	Cyanthula polycephala	1	0	0.02	
	Tagetes minuta	1	0	0.07	
	Capparis tomentosa	1	0	0.2	
	Rhus na talensis	0	4	1.2	0.09
	Crotalaria incana	1	0	0.37	
	Lippia carviodora	2	0	0.8	
	Helichrysum odoratissimum	1	0	0.52	
	Hibiscus aponeurus	1	0	0.2	
	Kyllinga bulbosa	1	0	0.02	
	Ovaria lucida	2	0	0.34	
	Dichrocephala chrysanthemifoliaa	1	0	0.26	
7.	*Solanum nigrum*	1	0	0.4	
	Mimulopsis alpina	1	2	2.4	0.4

	Warburgia ugandensis	2	0	0.42
	Podocarpus milanjianus	0	18	36.0 1.2
	Orobanche minor	1	0	0.42
	Olea africana	0	15	20.6 1.05
	Polyscias kikuyuensis	12	0	0.8
	Prunus africana	0	6	18.6 1.03
	Juniperus procera	8	0	0.4
	Dovyalis abyssinica	3	2	8.2 0.62
	Clausena anisata	4	0	0.46
	Rhamnus prinoides	0	1	5.4 0.81
	Commiphora africana	0	1	2.6 0.34
	Teclea nobilis	2	4	8.6
	Asparagus africana	1	0	0.67
	Myrsine africana	3	2	19.5 1.2
	Carissa edulis	1	0	0.92
	Kigetia africana	3	2	3.4
	Olea hochstetteri	0	27	24.4 1.08
	Clutia robusta	1	0	0.67
	Xymalos monospora	17	2	14.3 0.46
	Ilex mitis	0	4	14.3 1.13
	Sanicula elata	1	1	1.4 0.20
	Cyphostemma kilimandscharicum	1	0	0.45
	Maytenus heterophylla	0	1	4.4 0.67
	Scutia myrtina	1	1	4.1 0.47
	Achemilla rathii	1	1	4.8 0.68
	Nuxia congesta	0	2	10.4 1.01
	Cancalis incognita	1	0	0.4
	Cineraria grandiflora	1	0	0.6
	Isoglossa gregorii	1	0	0.42
	Isoglossa substrobilina	1	1	2.2
	Gnaphalium lutea-album	1	0	0.2
	Helichrysum foetidum	1	0	0.4
	Ehrharta abyssinica	1	0	0.54
	Zehneria scabra	1	0	0.24
9.	*Myrsine africana*	0	37	4.10 0.34
	Podocarpus milanjianus	0	3	10.2 0.90
	Olea hochstetteri	0	34	19.3 1.40
	*Olmpoto**	8	8	4.30 0.25
	Rhus natalensis	1	6	4.23 0.30
	Psychotria orophila	1	0	0.61
	Capparis tomentosa	1	0	0.34
	Plectranthus assurgens	1	0	0.21
	Achyranthes aspera	1	0	0.42
	Scutia myrtina	9	7	6.10 0.8
	Commiphora spp	4	0	0.41
	Helichrysum odoratissimum	1	0	0.36
	Sporobolus pyramidalis	1	0	0.48
	Trichocladus ellipticus	1	0	0.41
	Teclea nobilis	67	108	3.40 0.42
	Cymbopogon afrinadus	1	0	0.31
	Toddalia asiatica	1	1	4.20 0.26
	Mikaniopsis clematoides	1	0	0.41
	Rhamnus prinoides	5	2	4.3 0.21

	Juniperus procera	0	8	21.6 2.24
	Asparagus africana	1	0	0.21
	Tarenna graveolens	1	0	0.81
	Carissa edulis	1	0	0.38
	Olinia usambarensis	1	0	0.41
	Clausena anisata	1	3	4.2
	Achemilla rathii	1	0	0.46
	Commiphora habessinica	1	0	0.38
	Dombeya dawei	0	1	20.8 1.8
	Vernonia auriculifera	2	0	0.34
	Harungana madagascarensis	1	0	0.44
	Polyscias kikuyuensis	0	1	12.0 0.43
	Pennisetum schimperi	1	0	0.41
	Digitaria scalarum	1	0	0.38
	Tagetes minuta	1	0	0.29
	Crassocephalum rubens	1	0	0.46
	G. ciliata	1	0	0.31
	Olea africana	0	2	13.0 0.43
12.	*Halleria lucida*	1	0	0.49
	Dombeya goetzenii	0	12	20.41 0.62
	Monechma subsessile	1	0	0.48
	Setaria longiseta	1	0	0.34
	Abutilon mauritianum	1	0	0.38
	Asparagus africana	1	2	1.86 0.12
	Achyranthes aspera	1	0	0.69
	Albizia gummifera	1	4	3.82 0.47
	Croton macrostachyus	0	10	14.3 0.90
	*Omosobeti**	0	4	14.6 0.56
	Carissa edulis	1	2	1.87 0.04
	Polyscias kikuyuensis	0	2	15.5 0.90
	Teclea nobilis	30	20	4.80 0.40
	Prunus africana	0	1	5.30 0.20
	Vernonia auriculifera	0	1	5.00 0.20
	Rhus natalensis	0	2	11.0 0.30
	Cassipourea malosana	0	3	15.56 0.7
	Tarenna graveolens	1	0	0.88
	Cyperus esculentus	1	0	0.36
	Grewia similis	0	4	15.2 0.5
	Stephania abyssinica	1	4	1.84 0.12
	Piper capense	1	0	0.79
	Teclea simplifolia	49	2	12.2 0.9
	Urena hypselodendra	1	1	2.81 0.14
	Allophyllus abysinicus	1	0	0.61
	Crotalaria kiensis	0	2	4.2 0.12
	Crassocephalum montuosum	1	0	0.94
	Toddalia asiatica	1	0	0.83
	*Mshame**	0	5	6.3 1.20
	Pteridium aquilinum	1	0	0.92
	Isoglossa gregorii	1	0	0.93
	Scutia myrtina	2	6	15.8 0.80
	Nuxia congesta	0	2	14.6 0.70
31.	*Olea africana*	17	9	9.2 0.82

Capparis tomentosa	1	0	0.21	
Monechma subsessile	1	0	0.19	
Cynanthula cylindrica	1	0	0.41	
*Olokorododai**	0	12	6.4	0.40
Asparagus africana	1	2	1.41	0.02
Saturea biflora	1	0	0.21	
Podocarpus milanjianus	32	40	11.9	0.62
Nuxia congesta	12	14	5.6	0.53
Grewia similis	4	8	6.3	0.32
Pteridium spp	1	0	0.64	
*Oldangotua**	1	0	0.73	
Pteridium aquilinum	1	0	0.82	
Rapanea melanophloeos	3	14	5.8	0.46
Rubia cordifolia	1	0	0.21	
Rhamnus prinoides	1	0	0.30	
Euphorbia ugandensis	1	0	0.46	
Arundinaria alpina	1	0	2.1	
*Oloilondoi**	2	16	7.2	0.60
*Omobamba**	0	4	2.4	0.10
*Olkireny**	0	3	8.0	0.28
Juniperus procera	10	8	10.12	0.71
*Olkirusha**	5	30	14.2	0.94
Rhus vulgaris	0	8	5.2	0.06
*Osiralei**	2	1	1.81	0.30
Faurea saligna	0	5	6.21	0.45
*Rigeri**	1	0	0.21	
Themeda triandra	1	0	0.41	
Cassia didymobotrya	30	0	0.23	
Polygala sphenoptera	1	2	1.42	0.04
Dombeya goetzenii	0	1	7.60	0.02
Pavetta oliveriana	1	0	0.24	
Crassula aloenoides	1	0	0.31	
Schefflera volkensii	1	0	0.42	
Cyphostemma kilimandscharicum	1	0	0.67	
Maytenus arbutifolia	1	0	0.91	
Achemilla rathii	1	0	0.24	
Panicum calrum	1	0	0.41	
Helichrysum cymosum	1	0	0.19	
Carex chlorosaccus	1	0	0.44	
Andropogon chrysoastachyus	1	0	0.22	
Aristea alata	1	0	0.28	
Schoenoxiphium lehmanii	1	0	0.31	
Monsonia senegalensis	1	0	0.44	
38. Monechma subsessile	1	0	0.50	
Capparis tomentosa	1	0	0.75	
Setaria longiseta	1	0	0.44	
Solanum incanum	1	0	0.22	
Achyranthes aspera	1	0	0.64	
Isoglossa gregorii	1	0	0.98	
Cyanthula cylindrica	1	1	1.52	0.01
Rubia cordifolia	1	0	0.24	
Bidens pilosa	1	0	0.31	
Sonchus luxurians	1	0	0.48	

Kyllinda bulbosa	1	0	0.29	
Cynoglosium caeruleum	1	0	0.38	
Dombeya goetzenii	0	22	28.4	1.64
Rapanea melanophloeos	0	5	18.6	0.68
Olea africana	0	2	19.2	1.20
Nuxia congesta	0	11	20.1	1.30
Carissa spp	1	3	1.92	0.02
Asparagus africana	1	4	1.81	0.02
Zehneria scabra	1	2	12.1	
Nuxia spp	1	0	0.93	
Carissa edulis	0	2	12.02	0.7
Clutia robusta	1	3	1.87	0.02
Euphorbia ugandensis	0	1	2.1	0.06
Prunus africana	0	1	13.2	0.8
Sparmannia ricinocarpa	1	1	1.42	0.03
Buddleja polystachya	1	0	0.43	
Senecio moorei	1	0	0.64	
Dichrocephala chrysanthemifoliaa	1	1	0.86	
Conyza pyrifolia	1	0	0.54	
Anthriscus silvestris	1	0	0.51	
Hypoestes trifola	1	0	0.28	
Helichysum maranguense	1	0	0.58	
Cynoglosium geometricum	1	0	0.62	
Saturea biflora	1	0	0.64	
Disturbed forest				
6. *Capparis tomentosa*	1	0	0.02	
Dovyalis abyssinica	1	0	0.31	
Podocarpus milanjianus	9	4	32.3	1.8
*Orsushet**	1	5	30.2	1.4
Pennisetum clandestinum	1	0	0.12	
Tagetes minuta	1	0	0.56	
Oxalis corniculata	1	0	0.021	
Olea hochstetteri	2	3	1.47	0.04
Chenopodium opulifolium	1	0	0.4	
Cucurbita spp	1	0	4.3	
Cynoglosium caeruleum	1	0	0.3	
Solanum tuberosum	1	0	0.28	
Helichrysum odoratissimum	1	0	0.24	
Leonotis nepetifolia	1	0	0.13	
Physalis peruviana	1	0	0.13	
Solanum nigrum	3	0	0.38	
Myrsine africana	3	0	0.48	
Olea africana	0	1	40.0	2.1
Clausena anisata	1	0	0.18	
Amaranthus hybridus	1	0	0.23	
Clutia robusta	1	0	0.21	
Carissa edulis	1	0	0.48	
Cyanthula cylindrica	1	0	0.28	
Bidens pilosa	1	0	0.25	
Conyza floripunda	1	0	0.34	
Polygonum nepalense	1	0	0.51	
Olea hochstetteri	0	2	28.2	2.1

Rumex bequaertii	1	0	0.24	
Stephania abyssinica	1	1	1.4	0.01
Trifolium ruepellianum	1	1	0.51	
Achemilla rathii	1	0	0.83	
Senecio moorei	1	0	0.8	
Mimulopsis alpina	1	4	2.4	0.01
Torilis arvensis	1	1	0.41	
Pencedanum elgonense	1	0	0.24	
Anthemis tigrensis	1	0	0.52	
Panicum trichocladum	1	0	0.23	
Plectranthus barbatus	1	0	0.23	
Plantago major	1	0	0.42	
Alectra sessiflora	1	1	2.4	
Laggera elatior	1	3	1.4	
Senecio syringifolius	4	1	2.2	0.01
Crassocephalum crepidioides	1	0	0.56	
Circium vulgare	1	0	0.4	
Salvia nilotica	1	0	0.56	
Sonchus oleraceus	1	0	0.8	
Warburgia ugandensis	4	1	4.8	0.02
Commiphora spp	16	0	0.15	
8. *Juniperua procera*	0	62	8.80	0.42
*Olmpoto**	0	20	6.20	0.02
Hypericum lanceolatum	50	14	0.90	0.01
Myrsine africana	37	64	1.34	0.30
Rhus vulgaris	2	1	4.80	0.40
Olea africana	3	0	0.46	
Faurea saligna	2	0	0.48	
Euphorbia ugandensis	1	4	0.97	
Capparis tomentosa	1	0	0.41	
Rubia cordifolia	1	0	0.21	
Monechma subsessile	1	0	0.89	
Prunus africana	1	0	0.21	
Pyhsalis peruviana	1	0	0.38	
Solanum incanum	1	2	1.20	0.01
Stephania abyssinica	1	0	0.26	
Oxalis corniculata	1	0	0.11	
Clutia robusta	4	0	0.36	
Circium vulgare	1	0	0.14	
Sparmannia ricinocarpa	1	1	2.10	
Pennisetum clandestinum	1	0	0.21	
Trifolium semipilosum	1	0	0.41	
Carex fischeri	1	0	0.61	
Conyza welwitschii	1	0	0.31	
Desmodium repadum	1	0	0.54	
Psorea faliosa	0	14	2.00	0.03
Dischrocephala integrifolia	1	0	0.31	
Helichrysum odoratissimum	1	0	0.42	
Laggera elatior	1	0	0.51	
Senecio subsessiles	1	0	0.22	
Saturea biflora	1	0	0.69	
Saturea pseudosimensis	1	0	0.82	
Asparagus africana	1	0	1.2	

11.	*Croton macrostachyus*	7	9	22.8	1.3
	Dombeya goetzenii	0	3	14.7	0.6
	Albizia gumnifera	0	3	3.1	1.2
	Pennisetum clandestinum	1	0	0.42	
	Amaranthus spp	1	0	0.44	
	Bidens pilosa	1	0	0.48	
	Zea mays	1	0	0.21	
	Solanum nigrum	1	0	0.90	
	Phaseolus lunatus	1	0	0.28	
	Helichrysum odoratissimum	1	0	0.32	
	Conyza floripunda	1	0	0.92	
	Sonchus oleraceus	1	0	0.62	
	Pavonia urens	1	0	0.89	
	Tarrena graveolens	1	0	0.42	
	Olia rochetiana	1	0	0.92	
	Commelina benghalensis	1	0	0.51	
	Solanum incanum	1	0	0.92	
	Thalictrum rhyncocarpum	1	0	0.43	
	Cyphostemma orondo	1	0	0.82	
	Gouania longispicata	1	0	0.73	
	Nuxia congesta	1	0	0.68	
	Solanum mauritianum	1	0	0.87	
	Dracaena afromontana	1	0	0.82	
	*Omosobeti**	0	19	14.6	1.0
	*Mathakwa**	12	0	0.82	
	*Stinging nestle**	1	0	0.92	
13.	*Olea africana*	1	12	25.9	1.3
	Celtis africana	2	1	4.8	0.3
	Solanum indicum	1	0	0.82	
	Chenopodium schraderanum	1	0	0.14	
	Helichrysum odoratissimum	114	0	0.62	
	Croton macrostachyus	4	1	1.38	0.23
	Commiphora sambarensis	1	0	0.42	
	Hibiscus aponeurus	1	0	0.28	
	Monechma subsessile	1	0	0.49	
	Solanum nigrum	1	0	0.68	
	Physalis peruviana	1	0	0.57	
	Sonchus oleraceus	1	0	0.34	
	Zea mays	1	0	0.89	
	Cyperus rotundus	1	0	0.33	
	Malva vecticcilate	1	0	0.28	
	Solanum tuberosum	1	0	0.23	
	Oxalis corniculata	1	0	0.11	
	Albizia gumnifera	1	0	0.46	
	Veronica abyssinica	1	0	0.46	
	Leucas microntha	1	0	0.24	
	Halleria lucida	1	0	0.49	
	*Omorande bwenda**	1	0	0.89	
	Gouania longispicata	1	0	0.68	
	Digitaria abyssinica	1	0	0.06	
32.	*Pennisetum clandstinum*	1	0	0.31	

Amaranthus spp	1	0	0.28	
Silene gallica	1	0	0.30	
*Ray grass**	1	0	0.51	
Capparis tomentosa	1	0	0.22	
Tagetes minuta	1	0	0.64	
Zea mays	1	0	1.30	
Leonotis nepetifolia	1	0	0.22	
Blumea alata	1	0	0.40	
Rumex bequaertii	1	0	0.28	
Cyanthula cylindrica	1	0	0.62	
Cupperessus benthemii	0	3	7.9	0.4
Solanum indicum	1	0	0.97	
Achyranthes aspera	1	0	0.43	
Circium vulgare	1	0	0.52	
Saturea biflora	1	0	0.24	
Oxalis corniculata	1	0	0.18	
Stephania abyssinica	1	0	4.1	
Dasyphaera prostrata	1	0	0.21	
Nuxia congesta	7	4	12.1	
Juniperus procera	4	0	0.45	
Cyperus rotundus	1	0	0.31	
Olea africana	4	0	0.66	
Pellae adiantoides	1	0	0.12	
Verninica abyssinica	1	0	0.36	
Olinia usambarensis	0	7	12.2	0.6
Rubia cordifolia	1	0	0.61	
*Olturoy**	0	2	14.6	0.9
Rhus na talensis	3	0	0.18	
Maytenus undata	1	0	0.42	
*Omotagara**	1	0	0.54	
Monechma subsessile	1	0	0.24	
Polygonum nepalense	1	0	0.21	
Solanum terminale	1	0	0.18	
Ilex mitis	1	0	0.12	
Antopetia abyssinica	1	0	0.41	
Crepis rueppelli	1	0	0.26	
Cotula abyssinica	1	0	0.44	
Cancalis incognita	1	0	0.31	
Vernonia lasiopus	1	0	0.62	
Gomphocarpus physocarpus	1	0	0.34	
Helichrysum foetidum	1	0	0.19	
Lactuca glandulifera	1	0	0.31	
Sonchus luxurians	1	0	0.18	
Eragrostis kiwuensis	1	0	0.41	
Amaranthus hybridus	1	0	0.28	
Aerva lanata	1	0	0.23	
33. *Crassocephalum picridifolia*	1	0	0.34	
Solanum indicum	1	0	0.39	
Sida cuneifolia	1	0	0.21	
Pennisetum clandestinum	1	0	0.24	
Eragrostis tenuifolia	1	0	0.29	
Circium vulgare	1	0	0.22	
Ocimum suave	1	0	0.33	

*Ekenyunyunta maino**	1	0	0.29	
Centella asiatica	1	0	0.31	
Cyperus rotundus	1	0	0.19	
Blumea alata	1	0	0.49	
Trifolium ruepellianum	1	0	0.61	
Oxalis corniculata	1	0	0.22	
Hibiscus canabinus	12	6	1.2	
Amaranthus spp	1	0	0.41	
Indigofera spicata	1	0	0.62	
Pennisetum schimperi	1	0	0.49	
Sporobolus angustifolia	1	0	0.43	
Cassia mimosaides	1	0	0.21	
Juniperus procera	1	0	0.65	
Solanum incanum	279	360	1.89	0.2
Ehretia cymosa	11	4	12.9	0.62
Halleria lucida	1	0	0.6	
Lantana rhodensiensis	1	10	2.49	0.29
Physalis peruviana	1	0	0.43	
Tagetes minuta	1	0	0.68	
Olea africana	58	7	14.4	0.54
Pavonia patens	1	0	0.49	
Cassia didymobotyra	6	0	0.69	
Rhus natalensis	13	6	2.7	
Solanum spp	1	0	0.45	
Conyza pyrifolia	1	0	0.26	
Neonotonia wightii	1	0	0.61	
Toddalia asiatica	1	0	0.21	
Solanum nigrum	1	0	0.36	
Clematis hitsuta	1	0	0.21	
Rhamnus staddo	1	0	0.42	
Hibiscus aponeurus	1	0	0.24	
Commelina benghalensis	1	0	0.34	
Teclea nobilis	48	0	0.63	
Teclea simbilis	33	27	5.7	0.06
Canthium gueinzii	1	0	0.24	
Artemisia afra	1	0	0.64	
Celtis africana	1	0	0.82	
Abutilon longicuspe	1	0	0.34	
Conyza stricta	1	0	0.31	
Conyza floripunda	1	0	0.37	
Acacia oldobesi	1	0	0.96	
Conyza schimperi	1	0	0.26	
Achyranthes aspera	1	0	0.28	
Monechma subsessile	1	0	0.62	
Galium simense	1	0	0.31	
Helichrysum odoratissimum	1	0	0.38	
Commiphora africana	1	0	0.47	
Lippia carviodora	1	1	2.3	0.06
Dombeya goetzenii	1	0	0.86	
Bidens pilosa	1	0	0.36	
Senecio hyratus	1	0	0.21	
Cynanchum altiscandens	1	0	0.84	
Lycium europeum	1	0	0.47	
Plectranthus kamerunensis	1	0	0.42	

Salvia nilotica	1	0	0.28	
Eragrostis paniciformis	1	0	0.26	
Sonchus luxurians	1	0	0.33	
39. Pennisetum clandestinum	1	0	0.07	
Kyllinda bulbosa	1	0	0.02	
Pennisetum schimperi	1	0	0.12	
Cyanthula cylindrica	1	0	0.31	
Cynoglosium caeruleum	1	0	0.38	
Capparis tomentosa	1	0	0.23	
*Stinging nestle**	1	0	0.61	
Sonchus luxurians	1	0	0.32	
Leonotis nepetifolia	1	0	0.17	
Blumea alata	1	0	0.31	
Geranium arabicum	1	0	0.28	
Saturea biflora	1	0	0.19	
Monechma subsessile	1	0	0.31	
Conyza floripunda	1	0	0.04	
Oxalis latifolia	1	0	0.19	
Achyranthes aspera	1	0	0.21	
Vicia sativa	1	0	0.19	
Tagetes minuta	1	0	0.08	
Oxalis corniculata	1	0	0.04	
Centella asiatica	1	0	0.19	
Crotalaria oocarpa	1	0	0.21	
Colutea abyssinica	1	0	0.31	
Cassia tomentosa	1	0	0.24	
Senecio moorei	1	0	0.31	
Anthriscus silvestris	1	0	0.28	
Cancalis incognita	1	0	0.23	
Dichrocephala chrysanthemifolia	1	0	0.41	
Cineraria grandiflora	1	0	0.23	
Dipsacus pinnatifidus	1	0	0.28	
Gnaphalium undulatum	1	0	0.19	
Helichrysum schimperi	1	0	0.20	
Helichrysum foetidum	1	0	0.18	
Helichrysum nandense	1	0	0.23	
Eustachys parpaloides	1	0	0.16	
Lysimachia ruhmeriana	1	0	0.21	
Cassia didymobotrya	1	0	0.23	
Undisturbed woodland				
10. Teclea nobilis	142	75	6.40	0.35
Helichrysum odoratissimum	245	0	0.42	
Rhus vulgaris	6	24	6.2	0.3
Commiphora erythraea	3	8	4.9	0.4
Grewia similis	4	0	0.24	
Hibiscus aponeurus	0	5	2.8	0.12
Olea africana	88	34	6.6	0.34
Microglossa pyrifolia	66	0	0.42	
Solanum indicum	2	0	0.72	
Euclea divinorium	0	26	10.6	0.4
Scutia myrtina	0	8	1.2	0.1

	Halleria lucida	1	0	0.8	
	Rhoicissus revoilii	1	0	0.42	
	Euphorbia ugandensis	0	20	1.78	
	Juniperus procera	2	14	16.4	0.6
	Trimeria bakeri	0	1	3.0	0.1
	Maytenus putterlickioides	11	9	3.6	0.25
	Prunus africana	0	7	4.8	0.2
	Setaria longiseta	1	0	0.21	
	Commelina benghalensis	1	0	0.18	
	Rubia cordifolia	1	0	0.41	
	Tachonanthus camphoratus	13	4	2.10	0.12
	Pentas lanceolata	1	0	0.31	
	Cynodon dactylon	1	0	0.41	
	Saturea biflora	1	0	0.12	
	Tagetes minuta	1	0	0.28	
	Toddalia asiatica	1	0	0.41	
	Solanum incanum	1	0	0.21	
	Hibiscus fusca	8	0	0.34	
	Achyranthes aspera	1	0	0.24	
	Peperonia tetraphylla	1	0	0.61	
	Euclea spp	0	3	6.6	0.2
	Tarrena graveolens	1	0	0.45	
	Salvadora persica	1	0	0.21	
	*Oldangotua**	1	0	0.34	
	Isoglosaa gregorii	1	0	0.89	
	*Rwathe**	0	4	7.4	0.5
	Teclea simplifolia	70	181	4.6	0.2
40.	*Aloe lateritia*	1	0	0.25	
	Vernonia karaguensis	4	2	5.3	0.13
	Erythrina abyssinica	0	1	5.7	0.42
	Combretum collinum	0	3	4.6	
	Ozoroa reticulata	3	1	4.69	0.3
	Rhus na talensis	0	4	5.2	0.22
	Olea hochstetteri	0	2	8.9	0.34
	Olea africana	14	3	6.4	0.28
	Eleaodendron buchananii	2	0	0.56	
	Teclea tricarpa	1	4	7.2	0.2
	Teclea nobilis	14	2	3.7	0.14
	Ocimum baccilicum	1	0	0.69	
	Loudetia kagerensis	1	0	0.82	
	Acacia hockii	0	2	4.9	0.6
	Themeda triandra	1	0	0.45	
	Cymbopogon excavatus	1	0	0.54	
	Combretum molle	0	1	6.6	1.31
	Maesa lanceolata	1	0	0.67	
	Lantana camara	4	0	0.39	
	Pennisetum schimperi	1	0	0.45	
	Brachiaria brizantha	1	0	0.23	
	Trichocladus ellipticus	1	0	0.56	
	Microchloa kunthii	1	0	0.21	
	Setaria sphacelata	1	0	0.28	
	Solanum incanum	4	1	6.7	0.04
	Lippia javanica	1	0	0.56	

Cordia molle	0	2	2.9	0.2
Commiphora africana	0	1	4.2	0.24
Eragrostis braunii	1	0	0.46	
Garbia brevicandata	1	0	0.67	
Kigelia aethiopum	1	0	0.32	
Ficus cycomorus	0	1	6.8	0.22
Hyperhenia rufa	1	0	0.34	
Cymbopogon spp	1	0	0.28	
Sporobolus pellucidus	1	0	0.34	
Conyza newii	1	0	0.23	
Rynchelytrum repens	1	0	0.19	
Croton dichogamus	0	2	5.6	0.2
Diospyros abyssinica	0	1	17.2	0.8
19. Markhamia platycalx	8	38	14.6	0.67
Ficus capensis	1	0	3.0	
Indigofera arrecta	0	13	3.4	
Strychnos lucens	1	6	3.6	0.2
*Entamori**	1	0	2.8	
Physalis peruviana	1	0	0.8	
Cyphostemma orondo	1	1	2.4	
Urena lobata	5	0	0.34	
Toddalia asiatica	1	1	4.2	
Commelina benghalensis	1	0	0.42	
Delonix regia	3	1	3.41	0.34
Diospyros abyssinica	1	1	12.3	0.51
Tragia benthamii	1	0	0.24	
Albizia gummifera	2	29	14.6	0.5
Commiphora boiviniana	1	0	0.8	
Vangueria acutiloba	3	1	1.86	0.1
Cassia didymobotyra	10	8	6.1	0.23
Cissus rotundifolia	1	1	2.24	0.06
Clausena anisata	6	5	1.8	0.13
Warburgia ugandensis	55	11	8.1	0.4
*Egentonkono**	1	0	0.87	
Allophyllus macrobotrys	4	10	6.12	0.36
Carissa edulis	1	0	0.72	
Grewia bicolor	1	0	0.4	
Leucas calosatchyus	1	1	4.1	0.06
*Muratina**	0	3	9.0	0.5
Setaria longiseta	1	0	0.28	
Phyllanthus sepialis	1	1	2.5	0.2
Hibiscus aponeurus	0	4	4.1	0.12
Kebergia rueppelina	1	0	0.2	
Vernonia amygdalina	2	2	4.3	0.32
Croton macrostachyus	1	1	3.8	0.40
Uvaria schaffleri	3	2	1.7	0.3
Grewia spp	1	0	0.4	
Blighia unijugata	1	0	0.61	
Cardiospericum grandiflorium	1	0	0.08	
Setaria plicatilis	1	0	0.62	
Vernonia galamensis	2	0	0.42	
Pavetta termifolia	1	0	0.18	
Hypoestes verticillata	1	0	0.42	

Pentarrhinum inspidum	1	1	1.4
Ipomea spp	1	1	2.1
Justicia spp	1	0	0.4
Ipomea termistris	1	0	0.41
Justicia flava	1	1	0.08
Cissus spp	1	1	1.30 0.04
Dombeya dawei	4	0	0.38
Canthium gueinzii	1	0	0.29
Achyranthes aspera	1	0	0.41
Disturbed woodland			
14. Croton macrostachyus	1	0	0.34
Ageratum conyzoides	1	0	0.47
Amaranthus hybridus	1	0	0.32
Bidens pilosa	1	0	0.36
Cynodon dactylon	1	0	0.48
Cyperus rotundus	1	0	0.34
Tagetes minuta	1	0	0.14
Zea mays	1	0	0.22
Solanum tuberosum	1	0	0.26
Chyrsantherum cinerriaefolium	1	0	0.27
Pennisetum clandestinum	1	0	0.82
Solanum nigrum	1	0	0.49
Centella asiatica	1	0	0.36
Digitaria scalarum	1	0	0.43
Commelina benghalensis	1	0	0.36
Crotalaria incana	1	0	1.4
Musa paradisiaca	1	0	0.36
Oxalis corniculata	1	0	0.41
Abutilon mauritianum	1	0	0.31
Hoslundia opposita	1	0	0.12
Crassocephalum picridifolia	1	0	0.14
*Ekenyunyunta maino**	1	0	0.18
Veronica abyssinica	1	0	0.36
Aspilia alpina	1	0	0.45
Phyllanthus amarus	1	0	0.18
Physalis peruviana	1	0	0.36
Portulacca oleracea	1	0	0.42
Digitaria velutina	1	0	0.61
*Riboroche**	1	0	1.68
Pennisetum pupurcum	1	0	0.82
Cissus rotundifolia	1	0	0.31
20. Digitaria scalarum	1	0	0.01
Conyza newii	1	0	0.08
Oxalis latifolia	1	0	0.02
Cyperus esculentus	1	0	0.018
Ocimum suave	1	0	0.2
Crassocephalum picridifolia	1	0	0.08
Cynodon dactylon	1	0	0.09
Pennisetum schimperi	1	0	0.08
Cyperus spp	1	0	0.21
Leonotis nepetifolia	1	0	0.23

Eleusine indica	1	0	0.18	
*Guavas**	2	0	0.34	
Sida cuneifolia	1	0	0.28	
Erythrina abyssinica	2	0	0.3	
*Egetonkono**	1	0	0.23	
Lantana javanica	1	1	1.41	0.08
Hibiscus aponeurus	1	0	0.21	
Dombeya burgessiae	1	0	0.32	
Thunbergia alata	1	0	0.21	
Clerodendrum johnstonii	2	0	0.34	
Cassia didymobotyra	3	0	0.22	
Commelina benghalensis	1	0	0.02	
Pennisetum clandestinum	1	0	0.18	
Ageratum conyzoides	1	0	0.06	
Centella asiatica	1	0	0.08	
Bridalia micrantha	1	0	0.31	
Solanum incanum	102	54	1.21	0.12
Sida cordifolia	1	0	0.34	
Dombeya dawei	4	1	1.87	0.08
Triumfetta macrophylla	1	0	0.14	
Croton macrostachyus	2	0	0.43	
Cyphostemma orondo	1	0	0.41	
*Obong'u**	1	0	0.87	
Abutilon mauritianum	14	1	0.02	
Trifolium semipilosum	1	0	0.36	
Desmodium spp	1	0	0.41	
Pseudarthria hookeri	1	2	2.21	0.01
Justicia flava	1	1	0.28	
Chloris virgata	1	0	0.24	
Blumea perrottetiana	1	1	0.81	
*Aganga**	1	0	0.21	
Conyza floripunda	1	0	0.47	
*Stinging nestle**	1	0	0.82	
Aristida adoensis	1	0	0.18	
Blighia unijugata	2	0	0.31	
Premna oligotricha	1	0	0.41	
41. Eleaodendron buchananii	1	0	0.98	
Trichocladus ellipticus	1	0	0.43	
Pennisetum schimperi	1	0	0.48	
Loudetia kagerensis	1	0	0.23	
Themeda triandra	1	0	0.43	
Olea africana	2	1	1.79	0.18
Acacia drepanolobium	17	2	1.56	0.2
Acacia tortilis	2	9	2.91	0.14
Acacia zanzibarica	0	1	4.97	0.26
Croton dichogamus	6	0	0.75	
Solanum incanum	23	0	0.48	
Sporobolus pellucidus	1	0	0.24	
Microchloa kunthii	1	0	0.23	
Eragrostis braunii	1	0	0.21	
Aristida adoensis	1	0	0.12	
Cymbopogon afrinadus	1	0	0.19	
Digitaria milanjiana	1	0	0.21	

Leucas calostachyus	1	0	0.45	
Ocimum baccilicum	1	0	0.61	
Conyza newii	1	0	0.18	
Bridalia micrantha	1	0	0.08	
Carissa edulis	1	0	0.62	
Solanum spp	5	0	0.23	
Lippia javanica	2	0	0.56	
Heteropogon contortus	1	0	0.23	
Themeda triandra	1	0	0.23	
Leonotis mollissima	1	0	0.09	
Vernonia lasiopus	1	0	0.34	
Abutilon mauritianum	4	1	0.67	
Pennisetum bicolor	1	0	0.38	
Physalis peruviana	1	0	0.21	
Sida ovata	1	0	0.26	
Undisturbed bushland				
16. *Pennisetum schimperi*	1	0	0.14	
Hyparrheria spp	1	0	0.13	
Leucas calosatchyus	1	0	0.46	
Dodonea latifolia	49	48	3.24	0.24
Tachonanthus camphoratus	16	106	1.73	0.20
Euclea divinorium	0	1	2.0	0.1
Acokanthera oppositifolia	29	0	0.45	
Pterolobium stellatum	1	1	4.8	0.12
Rhus natalensis	32	9	1.6	0.08
Pentas lanceolata	1	0	0.5	
Hoslundia opposita	1	0	0.24	
Asparagus africana	1	0	0.96	0.01
Teclea nobilis	153	19	6.34	0.23
Maesa lanceolata	3	2	1.8	0.14
Rhus vulgaris	0	1	6.24	0.2
Conyza floripunda	1	0	0.01	
Canthium gueinzii	1	0	0.18	
Olea africana	13	6	0.48	
Pentas lanceolata	1	0	0.36	
Commelina benghalensis	1	0	0.34	
Aspilia pluriseta	1	0	0.14	
Croton macrostachyus	1	0	0.33	
Salvadora persica	0	1	1.4	0.12
Saturea biflora	1	0	0.24	
Galium spurium	1	0	0.23	
Solanum indicum	1	0	0.46	
Crassocephalum picridifolia	1	0	0.21	
Lippia carviodora	4	0	0.24	
Sida cordifolia	1	0	0.12	
Eleaodendron buchananii	3	4	2.12	0.2
Erlangea cordifolia	1	0	0.21	
Acokanthera spp	40	29	4.14	
Apodytes dimidiata	8	4	2.6	
Croton macrostachyus	7	0	0.24	
Carissa edulis	3	2	1.60	0.06
Euclea spp	8	10	6.1	0.4

	Garcinia livingstonei	0	1	17.0	1.2
	Triumfetta macrophylla	1	0	0.2	
	Teclea simplifolia	1	1	9.6	0.4
	Bridalia micrantha	1	0	0.21	
	Setaria longiseta	1	0	0.12	
	Cassia didymobotyra	48	0	0.4	
	Olea hochstetteri	0	1	18.3	1.3
	Trimeria tropica	0	1	2.14	0.04
	Myrsine africana	12	1	16.1	1.4
	Parinari curatellifolia	4	2	5.14	1.6
	Viscum tuberculatum	1	1	0.51	
	Rhamnus staddo	2	1	1.81	
	Argrolobium friesianum	1	0	0.4	
	Schrebera alata	1	0	0.21	
	Conyza spp	1	0	0.18	
	Crepis carboneria	1	0	0.11	
	Erythrococca bongensis	1	0	0.2	
	Vernonia branchycalyx	1	0	0.16	
	Aspilia spp	1	0	0.8	
	Spermacoce princei	1	1	0.61	
	Pachycarpus grantii	1	0	0.31	
	Leptaderia hestata	1	0	0.21	
	Gorncarpus stenophyllus	1	0	0.01	
	Lobelia holstii	1	1	0.02	
	Pletrachtus longipes	1	0	0.2	
	Helichrysum cymosum	1	0	0.18	
	Laggera brevipes	1	0	0.41	
	Leucas spp	1	0	0.34	
	Lantana trifolia	4	0	0.21	
	Schoenoxiphium lehmanii	1	0	0.12	
	Hypenthelia dissoluta	1	0	0.18	
17.	*Pennisetum schimperi*	1	0	0.20	
	Commelina benghalensis	1	0	0.24	
	Themeda triandra	1	0	0.18	
	Conyza floripunda	1	0	0.34	
	Fuerstia africana	1	1	3.21	0.13
	Ocimum suave	34	0	0.41	
	Triumfetta macrophylla	1	0	0.4	
	Cyphostemma adnocaule	1	1	4.1	
	Rhus na talensis	7	7	1.9	0.23
	Teclea simbilis	439	59	9.24	
	Salvadora persica	4	11	5.81	6.1
	Solanum incanum	3	0	0.14	
	Euclea divironum	0	17	6.21	
	Eleaodendron buchananii	20	0	0.40	
	Dombeya dawei	2	0	0.48	
	Setaria longiseta	1	0	0.21	
	Grewia bicolor	2	3	1.1	0.15
	Grewia similis	1	0	0.21	
	Grassocephalum picridifolia	1	0	0.23	
	Teclea nobilis	21	45	4.56	0.32
	Hibiscus aponeurus	1	0	0.21	
	Olea hochstetteri	2	3	4.8	0.38

Capparis tomentosa	1	0	0.24	
Cynoglosium caeruleum	1	0	0.28	
Cammiphora africana	3	0	0.41	
Leucas calosatchyus	1	0	0.40	
Bridalia micrantha	1	1	2.21	0.18
Olea africana	8	0	0.24	
Bidens pilosa	1	0	0.18	
Lippia carviodora	1	0	0.41	
Pappea capensis	1	0	0.24	
Trimeria tropica	0	1	2.74	0.02
Rhamnus prinoides	4	1	2.56	0.19
Pterolobium stellatum	1	0	0.21	
Pavetta oliveriana	2	2	1.45	0.18
Psydrax sch mperi	1	7	8.8	0.32
Grumilea lauracea	1	28	6.4	0.30
Toddalia asiatica	1	0	0.21	
*Omotagara**	0	2	2.40	0.24
Physalis peruviana	1	0	0.41	
Asparagus africana	1	0	0.31	
Cyperus esculentus	1	0	0.42	
Cyperus rotundus	1	0	0.41	
Loudetia kagerensis	1	0	0.34	
Digitaria scalarum	1	0	0.38	
Oncoba spinosa	1	0	0.46	
Maerua triupylla	2	0	0.48	
Myrsine africana	6	1	4.62	
Maytenus arbutifolia	3	0	0.40	
Allophyllus macrobotrys	1	0	0.41	
Indigofera swaziensis	2	1	1.60	0.16
Panicum maximum	1	0	0.82	
Senecio syringifolius	1	1	0.46	
Briachiaria brizantha	1	0	0.34	
Notoria hildebrandtii	1	0	0.51	
Tarenna graveoleus	4	1	1.21	0.12
Setaria sphacelata	1	0	0.42	
*Olmanguye**	1	1	1.81	
*Enjange'geshie**	1	0	0.21	
Scutia myrtina	3	0	0.41	
Canthium gueinzii	1	0	0.21	
Cordia sinensis	2	0	0.42	
Rhoicissus revoilii	3	1	1.41	0.03
21. Strychnos lucens	0	1	15.0	0.72
Warburgia ugandensis	1	12	14.2	0.98
Teclea simplifolia	163	15	4.4	0.4
Bridalia micrantha	1	0	0.21	
Albizia coriaria	2	1	4.8	0.18
Teclea nobilis	12	84	8.9	0.26
Setaria longiseta	1	0	0.14	
Albizia gumnifera	4	9	12.2	0.56
Manilkara mochisia	3	2	8.2	0.44
Turea robusta	1	9	14.6	0.34
Manilkara zanzibarensis	0	4	5.9	0.40
Olea hochstetteri	1	3	16.8	0.73

Delonix regia	0	4	6.0	0.40
Rothmania urcelliformis	1	0	0.25	
Grumilea lauracea	1	0	0.34	
Dombeya fecuola	3	0	0.67	
Clausena anisata	6	10	1.82	0.09
Cassia didymobotyra	13	6	4.49	0.32
Scutia myrtina	1	0	0.48	
Markhamia platycalx	1	6	8.4	0.2
Vangueria acutiloba	5	0	0.74	
Egetonkono*	1	0	0.4	
Hibiscus aponeurus	2	0	0.2	
Pteridium aquilinum	4	2	1.14	0.06
Solanum incanum	4	0	0.18	
Achyranthes aspera	1	0	0.24	
Canthium gueinzii	5	2	14.61	0.9
Dypetes gerrardii	0	4	3.1	0.04
Dioscorea odoratissima	1	0	0.4	
Bridalia spp	4	6.6 0.4		
Dombeya dawei	0	1	10.0	0.1
Allophyllus macrobotrys	0	4	4.7	0.3
Euclea divinorium	0	2	11.6	0.5
Desmodium repadum	1	0	0.21	
Paspalum cammersonii	1	0	0.36	
Rutidae fuscescens	1	0	0.45	
Culcasia scandens	1	0	0.89	
Halleria lucida	1	0	0.28	
Trichocladus ellipticus	1	0	0.39	
Osongoroi*	2	1	10.43	0.8
Kebergia rueppelina	1	1	6.41	0.13
Ficus capensis	0	2	12.1	0.72
Toddalia asiatica	1	0	0.28	
Sansieviera spp	1	0	0.56	
23. Cassia mimosaides	1	0	0.02	
Lantana camara	11	0	0.42	
Hoslundia opposita	3	0	0.11	
Pseudarthria hookeri	1	0	0.24	
Harrisonia abyssinica	1	0	0.56	
Grewia bicolor	3	2	9.8	0.65
Rhus vulgaris	8	12	5.6	0.24
Acacia nilotica	9	0	0.23	
Aspilia pluriseta	1	0	0.19	
Maytenus spp	1	2	2.2	0.3
Abutilon longicuspe	1	0	0.14	
Teclea simplicifolia	2	2	5.62	0.12
Erythrina spp	0	1	3.19	0.4
Halleria lucida	1	0	0.32	
Ekebergia rueppeliana	1	0	0.43	
Blumea alata	1	0	0.26	
Dypetes gerrardii	1	2	0.48	
Bridalia micrantha	27	3	5.26	0.4
Balanites aegyptiaca	4	0	0.21	
Circium vulgare	1	0	0.31	
Rhus na talensis	2	0	0.46	

Conyza floripunda	1	0	0.03	
Ficus vallis-cloudea	1	6	4.1	
*Nginyoi**	1	0	0.43	
Indigofera spicata	1	2	0.86	
Bidens pilosa	1	0	0.21	
*Milky climber**	1	0	0.88	
Triumfetta macrophylla	1	0	0.21	
*Akech**	1	0	0.46	
Vitex doniana	5	0	0.74	
Nuxia congesta	1	0	0.38	
Cyperus rotundus	1	0	0.21	
Eragrostis tenuifolia	1	1	1.3	
Piliostigma thonningii	1	0	0.36	
Asparagus africana	1	0	0.71	
Leucas densiflora	17	1	1.31	0.10
Cynoglosium caeruleum	1	0	0.41	
Cleredondrum myricoides	1	0	0.12	
Cyphostemma orondo	1	0	0.62	
Cissus rotundifolia	1	0	0.48	
Sonchus oleraceus	1	0	0.21	
Oreosyce africana	1	0	0.42	
Phragmanthera rufescens	1	0	0.38	
Viscum triflorum	1	0	0.40	
Maytenus senegalensis	3	0	0.21	
Vigna parkeri	1	0	0.14	
Neonotonia wightii	1	0	0.61	
Indigofera rohemarensis	1	1	0.92	
Desmodium setigenum	3	0	0.41	
Alysicarpus rugosus	1	0	0.29	
Rynchosia hirta	1	0	0.12	
Psendarthria hookeri	0	1	2.1	0.04
Themeda triandra	1	0	1.8	
Aspilia spp	1	0	0.9	
Chrysanthellum americanum	1	0	0.21	
Schkuhria pinnata	1	0	0.29	
Andropogon canaliculatus	1	0	0.89	
Digitaria diagonalis	1	0	0.98	
Cynodon dactylon	1	0	0.87	
Setaria plicatilis	1	0	0.78	
Sporobolus festivus	1	0	0.21	
Loudetia kagerensis	1	0	0.42	
Paspalum cammersonii	1	0	0.26	
Rhyuchelytrum repens	1	0	0.38	
Rubia cordifolia	1	0	0.23	
Brachiaria brizantha	1	0	0.19	
Setaria sphacelata	1	0	0.64	
Spermacoce pusilla	1	0	0.26	
Andropogon canaliculatus	1	0	0.82	
Cymbopogon caesius	1	0	1.3	
Hyparrhenia lintonii	1	0	1.4	
Cynoglosium geometricum	1	0	0.61	
Plectranthus caninus	1	0	0.21	
Tricalysia niamniamensis	0	2	1.92	0.02
Tricalysia niam	0	1	1.91	0.02

Hypenthelia dissoluta	1	0	0.23	
Panicum atrosanguineum	1	0	0.39	
Disturbed bushland				
15. Crassocephalum pioridifolia	1	0	0.21	
Solanum incanum	129	0	0.61	
Cynoglosium caeruleum	1	0	0.32	
Sida cordifolia	1	0	0.22	
Tagetes minuta	1	0	0.62	
Pennisetum clandestinum	1	0	0.12	
Salanum indicum	1	0	0.44	
Triumfetta rhomboidea	1	0	0.32	
Veronica abyssinica	1	0	0.10	
Phyllanthus amarus	1	0	0.14	
Cynodon dactylon	1	0	0.24	
Digitaria scalarum	1	0	0.23	
Bidens pilosa	1	0	0.24	
Commelina benghalensis	1	0	0.28	
*Ekenyunyunta maino**	1	0	0.12	
Euphorbia schimperi	1	0	0.18	
Abutilon mauritianum	1	0	0.42	
Thunbergia alata	1	0	0.46	
Chenopodium procerum	1	0	0.58	
Erythrina abyssinica	0	1	7.0	2.8
Oxalis cordifolia	1	0	0.31	
Urena alata	1	0	0.82	
Dombeya dawei	2	0	0.62	
Risinus communis	3	0	0.31	
Vernonia auriculifera	1	0	0.14	
Croton macrostachyus	4	1	13.6	0.9
Rhus nantalensis	1	1	2.41	0.6
Cyanthula cylindrica	1	0	0.31	
Asparagus africana	1	0	0.34	
Cleredondrum myricoides	0	3	3.5	0.42
Solanum nigrum	1	0	0.42	
Tragia brevipes	1	0	0.34	
Achyranthes aspera	1	0	0.21	
Canthium guenzii	1	0	0.48	
Zehneria scabra	1	0	0.83	
Physalis peruviana	1	0	0.49	
Cyperus esculentus	1	0	0.22	
Phaseolus lunatus	1	0	0.12	
Crotalaria incana	1	0	0.24	
Cucumis fiafoluis	1	0	0.36	
Ekebergia capensis	0	9	11.0	
Toddalia asiatica	1	0	0.49	
Rhoicissus revoilii	1	0	0.64	
Crassocephalum sarcobasis	1	0	0.48	
Conyza steudelii	1	0	0.31	
Ageratum conyzaides	1	0	0.42	
Spermacoce princei	1	0	0.38	
Eleusine indica	1	0	0.21	
Thunbergia spp	1	0	0.31	

	Grewia tenax	1	0	0.81
	Gloriosa superba	1	0	0.28
	Erlangea cordifolia	1	0	0.42
	Salvadora persica	0	1	4.0 0.22
	Scutia myrtina	1	0	0.26
	Eleaodendron buchananii	1	0	0.21
	Conyza floripunda	1	0	0.41
	Vangueria acutiloba	1	0	0.34
18.	*Leucas calosatchyus*	1	0	0.8
	Sida schimperi	1	0	0.41
	Pennisetum schimperi	1	0	0.20
	Digitaria scalarum	1	0	0.12
	Helichrysum odoratissimum	1	0	0.21
	Conyza floripunda	1	0	0.34
	Lippia carviodora	47	0	0.14
	Crassocephalum picridifolia	1	0	0.14
	Maesa lanceolata	1	0	0.13
	Bridalia micrantha	2	0	0.24
	Eragrostis tenuifolia	1	0	0.16
	Acacia lahai	2	0	0.14
	Commelina benghalensis	1	0	0.08
	Ocimum suave	1	1	1.17 0.09
	Solanum incanum	60	0	0.52
	Vernonia auriculifera	3	0	0.38
	Canthium gueinzii	1	0	0.21
	Cassia didymobotyra	1	1	2.41 0.02
	Abitalon apeurus	3	0	0.34
	Cyperus rotundus	1	0	0.21
	Saturea biflora	1	0	0.01
	Crotalaria incana	1	0	0.13
	Blumea alata	1	0	0.21
	Pentas lanceolata	1	0	0.21
	Rhus nantalensis	1	0	0.08
	Indigofera spicata	1	0	0.21
	Pennisetum clandestinum	1	0	0.34
	Triumfetta rhomboidea	1	0	0.03
	Centella asiatica	1	0	0.18
	Rhynchosia hirta	1	0	0.02
	Conyza schimperi	1	0	0.41
	Vernonia galamensis	1	0	0.21
	Conyza pyrifolia	1	0	0.34
	Blumea perrottetiana	1	0	0.08
	Hydrocotyle monticola	1	0	0.24
	Paspalum cammersonii	1	0	0.14
	Pavetta termifolia	1	0	0.14
	Setaria sphacelata	1	0	0.18
	Spermacoce princei	1	0	0.28
	Asystasia gangetica	1	0	0.31
	Crassocephalum crepidioides	1	0	0.14
	Dyschorista radicans	1	0	0.18
	Thunbergia alata	1	0	0.21
	Hoslundia opposita	1	0	0.14
	Brachiaria spp	1	0	0.16

	Hypenthelia exasperata	1	0	0.08
	Aristida adoensis	1	0	0.07
	Aspilia pluriseta	1	0	0.58
	Orobanche minor	1	0	0.01
	Abutilon longicuspe	3	1	1.92 0.06
	Eragrostis exasperata	1	0	0.18
22.	*Erythrina abyssinica*	13	2	7.2 0.7
	Abutilon longicuspe	2	0	0.31
	Hibiscus fusca	8	2	0.62
	Kyllinda vernosa	1	0	0.01
	Ocimum suave	1	0	0.34
	Hoslundia opposita	0	2	2.6
	Lantana camara	37	7	2.51 0.08
	Trichocladus ellipticus	2	0	0.16
	Cammiphora africana	4	0	0.32
	Rhus vulgaris	4	2	7.41 0.5
	Grewia bicolor	4	2	6.92 0.45
	Sida cordifolia	1	0	0.09
	Sida ovata	1	0	0.16
	Clausena anisata	1	0	0.34
	Grewia similis	3	0	0.46
	Halleria lucida	1	0	0.31
	Achyranthes aspera	1	0	0.16
	Cyphostemma orondo	1	0	0.21
	Pteridium aquilinum	1	0	0.09
	Psidium quajava	1	0	0.19
	Eleusine indica	1	0	0.18
	Cleredondrum myricoides	6	6	2.53 0.06
	Commelina benghalensis	1	0	0.21
	Portulaca quadrifida	1	0	0.09
	Amaranthus spinosa	1	0	0.04
	Cassia mimosaides	1	0	0.08
	Justicia spp	1	0	0.16
	Digitaria scalarum	1	0	0.12
	Aristida adoensis	1	0	0.18
	Delonix regia	2	0	0.30
	Centella asiatica	1	0	0.21
	Rubia cordifolia	1	0	0.28
	Combretum molle	2	0	0.45
	Bridalia micrantha	1	0	0.43
	Croton macrostachyus	55	11	5.6 0.6
	Ekebergia rueppeliana	1	2	6.8 0.55
	Rhus nantalensis	3	0	0.28
	Canthium gueinzii	2	0	0.32
	Tragia benthamii	1	0	0.25
	Cynoglosium caeruleum	1	0	0.31
	Solanum incanum	12	0	0.43
	Lantana rhodensiensis	3	0	0.61
	Triumfetta macropyhlla	1	0	0.21
	Cynodon dactylon	1	0	0.33
	Kyllinga bulbosa	1	0	0.09
	Conyza spp	1	0	0.21
	Cyperus rotundus	1	0	0.09

Amaranthus spp	1	0	0.18	
Sida cuneifolia	1	0	0.19	
Ficus capensis	0	1	9.0	0.6
Carissa edulis	1	0	0.58	
Pennisetum clandestinum	1	0	0.12	
Blumea alata	1	0	0.42	
Leonotis nepetifolia	1	0	0.36	
Bidens pilosa	1	0	0.21	
Indigofera spicata	1	0	0.41	
Crotalaria incana	1	0	0.26	
Lippia javanica	3	0	0.43	
Acacia lahia	0	1	14.2	0.9
Cyphostemma bambuseti	1	0	0.31	
Panicum maximum	1	0	0.92	
Eragrostis tenuifolia	1	0	0.41	
Chloris virgata	1	0	0.32	
Paspalum cammersonii	1	0	0.24	
Solanum sessilistellatum	1	0	0.63	
Brachiaria brizantha	1	0	0.41	
Clerodendrum spp	1	0	0.28	
Cymbopogon afrinadus	1	0	0.31	
Combretum collinum	2	0	0.37	
Striga haemonthica	1	0	0.32	
Leonotis mollissima	1	0	0.62	
Bridalia micrantha	1	0	0.17	
24. *Sida cordifolia*	1	0	0.21	
Cynodon dactylon	1	0	0.81	
Cyperus rotundus	1	0	0.81	
Digitaria scalarum	1	0	0.24	
Achyranthes aspera	1	0	0.36	
Dyschorista radicans	1	0	0.52	
Amaranthus spp	1	0	0.28	
Cleredondrum myricoides	12	2	1.05	0.05
Lantana camara	3	0	0.38	
Triumfetta macrophylla	1	0	0.54	
Tagetes minuta	1	0	0.68	
Rhus vulgaris	4	1	6.09	0.10
Bidens pilosa	1	0	0.14	
Chenopodium schraderanum	2	0	0.43	
Erlangea cordifolia	1	0	0.22	
Kyllinga vernosa	1	0	0.19	
Nappier grass	1	0	0.61	
Cynoglosium caeruleum	1	0	0.34	
Lantana lippia	4	0	0.76	
Ficus vallis-cloudea	0	2	10.3	2.0
Ekebergia rueppeliana	2	2	9.3	0.93
Maytenus senegalensis	1	0	0.26	
Eragrostis tenuifolia	1	0	0.14	
Solanum incanum	,972	0	0.63	
Grewia trichocarpa	4	3	5.5	0.25
Capsicum frutescens	1	0	0.31	
Cissus rotundifolia	1	0	0.4	
Teclea nobilis	3	1	8.1	0.8

Asparagus africana	1	0	0.41
Mystroxylon aethiopicum	0	1	5.3 0.5
Phylaris peruviana	1	0	0.65
Canthium gueinzii	0	1	4.5 0.3
Cassia didymobotrya	1	0	0.87
Hoslundia opposita	1	0	0.41
Crassocephalum picridifolia	1	0	0.24
Solanum nigrum	1	0	0.38
Solanum indicum	1	0	0.41
Abutilon mauritianum	2	0	0.67
Rhus na talensis	1	0	0.13
Dombeya goetzenii	3	0	0.39
Commiphora habessinica	1	0	0.64
Indigofera spicata	1	0	0.29
Amaranthus spp	1	0	0.31
Commelina benghalensis	1	0	0.23
Cyppressus benthenii	0	28	3.9 0.25
Maerua triupylla	1	0	0.21
Cyphostemma orondo	1	0	0.36
Indigofera swaziensis	1	0	0.23
Acacia hockii	0	1	2.0 0.06
Cassia mimosaides	1	0	0.01
Panicum maximum	1	0	0.46
Dichrocephala intergrifolia	1	0	0.27
Helichysum cymosum	1	0	0.12
Brachiaria brizantha	1	0	0.48
Sporobolus pellucidus	1	0	0.68
Loudetia kagerensis	1	0	0.49
Sporobolus pyramidalis	1	0	0.45
Cissus cordifolia	1	0	0.61
Vernonia karaguensis	1	0	0.32
Themeda triandra	1	0	0.64
Withania somnifera	1	0	0.26
Setaria sphacelata	1	0	0.38
Cymbopogon caesius	1	0	0.72
Cynodon ulemfluensis	1	0	0.51
Dyschorista radicans	1	0	0.28
Cynoglosum caeruleum	1	0	0.31
Cyperus maraguensis	1	0	0.40
Conyza floripunda	1	0	0.23
Undisturbed shrubland			
5. *Myrsine africana*	67	0	0.3
Vepris glomerata	1	0	0.4
Abutilon mauritianum	2	0	0.34
Teclea nobilis	4	0	0.36
Halleria lucida	1	0	0.31
Tachonanthus camphoratus	48	36	1.2 0.01
Juniperus procera	34	64	2.3 0.14
Dodonea latifolia	330	86	0.31 0.2
Rhus nantalensis	0	92	5.4 0.2
Euclea divinorium	4	0	0.2
Rubia cordifolia	1	0	0.24

Rhoicissus revoilii	1	0	0.01
Sida cuneifolia	1	0	0.14
Themeda triandra	1	0	0.09
Acacia drepanolobium	220	17	2.46 0.22
Olea africana	23	5	3.64 0.20
Scutia myrtina	1	0	0.21
Acokanthera longiflora	28	0	0.24
Asparagus africana	1	0	0.32
Grewia similis	8	0	0.46
Lippia carviodora	43	0	0.24
*Ejani ekashe**	4	0	0.024
*Olosasia**	4	0	0.21
*Oltangotora**	2	1	2.34 0.12
Dichrocephala chrysanthemifoliaa	1	0	0.02
Turraea mombassana	1	2	4.42 0.24
Erigeron bonariensis	1	0	0.37
*Orokokola**	13	6	4.48 0.2
*Olobai**	86	0	0.03
*Lorookililen**	13	0	0.04
Fuerstia africana	1	0	0.12
Euphorbia heterochroma	1	0	0.41
42. Vernonia lasiopus	1	0	0.24
Vangueria apieutala	2	1	10.67 0.4
Leucas calosatchyus	4	1	1.01 0.04
Pennisetum schimperi	1	0	0.34
Digitaria scalarum	1	0	0.28
Digitaria milanjiana	1	0	0.09
Cordia molle	7	2	11.9 0.81
Commiphora africana	3	4	8.8 0.64
Themeda triandra	1	0	0.21
Aristida adoensis	1	0	0.24
Loudetia kagerensis	1	0	0.19
Cynodon plectostachyus	1	0	0.49
Albizia coriaria	3	0	0.72
Croton macrostachyus	4	0	0.48
Saesbania sesban	2	1	14.8 0.78
Cynodon dactylon	1	0	0.46
Bridalia micrantha	1	0	0.42
Kigelia aethiopum	1	0	0.36
Setaria sphacelata	1	0	0.21
Microchloa kunthii	1	0	0.25
Abutilon mauritianum	4	2	2.46 0.06
Tachonanthus camphoratus	2	12	3.42 0.43
Eragrostis aethiopicus	1	0	0.18
Oxalis latifolia	1	0	0.09
Physalis vulgaris	1	0	0.56
Disturbed shrubland			
1. *Tachonanthus camphoratus*	16	109	2.5 0.08
Achyranthes aspera	1	0	0.2
Acacia drepanolobium	4	7	2.5 0.24
Fuerstia africana	1	1	1.4 0.06

Lantana trifolia	2	0	0.4	
Lantana rhodensiensis	1	0	0.5	
Trifolium ruepellianum	0	1	2.2	0.02
Cunterbergia cordifolia	1	1	2.4	0.08
Bidens pilosa	1	1	0.5	
Lippia ukambensis	40	3	1.1	
Acacia nilotica	0	1	1.2	
Asparagus africana	1	0	0.45	
Cucumis fiafoluis	25	36	0.3	
Sida schemperi	1	1	0.05	
Leonotis nepetifolia	1	1	0.4	
Sonchus oleraceus	1	1	0.02	
Conyza floripunda	1	0	0.02	
Pollichia campestris	1	0	0.01	
Pentas lanceolata	1	0	0.03	
Dichrocephala chrysanthemifoliaa	1	0	0.09	
Helichrysum schemperi	1	0	0.29	
Polygala sphenoptera	1	1	0.02	
Trifolium semipilosum	1	1	0.02	
Chloris virgata	1	1	0.01	
Pennisetum schemperi	1	1	0.09	
Hibiscus ritifolius	25	3	1.37	0.02
Heliotropium undulatifolium	2	0	0.02	
Hypoestes verticillata	1	0	0.01	
Cynodon dactylon	1	0	0.01	
Eragrostis tenuifolia	1	0	0.03	
Solanum incanum	156	193	1.09	0.02
Lippia carviodora	401	91	1.02	0.01
Cucumis acuteatus	17	0	0.3	
Helichrysum cymosum	1	1	0.29	
Rubia cordifolia	1	0	0.02	
Crotalaria incana	1	0	0.2	
Indigofera spicata	1	0	0.5	
Cyperus rotundus	1	0	0.04	
Solanum indicum	5	17	1.04	0.01
Cyanthula polycephala	1	0	0.12	
Erlangea tomentosa	1	0	0.2	
Vernonia lasiopus	1	0	0.01	
Sonchus spp	1	0	0.02	
Ocimum suave	4	0	0.22	
Digitaria scalarum	1	0	0.01	
Grewia similis	24	0	0.40	
Maytenus undata	1	0	0.02	
Capparis tomentosa	1	0	0.19	
Kalanchoe clensiflora	1	0	0.03	
Rhus nantalensis	2	0	0.3	
Laggera brevipes	1	0	0.25	
Blumea alata	1	0	0.2	
Saturea biflora	1	0	0.02	
Hibiscus aponeurus	3	0	0.4	
Cyphostemma nierense	1	0	0.2	
Rynchosia minima	1	0	0.2	
Tagetes minuta	1	0	0.24	
Themeda triandra	1	0	0.01	

	Withania braunii	1	0	0.02
	Hyparrhenia lirta	1	0	0.01
	Panicum paoides	1	0	0.02
	Eragrostis braunii	1	0	0.02
	Ricinus communis	1	0	0.08
	Cassia mimosaides	1	0	0.12
	Thunbergia spp	1	0	0.02
	Amaranthus hybridus	1	0	0.14
	Phytollace dodecandra	1	1	1.4 0.02
	Indigofera subulata	2	0	0.51
	Artemisia afra	4	2	2.25 0.1
	Conyza spp	1	1	0.02
	Pavernia patens	127	0	0.4
	Dombeya dawei	1	0	0.2
	Teramnus labialis	1	1	0.24
	Nicotiana tabaccum	1	0	0.34
	Acacia seyal	2	0	0.2
4.	*Dodonaea latifolia*	13	18	1.3 0.06
	Sida cuneifolia	1	0	0.4
	Tachonanthus camphoratus	34	39	1.2 0.07
	Acacia drepanolobium	27	0	0.6
	Solanum incanum	1	0	0.4
	Amaranthus hybridus	1	0	0.2
	Cucumis fiafoluis	1	0	0.03
	Commiphora africana	4	0	0.29
	Teclea nobilis	2	0	0.68
	Asparagus africana	1	0	0.3
	Juniperus procera	3	15	1.6
	Acokanthera longiflora	0	1	2.1
	Rhus nantalensis	0	1	1.02
	Euclea divinorium	1	0	0.8
	Trifolium ruepellianum	1	0	0.01
	Themeda triandra	1	0	0.02
	Olea africana	4	0	0.35
	Maytenus undata	1	0	0.05
	Helichrysum edaratissimum	1	0	0.02
	Erigeron bonariensis	1	0	0.2
	Clausena anisata	0	1	2.65
	Otomeria oculata	1	0	0.3
	Pavetta oliveriana	1	0	0.24
	Halleria lucida	1	0	0.14
Undisturbed grassland				
27.	*Eragrostis tenuifolia*	1	0	0.23
	Solanum incanum	84	0	0.21
	Sida cordifloia	1	0	0.14
	Sida cuneifolia	4	0	0.21
	Achyropsis greenwayi	1	0	0.30
	Commelina benghalensis	1	0	0.21
	Phyllanthus maderaspantesis	1	0	0.25
	Kyllinga vernosa	1	0	0.12
	Chenopodium opulifolium	1	0	0.15

	Capparis tomentosa	1	0	0.20
	Sporobolus discosporus	1	0	0.12
	Pennisetum manzianum	1	0	0.62
	Harpachne schimperi	1	0	0.52
	Bothriochloa insculpta	1	0	0.67
	Themeda triandra	1	0	0.58
	Aristida adoensis	1	0	0.39
	Panicum poaiodes	1	0	0.34
	Nidorella pedunculata	1	0	0.24
	Hirpicium diffusum	1	0	0.28
	Felicia muricata	1	0	0.08
	Sporobolus marginatus	1	0	0.28
	Barleria spinisepala	1	0	0.29
	Digitaria macroblephala	1	0	0.39
	Ipomea jaegeri	1	0	0.21
	Ebolium revolutum	1	0	0.30
	Cynodon dactylon	1	0	0.41
29.	*Aristida adoensis*	1	0	0.43
	Pennisetum spacelata	1	0	0.40
	Circium vulgare	1	0	0.21
	Cyperus rotundus	1	0	0.22
	Centella asiatica	1	0	0.02
	Pennisetum clandestinum	1	0	0.08
	Oxalis latifolia	1	0	0.04
	Cyperus esculentus	1	0	0.07
	Erucastrum arabicum	1	0	0.22
	Achemilla gracilipes	1	0	0.41
	Crepis carboneria	1	0	0.24
	Gnaphalium declinatum	1	0	0.15
	Lobelia anceps	1	0	0.32
	Scirpus fluitans	1	0	0.40
	Andropogon chrysoastachyus	1	0	0.28
	Pennisetum glabrum	1	0	0.34
	Eragrostis schweinfurthii	1	0	0.44
	Eragrostis paniciformis	1	0	0.26
34.	*Eragrostis tenuifolia*	1	0	0.35
	Aristida adoensis	1	0	0.52
	Themeda triandra	1	0	0.24
	Sporobolus stapfianus	1	0	0.09
	Solanum incanum	270	0	0.43
	Sida cuneifolia	1	0	0.21
	Cynodon dactylon	1	0	0.80
	Pennisetum manzianum	1	0	0.41
	Helichrysum odoratissimum	1	0	0.26
	Sporobolus discosporus	1	0	0.31
	Phyllanthus maderaspatensis	1	0	0.24
	Cucumis prophetarum	1	0	0.28
	Indigofera volkensii	1	0	0.21
	Cassia mimosaides	1	0	0.08
	Cenchrus ciliaris	1	0	0.35
	Crossandra subacaulis	1	0	0.24
	Solanum dennekense	2	0	0.34

	Rhamphicarpa montana	1	0	0.28
	Gutenbergia fischeri	1	0	0.36
	Priva curtisiae	1	0	0.21
36.	*Eragrostis tenuifolia*	1	0	0.14
	Themeda triandra	1	0	0.19
	Pennisetum manzianum	1	0	0.12
	Cyperus esculentus	1	0	0.14
	Aristida adoensis	1	0	0.18
	Cynodon dactylon	1	0	0.21
	Solanum incanum	1	0	0.20
	Alternanthera pungens	1	0	0.31
	Gomprena celosoides	1	0	0.18
	Commelina benghalensis	1	0	0.26
	Justicia mantammensis	1	0	0.34
	Harpachne schimperi	1	0	0.33
	Bothriochloa insculpta	1	0	0.28
	Sporobolus nervosus	1	0	0.33
	Digitaria ternata	1	0	0.19
37.	*Solanum incanum*	230	0	0.50
	Cynodon dactylon	1	0	0.07
	Rhus vulgaris	2	0	0.30
	Lippia carviodora	3	0	0.20
	Cassia mimosaides	1	0	0.30
	Dichrostachys cinerea	1	0	0.32
	Commiphora schimperi	24	0	0.41
	Eragrostis tenuifolia	1	0	0.31
	Asparagus africana	1	0	0.41
	Themeda triandra	1	0	0.61
	Cyperus esculentus	1	0	0.21
	Brachiaria brizantha	1	0	0.31
	Phyllanthus maderaspatensis	1	0	0.42
	Heteropogon contortus	1	0	0.65
	Cyphostemma orondo	1	0	0.31
	Nidorella pedunculata	1	0	0.24
	Gutenbergia tuppelli	1	0	0.58
	Sporobolus pyramidalis	1	0	0.32
	Brancharia bovonei	1	0	0.62
	Panicum maximum	1	0	0.68
	Panicum poaiodes	1	0	0.42
	Loudetia kagerensis	1	0	0.41
	Chloris gayana	1	0	0.58
	Soporobolus aphacelata	1	0	0.62
	Orthosiphob pervifolius	1	0	0.28
	Cymbopogon caesius	1	0	0.48
	Evolvulus alsinoides	1	0	0.43
	Ericostema hyssopifolia	1	0	0.42
	Eragrostis kiwuensis	1	0	0.62
	Eragrostis exasperata	1	0	0.81
	Eragrostis racemosa	1	0	0.47
	Aristida adoensis	1	0	0.38
	Loudetia spp	1	0	0.42
	Acacia gerarrdii	8	0	0.38

Disturbed grassland			
25. *Digitaria abyssinica*	1	0	0.03
Cynodon dactylon	1	0	0.14
Eragrostis tenuifolia	1	0	0.15
Panicum poaiodes	1	0	0.04
Kyllinga vermosa	1	0	0.02
Sporobolus discosporus	1	0	0.09
Microchloa kunthii	1	0	0.08
Pennisetum manzianum	1	0	0.21
Sida cuneifolia	4	0	0.12
Solanum incanum	11	0	0.22
Abutilon mauritianum	251	0	0.26
Acacia drepanolobium	20	0	0.13
Cassia mimosaides	1	0	0.02
Commelina benghalensis	1	0	0.03
Portulaca kermasiana	1	0	0.04
Oxygonum sinuatum	1	0	0.14
Indigofera bogdanii	1	0	0.03
Cassia spp	1	0	0.06
Harpachne schimperi	1	0	0.26
Notonia petraca	1	0	0.16
Dyschorista radicans	1	0	0.14
Justicia oxigna	1	0	0.09
Senecio mesogrammoides	1	0	0.17
Digitaria macroblephala	1	0	0.09
Ipomea jaegeri	1	0	0.04
Sida cordifolia	1	0	0.12
*Oloireroi**	0	1	7.0 0.84
26. *Eragrostis tenuifolia*	1	0	0.12
Cynodon dactylon	1	0	0.10
Kyllinga vernosa	1	0	0.09
Acacia drepanolobium	109	0	0.30
Commelina benghalensis	1	0	0.12
Cyperus rotundus	1	0	0.09
Trifolium semipilosum	1	0	0.12
Themeda triandra	1	0	0.21
Panicum poaiodes	1	0	0.21
Rhamphicarpa montana	1	0	0.24
Gnaphalium declinatum	1	0	0.19
Becium oboratum	1	0	0.18
Eragrostis exasperata	1	0	0.14
Pollichia campestris	1	0	0.21
28. *Eragrostis tenuifolia*	1	0	0.13
Themeda triandra	1	0	0.25
Cynodon dactylon	1	0	0.17
Sida cuneifolia	1	0	0.21
Hirpicium diffusum	1	0	0.34
Sporobolus festivus	1	0	0.13
Pennisetum manzianum	1	0	0.08
Digitaria macroblephala	1	0	0.12

Becium oboratum	1	0	0.05
Cassia mimosaides	1	0	0.12
Solanum incanum	14	0	0.23
Barleria spinisepala	1	0	0.21
Ipomea jaegeri	1	0	0.16
Ebolium revolutum	1	0	0.09
Sida cordifolia	1	0	0.12
Nidorella pedunculata	1	0	0.02
*30. Rigeri**	1	0	0.22
Solanum indicum	20	0	0.34
Blumea alata	1	0	0.19
Digitaria scalarum	1	0	0.14
Aristida adoensis	1	0	0.11
Cassia mimosaides	1	0	0.09
Capparis tomentosa	1	0	0.21
Veronica abyssinica	1	0	0.26
Cyperus rotundus	1	0	0.10
Pennisetum clandestinum	1	0	0.21
Euphorbia ugandensis	1	0	0.14
Oxalis corniculata	1	0	0.12
Pennisetum clandestinum	1	0	0.18
Leonotis mollissima	1	0	0.19
Helichrysum odoratissimum	1	0	0.21
Saturea biflora	1	0	0.20
*Ray grass**	1	0	0.26
*Ekenyunyunta maino**	1	0	0.11
Triflium lugardii	1	0	0.21
Trifolium semipilosum	1	0	0.26
Achemilla gracilipes	1	0	0.41
Gnaphalium lutea-album	1	0	0.41
Circium vulgare	1	0	0.21
Haplosciadum abyssinicum	1	0	0.12
Chloris virgata	1	0	0.31
Eleusine jaegeri	1	0	0.21
Eragrostis kiwuensis	1	0	0.13
Eragrostis schweinfurthii	1	0	0.14
Eragrostis paniciformis	1	0	0.14
Indigofera spp	1	0	0.81
Dichrocephala chrysanthemifoliaa	1	0	0.26
35. Cynodon dactylon	1	0	0.03
Eragrostis tenuifolia	1	0	0.04
Sida cuneifolia	1	0	0.12
Solanum incanum	16	0	0.11
Sida cordifolia	1	0	0.06
Justicia mantammensis	1	0	0.05
Sporobolus phyllotrichus	1	0	0.04
Amaranthus hybridus	1	0	0.05
Commelina benghalensis	1	0	0.06
Achyranthes aspera	1	0	0.09
Gomprena celosoides	1	0	0.02
Alternanthera pungens	1	0	0.34
Digitaria abyssinica	1	0	0.12

Appendix B. Soil test results. Soil pH varies from moderate acid to near neutral reactions. Phosphorus is low-deficiencies underlined, see also Zn deficiencies. Organic matter is moderate to low.

Site	depth (cm)	pH	Na cmol/kg	K cmol/kg	Ca cmol/kg	Mg	Mn cmol/kg	P ppm	N %	C %	Fe ppm	Cu ppm	Zn ppm
Undisturbed forest													
2	0-10	6.6	0.57	1.37	2.8	1.8	0.22	20	0.60	4.94	14.50	0.00	15.00
	10-20	6.6	0.60	1.42	20.0	2.2	0.38	16	0.21	3.28	13.50	0.00	50.00
	20-30	5.8	0.50	0.88	10.4	2.0	0.44	10	0.12	1.99	37.50	0.00	34.50
3	0-10	7.1	0.46	0.79	30.0	3.0	0.11	171	0.55	5.53	7.50	0.00	5.50
	10-20	7.0	0.64	1.62	32.0	4.4	0.19	60	0.30	3.07	8.00	0.00	50.0
	20-30	6.4	0.64	1.62	14.4	2.0	0.50	37	0.19	2.18	17.50	0.50	50.0
7	0-10	5.7	0.50	1.28	14.4	1.6	0.98	14	0.29	4.03	40.00	0.00	38.00
	10-20	5.9	0.50	1.39	15.2	1.4	1.09	12	0.29	3.99	70.50	0.50	30.00
	20-30	5.6	0.40	0.96	9.2	1.6	0.85	16	0.25	2.76	123.00	0.50	17.50
9	0-10	6.3	0.76	2.00	3.0	3.2	0.50	16	0.50	5.29	11.00	0.00	39.00
	10-20	5.2	0.53	1.21	4.0	1.8	0.36	10	0.16	2.09	127.00	0.00	9.50
	20-30	4.9	0.50	1.00	2.4	1.2	0.72	20	0.11	1.70	148.00	0.00	6.50
12	0-10	5.9	0.60	1.28	35	4.2	1.00	8	0.50	5.24	13.50	0.50	12.50
	10-20	5.1	0.50	1.08	6.0	2.2	0.69	8	0.21	2.69	66.50	1.50	15.00
	20-30	6.1	0.60	0.81	6.6	2.0	0.65	8	0.13	0.98	135.0	0.50	9.50
38	0-10	6.4	0.62	1.32	32.0	3.5	0.11	20	0.65	5.24	6.50	0.00	50.00
	10-20	5.9	0.64	1.37	16.0	1.8	0.28	16	0.37	4.27	10.50	0.00	50.00
	20-30	6.1	0.35	0.76	15.4	2.2	0.54	18	0.47	4.77	8.00	0.50	50.00
Disturbed forest													
6	0-10	7.2	0.63	1.34	20.0	4.2	1.33	22.0	0.37	6.60	18.00	0.60	51.00
	10-20	7.0	0.79	2.30	18.6	2.2	1.00	21.0	0.32	6.24	21.00	2.00	50.00
	20-30	6.4	0.72	1.28	17.4	2.1	0.80	23.0	0.31	4.34	15.00	2.60	48.00
8	0-10	6.2	0.96	1.41	11.6	1.8	0.76	23	0.32	3.90	67.00	0.00	16.50
	10-20	4.8	0.39	0.71	3.6	2.2	0.38	10	0.14	1.91	100.00	0.00	21.50
	20-30	6.3	0.48	0.60	5.6	1.7	0.54	8	0.06	0.84	130.00	0.00	9.50
11	0-10	5.5	0.62	1.16	16.0	1.4	0.30	14	0.38	4.01	12.50	0.00	34.00
	10-20	6.1	0.48	0.94	18.6	2.0	0.83	14	0.50	4.21	11.00	1.00	50.00
	20-30	5.2	0.39	0.71	50.0	2.2	1.33	8	0.17	1.98	106.50	0.50	29.00
39	0-10	6.2	0.57	1.59	25.0	1.7	0.16	20.0	0.41	4.60	11.00	0.00	50.00
	10-20	6.4	0.60	1.12	26.0	1.8	0.22	20.0	0.36	4.01	10.50	0.00	47.00
	20-30	6.3	0.59	1.18	24.0	1.8	0.19	23.0	0.40	4.54	3.50	0.00	42.50
Undisturbed woodland													

10	0-10	6.3	0.32	1.64	24.0	3.4	0.60	34	0.60	3.22	159.00	1.20	8.00
	10-20	6.4	0.23	1.36	17.4	3.4	0.55	15	0.55	2.07	108.00	1.20	6.50
	20-30	6.6	0.41	1.28	20.0	2.8	0.42	13	0.45	1.94	128.00	0.50	5.60
19	0-10	5.7	0.46	0.97	24.0	4.9	1.44	7	0.40	5.86	14.50	1.75	0.90
	10-20	6.4	0.39	0.82	18.6	1.6	1.50	5	0.23	2.67	23.00	1.35	2.00
	20-30	6.4	0.36	0.62	18.0	5.1	1.74	5	0.20	2.31	22.50	1.30	1.10
Disturbed woodland													
14	0-10	5.5	0.30	0.50	5.6	1.2	1.91	3	0.33	3.16	45.00	1.10	2.20
	10-20	5.3	0.29	0.18	2.8	1.0	1.66	7	0.22	2.04	50.00	0.60	2.50
	20-30	5.3	0.16	0.16	3.4	1.1	1.66	2	0.19	1.69	36.50	0.45	2.40
20	0-10	6.2	0.29	0.66	17.6	1.8	1.89	9	0.17	3.00	39.50	1.35	2.40
	10-20	6.3	0.39	0.61	15.6	2.2	1.61	7	0.11	2.13	26.50	1.20	2.40
	20-30	6.3	0.29	0.43	10.8	2.9	1.84	3	0.08	1.55	34.00	0.70	2.90
Undisturbed bushland													
17	0-10	5.9	0.50	0.64	12.8	2.2	1.33	7	0.15	2.80	41.50	0.40	1.90
	10-20	5.7	0.39	0.75	6.0	3.4	1.66	3	0.08	1.39	54.00	0.40	1.60
	20-30	5.5	0.36	0.54	11.4	2.0	1.38	5	0.16	2.63	65.00	0.55	1.80
Disturbed bushland													
15	0-10	5.5	0.39	0.57	10.4	2.0	1.19	5	0.12	2.25	49.00	0.35	1.70
	10-20	5.5	0.64	1.41	14.8	1.0	1.05	11	0.06	1.09	38.00	0.35	2.20
	20-30	5.1	0.39	0.93	4.4	1.6	0.94	5	0.04	0.68	27.00	0.20	1.00
18	0-10	5.3	0.19	0.36	6.6	2.0	1.05	3	0.12	2.80	59.00	0.40	2.70
	10-20	6.2	0.19	0.19	4.8	2.2	0.61	11	0.12	1.74	40.00	0.30	2.00
	20-30	5.0	0.23	0.18	4.4	1.4	0.52	7	0.20	1.62	38.00	0.20	2.10
Undisturbed shrubland													
5	0-10	5.9	0.65	1.55	8.8	0.7	0.36	14	0.10	1.73	77.50	0.50	10.50
	10-20	5.9	0.85	1.65	8.4	0.9	0.72	8	0.07	1.15	64.00	0.50	7.00
	20-30	6.0	1.00	1.60	8.6	0.7	0.69	14	0.05	0.94	56.50	0.00	4.00
42	0-10	6.1	0.13	0.64	5.8	2.9	0.49	14	0.21	0.81	15.00	5.00	2.00
	10-20	6.1	0.20	0.53	4.4	3.0	0.41	8	0.16	0.42	21.00	2.00	2.40
	20-30	6.0	0.15	0.45	3.4	0.5	0.51	11	0.09	0.31	16.00	3.00	1.50
Disturbed shrubland													
1	0-10	6.4	0.67	1.24	8.8	1.3	0.72	14	0.07	1.59	132.00	0.00	16.50
	10-20	6.2	0.81	1.85	8.6	2.0	0.61	27	0.11	1.86	100.00	0.00	1.00
	20-30	6.0	0.64	1.21	7.0	1.6	0.50	10	0.07	1.13	100.00	0.50	15.00
4	0-10	7.4	2.00	2.50	16.4	3.2	0.30	20.0	0.34	0.08	26.5	0.00	4.50
	10-20	7.2	3.10	2.30	18.4	1.4	0.33	25.0	0.32	0.02	21.50	0.50	3.50
	20-30	7.8	3.55	2.00	16.0	1.9	0.44	23.0	0.18	0.01	21.0	0.00	4.0
Undisturbed grassland													
29	0-10	4.9	0.32	0.32	2.4	1.1	0.22	16	0.14	2.11	205.00	0.00	7.50
	10-20	4.7	0.46	0.46	2.6	1.5	0.72	10	0.09	1.37	148.00	0.00	5.50
	20-30	4.5	0.75	0.67	6.4	1.6	0.25	10	0.09	0.91	147.50	0.00	5.00

34	0-10	6.0	0.41	1.02	7.2	2.2	0.91	7	0.11	0.99	15.50	7.00	3.50
	10-20	6.1	0.77	1.84	9.4	2.1	0.38	3	0.25	0.86	18.00	8.50	1.00
	20-30	6.7	0.97	2.00	11.2	6.5	0.35	5	0.05	0.55	8.00	3.00	2.00
36	0-10	6.2	0.43	1.02	8.8	2.2	0.72	5	0.16	1.51	18.0	4.00	2.00
	10-20	6.1	0.30	1.07	13.6	2.3	0.91	11	0.25	2.51	26.50	5.00	5.00
	20-30	5.8	0.57	1.41	9.2	2.2	0.47	3	0.15	1.16	15.0	4.00	1.00
37	0-10	6.0	0.32	0.50	7.2	2.4	0.50	5	0.16	1.62	47.50	5.00	3.50
	10-20	6.1	0.66	0.61	9.4	2.2	0.38	3	0.13	0.89	29.50	5.00	2.00
	20-30	5.8	0.39	0.29	7.4	2.2	0.52	3	0.13	1.09	102.00	7.00	2.00
Disturbed grassland													
25	0-10	5.9	0.71	1.39	4.8	5.5	1.83	13	0.11	0.91	17.0	5.00	6.50
	10-20	6.2	1.41	2.0	9.2	1.3	1.05	5	0.12	0.59	6.50	3.00	3.00
	20-30	6.7	1.50	1.86	8.6	1.2	0.82	15	0.13	0.56	15.00	4.00	2.50
26	0-10	7.2	2.00	2.50	28.0	1.5	0.38	9	0.11	0.42	3.50	4.00	2.00
	10-20	6.7	1.57	2.00	9.2	1.2	1.08	18	0.13	0.61	15.00	3.00	3.00
	20-30	7.3	2.00	1.96	30.0	1.2	1.50	7	0.10	0.38	0.00	2.00	1.00
28	0-10	6.6	0.61	1.54	8.0	1.1	0.94	5	0.15	1.19	21.00	3.00	4.50
	10-20	6.2	0.61	1.41	7.4	1.1	1.70	3	0.12	0.79	21.00	4.00	2.50
	20-30	6.2	0.50	1.23	6.6	2.2	0.82	5	0.14	1.52	31.50	4.00	3.50
30	0-10	5.1	0.60	1.32	12.6	2.0	0.83	8	0.36	4.54	48.00	0.00	52.00
	10-20	5.4	0.54	1.32	13.6	1.5	0.98	19	0.38	4.80	50.00	0.00	51.00
	20-30	5.2	0.40	0.92	8.8	1.6	0.87	16	0.36	4.34	59.00	0.00	51.00
35	0-10	6.4	0.61	1.55	12.8	2.5	0.52	150.0	0.21	1.62	15.50	3.00	6.50
	10-20	6.6	0.81	2.20	10.4	4.4	0.52	80.0	0.15	1.36	11.55	3.00	2.50
	20-30	6.4	1.23	3.10	20.4	3.2	0.55	46.0	0.13	0.85	2.50	4.00	2.00

Site No.	2	3	7	9	12	38	6	8	11
	8.2	10.1	13.9	10.58	10.5	8.1	17.8	12.2	10.6
C:N	15.6	10.2	13.8	13.1	14.1	11.5	19.5	13.6	8.4
	16.6	11.5	11.04	15.5	7.5	10.1	14.0	14.0	11.6
	6.54	34.25	17.78	8.96	10.5	8.1	26.17	12.2	10.6
CEC	24.22	38.66	18.49	7.54	14.1	11.5	23.89	13.6	8.4
	13.78	18.46	12.16	5.1	7.5	10.1	21.5	14.0	11.6

Sites	39	10	19	14	20	17	15	18	5
	11.2	5.4	14.7	9.6	17.6	18.7	18.8	23.3	17.3
C:N	11.1	3.8	11.6	9.3	19.3	17.4	18.2	14.5	16.4
	11.2	4.3	11.6	8.9	19.4	16.4	17.0	8.1	18.8
	28.86	29.36	30.33	7.6	20.35	16.14	13.36	9.15	11.7
CEC	29.52	23.39	21.41	4.27	18.8	10.54	17.85	7.38	11.8
	27.57	24.49	24.08	4.82	14.42	14.3	7.32	6.21	11.9

Sites	42	1	4	29	34	36	37	25	26
	3.8	22.7	4.25	15.1	9.0	9.4	10.1	8.3	3.8
C:N	2.6	16.9	16.0	15.2	3.4	8.6	6.8	8.3	4.7
	3.4	16.1	18.0	10.1	11.0	7.7	8.4	4.3	3.8
	9.47	12.01	24.1	4.14	10.83	12.45	10.42	12.4	34.0
CEC	8.13	13.26	25.2	5.02	14.11	17.27	12.87	13.91	13.97
	4.5	10.45	23.45	9.4	20.67	13.38	10.28	13.16	35.16

Site	28	30	35
	7.9	15.1	7.7
C:N	6.6	12.6	9.1
	10.9	12.1	6.5
	11.25	16.52	12.65
CEC	10.52	16.96	18.62
	8.33	11.72	27.83

Appendix C Physiography and landuse history of the sites from where the soil was sampled, see also Chapter 5.

Site	Geology	Soil characteristics	Landuse history
1	Tertiary volcanics	well drained dark brown, deep humic Cambisols	domestic and some wild animal grazing more than 30 years
2 & 3	Tertiary volcanics	well drained dark brown, undifferentiated calcaric Regosols	forestry/light domestic & some wildlife grazing over 30 years
4	Quaternary volcanics	shallow well drained excessively eroded reddish	domestic and some wild animal grazing over 30 years
5	Quaternary volcanics	well drained, mediumly deep dark geyish brown mollic Andosols	domestic and wildlife grazing over 30 years
6	Quaternary volcanics	very deep well drained dark reddish brown, ando-humic Nitosols	domestic grazing, short fallow cultivation 8 years
7	Quaternary volcanics	deep well drained dark brown mollic Andosols	forestry, some domestic and wildlife grazing over 30 years
8	Quaternary volcanics	moderate deep dark soils	regenerating forest over 30 years old, some domestic and wildlife grazing
9	Quaternary volcanics	well drained dark reddish mollic Andosols	forestry, some light domestic and wildlife grazing over 30 years
10	Tertiary volcanics	well drained moderate deep dark brown ando-eutric Cambisols	domestic and some wildlife grazing over 30 years
11	Quaternary volcanics	deep well drained dark reddish mollic Andosols	forestry over 30 years cultivated for two years
12	Quaternary volcanics	dark greyish brown, deep well drained, endoluvic phaeozems	forestry over 30 years
14	Granites	well drained, deep dark brown verto-luvic Phaeozem	cultivation over 20 years short fallow, deferred domestic grazing
15	Granites	well drained shallow verto-luvic Phaeozems	20 years cultivation abandoned farm, grazing

17	Granites	deep reddish mollic Nitosols,well drained	grazing wildlife more than domestic
18	Bukoban	deep reddish brown chromo-luvic Phaeozems	abandoned farm, short fallow
19	Bukoban	deep well drained dark,mollic Nitosols	intact woodland,some wildlife grazing
20	Bukoban	moderate deep,well drained,nito-luvic Phaeozems	abandoned over 30 years cultivated farm,domestic grazing
25	Quaternary volcanics	shallow moderately drained solodic Planosols	domestic & some wildlife grazing
26	Quaternary volcanics	moderate deep, moderate drained solodic Planosols	wildlife and some domestic grazing over 30 years
28	Basement	moderate deep, well drained	domestic,some wildlife grazing over 30 years
29	Quaternary volcanics	well drained, mollic Andosols,clayey	Abandoned farms over 30 years
30	Quaternary volcanics	well drained deep mollic Andosols	under cultivation for over 30 years
34	Basement	well drained,shallow dark brown verto-luvic Phaeozems	domestic, wildlife grazing over 30 years
35	Tertiary volcanic	shallow, moderate drained verto-luvic Phaeozems	domestic,some wildlife grazing over 30 years
36	Tertiary volcanic	dark brown, deep verto-luvic Phaeozems	wildlife grazing over 30 years
37	Basement	greyish dark	wildlife and domestic grazing over 30 years
38	Quaternary volcanics	dark brown,deep well drained mollic Andosols	private forest over 30 years old
39	Quaternary volcanics	dark reddish brown brown ando-humic Nitosols	abandoned farm, cultivated over 30 years

Appendix D: Human activities and the impact on Vegetation Assessment Questionnare for Narok District for the Period Oct. 1989-Oct. 1990

Researcher Ogutu Z.A

1. a) Name of respondent_______Designation/Family position______
   b) Name of study site ___________________________________
   c) Land adjudicated Yes or No or otherwise _________________
   d) What are your views about land adjudication/ownership?____
   ____

2. a) Major human activities listed in priority____
   b) Is cultivation practiced? Yes/No. If yes, when was it introduced and why?______________________ ________________
   If no why____
   c) Size of farms__________ha; mechanised or not mechanised?
   d) What is the fallow period?__________________________
   e) Use(s) of abandoned farms____________________________
   f)i. Specify problems facing cultivation________________
   ii. How are they being overcome?_______________________
   g) Do you lease your land for farming? Yes/No. If yes why and what crops are grown?_________ _____________
   If no why?______________________________________
   h)i. What is the size of land leased?________________ha.
   ii. Do you experience problems from your tenant(s)? Yes/No_______________________
   iii. If yes, how do you solve them?_________________
   i) What do you think will happen to food situation if tenants are vacated? will decrease/remain constant/will increase
   j) Is productivity declining/increasing/constant?______
   k) For your choice in (j) what reasons do you give?______

3. a) How much land is under grazing? <1/2ha/ >1ha/all land
   b) What do you prefer, livestock or cultivation?_______
   c) For your choice in (b) what reasons do you offer?_____
   d) Are pastures adequate? Yes/No. If no, how is the shortage being overcome?____
   e) Has there been change(s) in livestock movement and population movement?____
   F) Accordingly, the changes in e) are______________ and______ respectively.
   g) Name the problems facing livestock industry?______________
   h) Are there more pasture for livestock/wildlife populations now than they were 10 to 30 years ago? Yes/No. If yes, why?_______________If no, why?_________________________
   h)i. Do you get advice from agricultural officers? Yes/No.
   ii. If yes from which ministries?____________________
   iii. If no, what are your views?_____________________

4. a) Is the predominant plant communities the same to that in 10 to 30 years ago? Yes/No. If yes why?_________If no, why______________

b) For your answer in a), in sum, has the community increased/decreased?________________ If increased why? If decreased why?____

c) Are medicinal and /or valuable plants for construction and fuelwood decreasing/decreasing? If increasing why?_______ If decreasing say why?____

D) For your answer in c) give the distance from which these plants are collected and the time spent_________________________

5. a) What was the number and distribution of wildlife in settled areas in 10 to 30 years ago? Rare/common/very common__________

b) For your answer in a) give reasons______________________

c) Is there competetion between wildlife and livestock over pastures and water? Yes/No.

i) If yes why?_____________ If no Why?______________________

d) What management suggestions do you offer concerning your answer and explanation in c)?.________________________________

e)Does wildlife benefit you? Yes/No. If yes how__________ If no, how?________________ What management suggestions do you offer for your answer?____

f) Do you practice deferred grazing(after harvesting)? Yes/No. If yes why?____________ If no why?________________________

6. a)Have activities and lifestyles in your family changed over the last 10 to 30 years ago? Yes/No. If yes specify the period and say why______________ If no say why_________________________

7. What are your views on traditional pastoralism, group ranching, individual ranching and the recently introduced cultivation?

8. a) What do you envisage is going to be the landuse type in this area in twenty years to come?________ why?________________________

i) If pastoralism, how do you think it should be managed?____

ii) If wildlife conservation, how do you think it should be developed?____

iii) If cultivation, how do you think it should be developed?

9. On the whole, are your recent activities detrimental or positive to the environment?__________________________________

i) If detrimental, how _________ and which ones?______________

ii) If positive, how_____________ and which ones? _____________

10. Are there any other important suggestions you could offer concerning environmental impact of your activities and those of your neighbours or immigrant cultivators?________________________