

**RANGELAND MANAGEMENT AND VEGETATION ORDINATION IN THREE
COMMUNITY RANCHES IN SAMBURU COUNTY, KENYA**

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DECLARATION

This thesis is my original work and has not been presented for the award of a degree in any other University.

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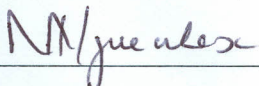
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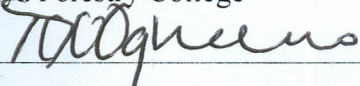
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DEDICATION

This work is dedicated to my beloved wife Rossa, my Mother Lucy and my two beautiful angels Eleanor and Maxine.

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ABBREVIATIONS AND ACRONYMS

ASAL	Arid and Semi Arid Lands
CBD	Convention on Biological Diversity
CEC	Cation Exchange Capacity
CITES	Convention on International Trade in Endangered Species
DCA	Detrended Correspondence Analysis
DCCA	Detrended Canonical Correspondence Analysis
DRSRS	Department of Remote Sensing and Resource Survey
EWI	Earthwatch Institute
ESRI	Environmental Systems Research Institute
FAO	Food and Agricultural Organization
GIA	Geographic Information and Analysis
GIS	Geographic Information Systems
GPS	Global Positioning System
KWS	Kenya Wildlife Service
SOC	Soil Organic Carbon
UNEP	United Nations Environmental Program
UTM	Universal Transverse Mercator

ABSTRACT

Rangelands have a harsh and variable physical environment typical of arid to semi arid areas that receive low and erratic rainfall of less than 450mm per year. The challenge of the rangeland potential today is to balance livestock productivity for a growing human population with conservation of vegetation for both wildlife and livestock. This study set to determine past and current land use management practices among the Samburu people in context of the social economic infrastructure development in the area. The study also aimed to establish whether there is clustering in the spatial distribution of plant species and the plant-soil relationship in the study area. Data was collected in Basalinga, Ngotuk Ongiron and Ngaloni community ranches of Samburu County. The results based on field land use data, observations and laboratory data obtained from soil chemical analysis revealed that Samburu people employ range, herd and wells management skills to ensure there is availability of forage for their livestock throughout the year. In addition, the study shows there has been an increase in the development of the social economic infrastructures in the area. The results further indicate that despite the Samburu community being pastoralist, their movement is continually constrained by availability of social amenities. Modified Braun Blanquet cover/abundance rating was used to determine the species abundance. Result indicates that plants with a height of less than a meter had highest abundance. Detrended Correspondence Analysis (DCA) results confirm floristic clustering in spatial distribution of plant species in Samburu eco-region while Detrended Canonical Correspondence Analysis (DCCA) indicated plant species had 68.1% relationship with measured soil variables. The sum of all unconstrained Eigen values for both DCA and DCCA in this study had similar value of 2.725 as expected in a normal (unconstrained) correspondence analysis. This implies important explanatory variables were measured and included in the analysis. For further understanding of the land use and vegetation condition in Samburu eco-region, this study recommends that further research be undertaken to determine the forage value of the vegetation in the study area for both wildlife and livestock.

CHAPTER 1

1.0 INTRODUCTION

1.1 Background of the study

Rangelands occupy about 50% of the world's land area (Friedel *et al.*, 2000), and occur on all continents, particularly in Africa, Australia and the United States. Research has been carried out on several rangelands and in each continent a different definition has been coined. Pratt *et al.* (1966) defined rangelands in Africa as "land carrying natural or semi-natural vegetation, which provides a habitat for wild or domestic ungulates". Harrington *et al.* (1984) defined Australian rangelands as "ecosystems in which man seeks to obtain a productive output by simply adding domestic livestock to a natural landscape". In the United States of America, Heady (1975) stated that "rangeland vegetation includes shrub lands, grasslands and open forests, where dry, saline or wet soils, steep topography and rocks preclude the growing of commercial farm and forest crops". In this study, the term rangeland is used in reference to ecosystems in which the climax or potential plant cover is composed principally of native grasses, grass-like plants, forbs or shrubs suitable for grazing and browsing as quoted by McGuire (1978). The term Savannah has been used to describe such plant communities in East Africa.

In Africa, these ecosystems are found between the rainforests and deserts, from about 29⁰ North to 16⁰ South (Pratt *et al.* 1966). Rangelands cover over 75% of the Kenya's total land area. In terms of utilization, 63% of the country's national parks and protected areas are located in rangelands (Ayuko, 1988; Belsky, 1990; Scholes and Walker, 1992). These areas are typically arid or semi-arid lands, receiving low and erratic precipitation usually of less than 450mm per year. Potential evapo-transpiration is usually high, often

exceeding 2000mm per year. These are areas of marginal agricultural potential without irrigation. Rangeland plant community distribution and species composition are known to be related to specific soil properties such as soil climate (moisture and temperature), texture, depth, structure, fertility, pH, salinity and toxic influences. These properties relate to spatial variability of vegetation responses ranging from broad geographic distributions to landscape influences to specific site characteristics. (Leonard *et al.*, 1988).

Balancing livestock productivity for a growing human population with conservation of vegetation for both wildlife and livestock is the principal challenge in rangelands today. During the late nineteenth century and throughout the first half of the twentieth century, wildlife conservation schemes meant the exclusion of the local population from a chosen area in order to "preserve" the environment. Significant areas of land were set aside as "wilderness", to be preserved, (untouched by humans). Problems such as soil erosion, degradation of rangelands and desertification were viewed as principally due to local, indigenous, misuse of resources. State and international conservation policies consequently deliberately planned to exclude the local population in order to preserve flora and fauna and to create wildlife parks or "natural" reserves.

State organs responsible for natural management and conservation views indigenous population as primitive and as impediment to conservation programmes (Chatty, 1996; Agrawal, 1997). Conservation programmes went ahead on the assumption that the range was previously unoccupied, with the pastoral population often being forced off its

grazing land by the attempts of colonial and early independent governments to assert some form of State control over land (Chatty, 1996; Agrawal, 1997). The negative consideration of indigenous knowledge and of indigenous social/political structures justified the need to exclude local groups from development efforts (Chatty, 1996; Agrawal, 1997). Moreover, this conservation paradigm failed to reckon coexistences of wildlife and people in the same area.

A study by Behnke, *et al.* (1993) challenged the basic assumptions underlying the tradition of range management which had proposed that pastoral ecosystems are potentially stable and balanced and that the local communities are the source of degradation. The study showed that pastoral environments are often "non-equilibrium environments", continuously adapting to changing conditions. Several other studies (e.g. Friedel *et al.*, 1990; Yan, 2004; DCG Report, 2004) have also produced evidence that local people in different parts of the world do value, utilize and efficiently manage their environment. The new perspectives indicate how nearly every part of the world has been inhabited and modified by people in the past, and underlie how the mythical pristine environment exists only in our imagination (Chatty, 1996).

Traditional knowledge among the local people has allowed sustainable utilization of the fragile rangeland ecosystems for thousands of years by use of grazing management strategies that are suited to uncertain and highly erratic weather (Mutiso, 1995). Part of the coping strategies has been migration to areas with available water and pasture as well as setting aside dry season grazing pasture and/or splitting of herds to minimize risks.

This has had the effect of maintaining a balance between land use and prevailing vegetation resources (Mutiso, 1995).

1.2 Statement of the Problem

Several models can be applied in rangeland management. Conservancy models or natural resource management model started taking root in rangeland conservation at the expense of climax or succession models (Clement, 1919). Natural resource management refers to the management of natural resources such as land, water, soil, plant and animals, with a particular focus on how management affects the quality of life for both the present and future generations. The application of climax or succession models resulted in creation of National parks and national reserves aimed at creating self regulating ecosystems with little or no human interference. This implied that communities who lived in these areas (parks and national reserves) were not supposed to reside there. In this regard, the models failed to recognise that local pastoral communities have co-existed with the wildlife for thousands of years. The applicability of these models in rangeland management is however not well studied in most African rangelands and more so in Northern Kenya.

The wealth of indigenous knowledge on how the local communities are able to adjust and adapt to arid and semi arid ecosystems through cyclic and migratory strategies and other opportunistic husbandry practices especially in East African rangelands is not yet well documented. This is partly because experts are mainly concerned with so-called modern approaches in rangeland management. Furthermore, a topical issue warranting more research has been on how the nomads prevent the extinction of their livestock herds and flocks and maintain the biodiversity of the local breeds regardless of the rangeland

dynamics in terms of resources. Also, of concern to researchers has been how the local communities in Samburu have coexisted for thousands of years with the wildlife. In this regard, this study sought to establish the traditional husbandry practices used by the local community in range management.

Vegetation change has been reported in rangelands of northern Kenya (Herlocker and Walther, 1991, IPAL, 1984). However, the effects of vegetation changes on the grazing land and the pastoralist communities are not fully understood, especially in relation to how this influences rangeland management. Knowledge on coexistence between livestock, wildlife and humans during resource scarcity in rangelands is scarce, with only a study pointing out that competition for key range resources (mainly water and forage) occurs between livestock and wildlife (ERI, 2004). Reduction in grass cover and the associated increased soil erosion, desertification and loss of plant species has been attributed to poor animal health (ERI, 2004). Nevertheless, aspects such as spatial distribution of vegetation and how this relates to soil characteristics in the rangelands are yet to be studied. In addition, detailed assessments of rangeland resources including their potential have not yet been made and there is a lack of quantitative data to support widespread claims of overgrazing and rangeland degradation. There is also a dearth of knowledge on the socio-economic and institutional arrangements in rangelands and livestock management that are in vogue in different parts of the rangelands and their impact on the environment, especially vegetation changes.

1.3 Objectives

The following specific objectives were formulated for this study

- 1) To determine past and current Samburu land use (grazing) management practices in the context of social economic infrastructure development in the area.
- 2) To determine if there is clustering in the spatial distribution of plant species in the Samburu eco-region.
- 3) Determine how plant species distribution relates to soil characteristics.

1.4 Research questions

This study explored to understand range management skill and vegetation characteristics in Samburu eco-region and the pertinent questions addressed included:

- (a) How do Samburu people traditionally manage rangeland resources in order to maintain their herds through out the year?
- (b) How do these practices relate to range condition, water availability, size and composition of the herd?
- (c) Is there clustering in the spatial distribution of plant species?
- (d) How does spatial distribution of plant species relate to soil characteristics?

1.5 Justification of Study Problem

Community based conservation programs such as Ilgvesi, Lekurruki, Namunyak and Kalama are gaining credence as the best solution for both wildlife and local communities' livestock (ERI, 2004). The study area is rich in wildlife such as gray's zebras, elephants and Somali ostrich. An understanding on the community traditional knowledge on range,

livestock and well management will add information on strategies and policies needed in managing resources. Community conservation model if implemented in these community group ranches would reduce range degradation while improving the local peoples' livelihood.

Knowledge generated by the study will inform the community and policy makers on the alternative use of rangeland. Protective management ethos for rangelands, securing their sustainable future through strategic investment well before degradation is a major issue and an unaffordable research cost imposition.

1.6 Significance of the Study

Eradication of extreme poverty and hunger, and ensuring environmental sustainability are two of the Millennium Development Goals adopted by United Nation General Assembly in September 2000. A link between depressed livelihood and unsustainable use of the land and natural resources has been observed in Kenyan rangelands (Okello, 2009). The local communities in Samburu are dependent on the land and her resources for their livelihood, but demand and competition are increasing, thus endangering both the resources they depend on and threatening the environmental health (Okello, 2009). Perennial droughts in northern Kenya rangelands are inevitable, and this largely leads to rural poverty. It would be expected that an improvement on socio-economic facilities such as schools, clinics and trading centres may influence rangeland management practices and nomadic community lifestyles. Therefore, an assessment on the

contribution of these facilities in implementing management practices aimed at reducing pressure on the already degraded land is necessary.

The community conservancy models where the community conserve resources within their territory have gained momentum in the recent past, compared to the national parks and game reserve model of late nineteenth century and throughout the first half of the twentieth century (FAO, 2007). The community conservancy model allows for a community to participate in conservation efforts and also share in the resources gained from the same. The current study is part of the Samburu Conservation Research Initiative, and is expected to make a significant contribution in understanding the conservation dynamics of the eco-region. The findings will enrich our knowledge of rangelands, especially in the understanding of vegetation change.

The result will provide data to conservation groups, the government and other interested bodies in conservation and development. The data may be used to formulate policies, strategies and tools to safeguard the biodiversity of community ranches. This may be achieved by enabling local communities to tackle the linked causes of poverty and incipient natural resource degradation. Participation of the community members provides an appropriate opportunity for creating conservation awareness.

The study recognises Kenya as a signatory to a number of environmental conventions and protocols (such as CBD, CITES, and Ramsar convention on wetlands) which call for domesticating policy recommendation, strengthening regional, national and local

institutions and increasing public/community participation. The answers from the questions addressed by the study will go a long way in helping the country achieve these commitments.

1.7 Limitations of the Study

The study was limited to socio-economic and soil chemical factors. The socio economic factors included schools, clinics, water points and churches as regards their spatial distribution over the study area. Though soil physical characteristics and morphology are possible indicators of change in vegetation due to land use, it was not factored in the current study. Although the carrying capacity, competition, biotic factors and climate influence the floristic characteristic of a rangeland, were also not factored in the current study.

1.8 Definition of Terms

Land cover

The observed physical surface of the earth, including various combinations of the vegetation types, soils, exposed rocks and water bodies

Land use

This refers to the purpose for which land is committed: way in which land is used to produce goods and services. Here, land use was taken as the way Samburu people utilize their land to meet their livelihood through livestock grazing.

Land use management practice

This refers to the means by which the land management objectives are achieved. The 'how' of land use, for example, how do Samburu people manage to have healthy animals through out the year despite sporadic climatic change?

Vegetation ordination

Ordination is the collective term for multivariate techniques that arrange sample plots along axes on the basis of data on species composition. The result of ordination in two dimensions (two axes) is an ordination diagram, in which sites are represented by points such that points close together have similar floristic composition. Points far apart correspond to sites that have dissimilar species composition.

CHAPTER 2

2.0 LITERATURE REVIEW

The chapter reviews the socio-economic potential and challenges experienced in Kenyan rangelands. In particular, the review focuses on the vegetation dynamics in the rangelands of northern Kenya. In addition, discourses on the rangeland studies are also presented.

2.1 The socio-economic potential and challenges of Kenyan rangelands

Agriculture is the backbone of the Kenya economy and is used to characterize land use potential. This characterization is normally based on the ecological factors of climate, soil and vegetation (Pratt and Gwynne, 1977; Sombroek *et al.*, 1982). Table 2.1 shows the different agro-climatic zones of Kenya with an indication of moisture availability, vegetation, and potential for vegetation growth and major limitation to production and land use.

Livestock keeping and tourism form the major land use practices in Kenyan rangeland. Tourism is among the high foreign exchange earners, with \$500 million each year. Rangelands produce over 50% of the meat requirement for the country. Wildlife, which forms the basis for Kenyan tourism, is found mainly in the rangelands. Pratt and Gwynne (1977) observed that vegetation is the basic resource for pastoralism and wildlife based tourism, and a change in vegetation has direct effect on rangeland productivity and therefore on the two land uses types.

Kenyan rangelands fall under zone 4 to 6 and cover more than 80% of total area of Kenya's land (Table 2.1). Rangelands have semi humid climate characterised by bimodal rainfall with unreliable pattern, of about 800mm per annum.

Table 2.1. The agro-climatic zones of Kenya (Sombroek *et al.*, 1982)

Zone	Climate	Annual Rainfall (mm)	Annual potential Evaporation (mm)	%Total Land	Vegetation	Major limitation
1	Humid	1000-2700	1200-2000	4.3	Humid Forest	Soil fertility and drainage
2	Sub-humid	1000-1600	1300-2100	4.1	Humid & dry forest	Soil fertility and drainage
3	Semi-humid	800-1400	1400-2200	4.4	Dry forest & humid woodland	Soil fertility and moisture
4	Semi-humid To semi arid	600-1000	1550-2200	4.9	Dry woodland & bush land	Soil moisture and fertility
5	Semi-arid	450-900	1650-2300	16.0	Bush land	Soil moisture and fertility
6	Arid	300-550	1900-2400	21.7	Bush land & Scrubland	Soil moisture
7	Very arid	150-350	2100-2500	45.6	Scrubland	Soil moisture

Soils are poorly developed, fragile and susceptible to dramatic decline in productivity. They are exposed to erosion hazards due to poor natural and human modified vegetation cover (IPAL, 1984). A major challenge in these areas is reduction in grazing areas leading to increased competition, depletion of natural resources and breakdown of coping mechanisms from drought management. The heightened stress and conflicts form major challenges for livelihood in Kenyan rangelands (Isack, 2009). Reduction in grazing area has been attributed to expansion of the cultivation areas and associated rapid population growth. The rapid diversification into farming and other livelihoods is taking place alongside drastic changes in tenure and accesses to resources (Homewood, 2009).

Land tenure changes involving fencing and the spreading commercial cultivation and other enterprises in what used to be dry season grazing area, leads to sedentary lifestyle of the pastoral community. The reduced movement of people and their livestock increase pressure on land resource in the reduced grazing area resulting into overgrazing (Ward, 2004). This depletes grass cover, thus reducing its competitive ability against shrubs and trees (Ward, 2004). Briske *et al.*, (2003) observed that such trees and shrubs are normally less/ or not palatable by both livestock and wildlife. The resulting bare lands force people, livestock and wildlife to move for long distances to sustain their food requirements. FAO (2008) observed that the distance walked per grazing orbit was 15.5 ± 5.0 and 10.8 ± 4.8 kilometres for adult and calves respectively by Maasai cattle.

Another big challenge in the arid and semi arid lands is water. The bare lands resulting from overgrazing are also prone to soil erosion and reduce the rate of water percolation,

increasing surface runoff. Hudak (2000) noted that dominant trees have long taproots and affect the water table by reducing the amount of surface water. The implication is that livestock, wildlife and humans move for long distances in search of water. The total effect is low rangeland productivity which translates to low income for the local communities from livestock due to low purchasing power, leading to increased rural poverty due to reduced sources of livelihood.

2.1 Vegetation dynamics in rangeland of Northern Kenya

Rangelands in northern Kenya are found in Mandera, Wajir, Marsabit, Turkana, Isiolo, Samburu and Baringo counties. Research conducted on rangeland vegetation on sites west of Marsabit across to Lake Turkana, and from the Huri hills near Ethiopia south to Korante plains by IPAL (1984) showed that the overall condition of Marsabit county was determined to be fair or poor in mid- 1980s and was as a result of overgrazing and climatic change. The area had been severely overgrazed in the past, resulting in suppression of desirable grass and woody plant species. As an adaptation to this, it was noted that pastoralist changed livestock composition from dominance by cattle to dominance by camel (Coppock and Jacobs, 1999). They also asserted that vegetation change was as a product of sporadic and low rainfall. However, areas exhibiting poor range condition were primarily associated with settlement and water points, and that sites without surface water were commonly under- utilized. Uncoordinated development projects that served to concentrate impact of people and livestock were being associated with such pressures (Herlocker and Walther, 1991; IPAL, 1984).

Vegetation changes for Mandera and Wajir have been documented for the past 20 to 40 years (Coppock and Jacobs, 1999), and this change was noted to be drought- related. Overall, shrubs were observed to be in decline and perennial grass cover had been dominated by annual species. The widespread insecurity of 1960s was cited as major drive for this change as it resulted in restricted movement of livestock.

In Isiolo County, vegetation changes are primarily characterized by an increase in woody cover with a concomitant decrease in grass (Herlocker, 1993). The author reports that increased access of livestock as a result of improved security in 1970 was an impetus for such change. However, he further portrays some instances where lack of foraging and fire had resulted in vegetation change. This could imply that, both under use and overuse have an implication in vegetation dynamics in Isiolo County (Coppock and Jacobs, 1999).

Overgrazing and over cultivation of Baringo County have been considered responsible for serious environmental degradation and reduction in rangeland productivity (Coppock and Jacobs, 1999). In the eastern and southern portion of Baringo County, a decline in fire frequency has led to woody encroachment in grassland. Ecological restoration schemes in Baringo during 1930s and 1950s aimed at controlling grazing, reduce shrub cover, and promote grass reseeding failed (Herlocker, 1994). In 1980s, communal land in southern portion of the County was changed to private smallholder ownership and group ranches; hence pastoralists in this region have become more sedentary. In northern portion of Baringo County, Herlocker (1994) observed that Pokot pastoralists had

retained transhumance pastoral system. Cattle are moved to lowlands during the wet seasons and highlands for the dry seasons. Construction of the schools and clinics, however, has discouraged stockowners from maintaining optimal livestock management practices.

Despite considerable ecological variability of rangelands in northern Kenya, it is evident from above literature that there is remarkable degree of consistence in vegetation changes. Rangelands have fundamentally been altered by woody plant encroachment resulting from concentration of grazing pressure necessitated by external pressure. Degradation is more pronounced in areas with consistent uses such as around schools, settlements and watering place as well as market places.

CHAPTER 3

3.0 MATERIALS AND METHODS

3.1 The Study Area

The study area is located in the arid and semi-arid southern part of Samburu County, northern Kenya. It lies between latitude $0^{\circ} 30' N$ and $1^{\circ}00'$ and longitudes $37^{\circ}00'$ and $37^{\circ} 30'$. The altitude ranges from 800m above sea level around Samburu Game Reserve to 1230 m above sea level at Mathews range. This area is part of the Laikipia- Samburu eco-region which traverses forests on the northern foothills of Mt. Kenya northwards through private and community lands and wildlife reserves to the Mathews range (Figure 3.1).

Data was collected in Basalinga, Ngotuk Ongiron and Ngaloni community ranches of Samburu County. In order to achieve the objective and test the hypothesis formulated for the study, data on land use management practice, environmental (soils) and vegetation were collected and analysed. This chapter presents the material and methods used in data collection and analysis. Description of the study area, method and material used are discussed under each data type.

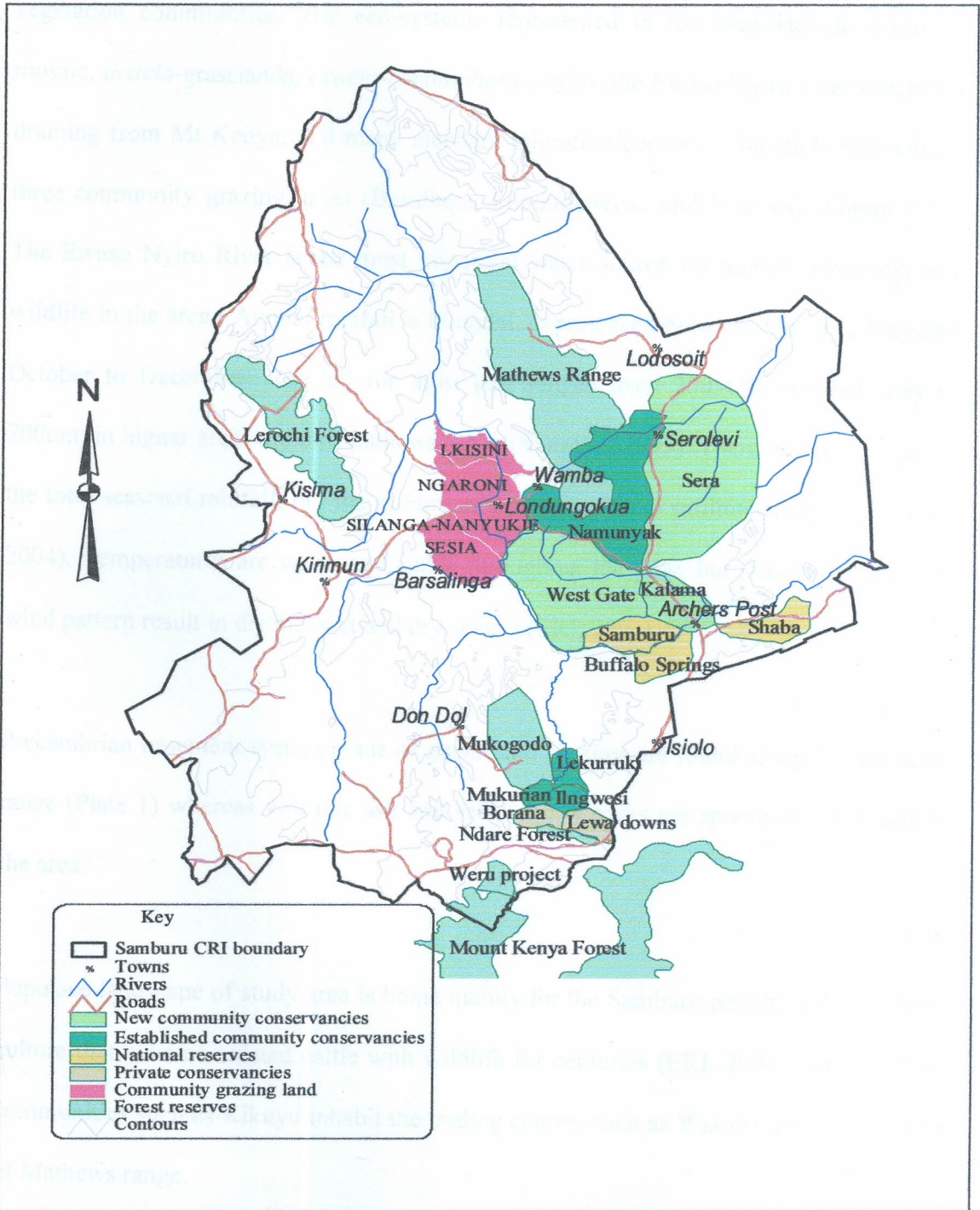


Figure 3.1 Map of Samburu- Laikipia eco-region showing various land use systems. (Source: ERI 2004).

Laikipia – Samburu eco-region is largely a semi arid landscape accommodating varied vegetation communities. The eco-systems represented in the area include savannah mosaic, *acacia*-grasslands, *acacia-commiphora* scrubs, the Ewaso Nyiro river watershed draining from Mt Kenya, and many elephant migration corridor. The study area covers three community grazing areas (Basalinga, Londungokwe, and Ngaloni) (Figure 3.2). The Ewaso Nyiro River is the most important water source for human, livestock, and wildlife in the area. Annual rainfall is bimodal, experienced between March to May and October to December. Rainfall for most part ranges from 200-450 mm but rises to 700mm in higher areas around Mathews range (Simpkin, 1995). There is a wide range in the total seasonal rainfall, but the minimum is at least 51mm millimeters per year (ERI, 2004). Temperatures are warm and stable throughout the year, but seasonal changes in wind pattern result in distinct wet and dry season (ERI, 2004).

Precambrian basement system made of gneiss and granites are found along the Mathews range (Plate 1) whereas volcanic ash and sedimentary rocks are spread on the plains of the area.

Populace landscape of study area is home mainly for the Samburu people with a pastoral culture that have co-existed cattle with wildlife for centuries (ERI, 2004). Other ethnic communities such as Kikuyu inhabit the trading centres such as Wamba town on the foot of Mathews range.



Plate1. Mathews range in the backdrop of a savannah plain (Author 2005)

3.2 Field Methods

The subsection present the methods used in the field to collect data on land use, socio-economic infrastructure, vegetation and soil samples for chemical analysis. Under each data type, the sampling method used is discussed in relation to specific data collected.

3.2.1 Land use practices

A total of 127 people were interviewed on various land use practices using an interview guide (Appendix 1). The interview guide was intended to ensure a general area of information is collected from each interviewee. This provided more focus with a degree of freedom and adaptability in getting information from the interviewee. The questions

were in three categories. Questions to help understand how they manage the herd formed the first set and were basically meant to give both quantitative and qualitative data on the herd size, composition, value and art of herding. The other set focused on range management skills whereby questions on techniques to save foliage for critical periods were asked. The last set of questions was based on water management in which case questions relating to watering schedules and water availability were asked.

3.2.3 Vegetation and Soil

Mixed purposeful sampling method was used to determine the sample interviewed. The criteria set for this study was to interview the herders (met in grazing fields), a randomly selected group of three people in: shopping centres (in shops in the villages excluding Wamba shopping centre), watering points and attendants in organized cultural dances. Convenience sampling is useful in getting general ideas about the phenomenon of interest. This method was used to get information from the various local community people such as government officials, members of parliament, health officers when visiting the research camp or when encountered during the period of study.

Observations were used to build on data obtained from the interviews. Observations centred on the observable land degradation indicators such as soil erosion. Photographs were taken to document such observations.

3.2.2 Socio-Economic Infrastructure

Census was done on the socio economic features in the study area as point spatial data. Spatial data describes the exact and relative location of geographic features. The target was to collect the location of schools, churches, clinics and watering points. Universal

Transverse Mercator (UTM) coordinates of schools, clinics churches and water points were collected using a hand held Global Positioning System (GPS) receiver. These data was superimposed on the road network, streams (lagas) and other natural features obtained from a topographic map covering the area using ArcGIS mapping software (Figure 3.3)

3.2.3 Vegetation and Soil Chemical Data

A stratified random sampling design was used in vegetation and soil data collection. With stratified random sampling, the population was first divided into a number of parts or 'strata' according to some characteristic related to the major variables being studied. The aim of the stratification in this process is to provide a structure to support the study objectives by ensuring the efficient allocation of field survey effort. The focus of this study was to gather information on vegetation species and soil from areas under various land use, grazing and settlement in different community ranches. To this end, the approach sought to sample the widest variation in plant communities present in the study area while having sufficient replication to explain them.

A total of 29 sampling plots each measuring 20m x 20m were randomly established on 6 lines-transects (Figure 3.3). Vegetation data was then collected three times over duration of 10 months between May 2004 and March 2005. The 10-month duration was aimed at providing a full species list.

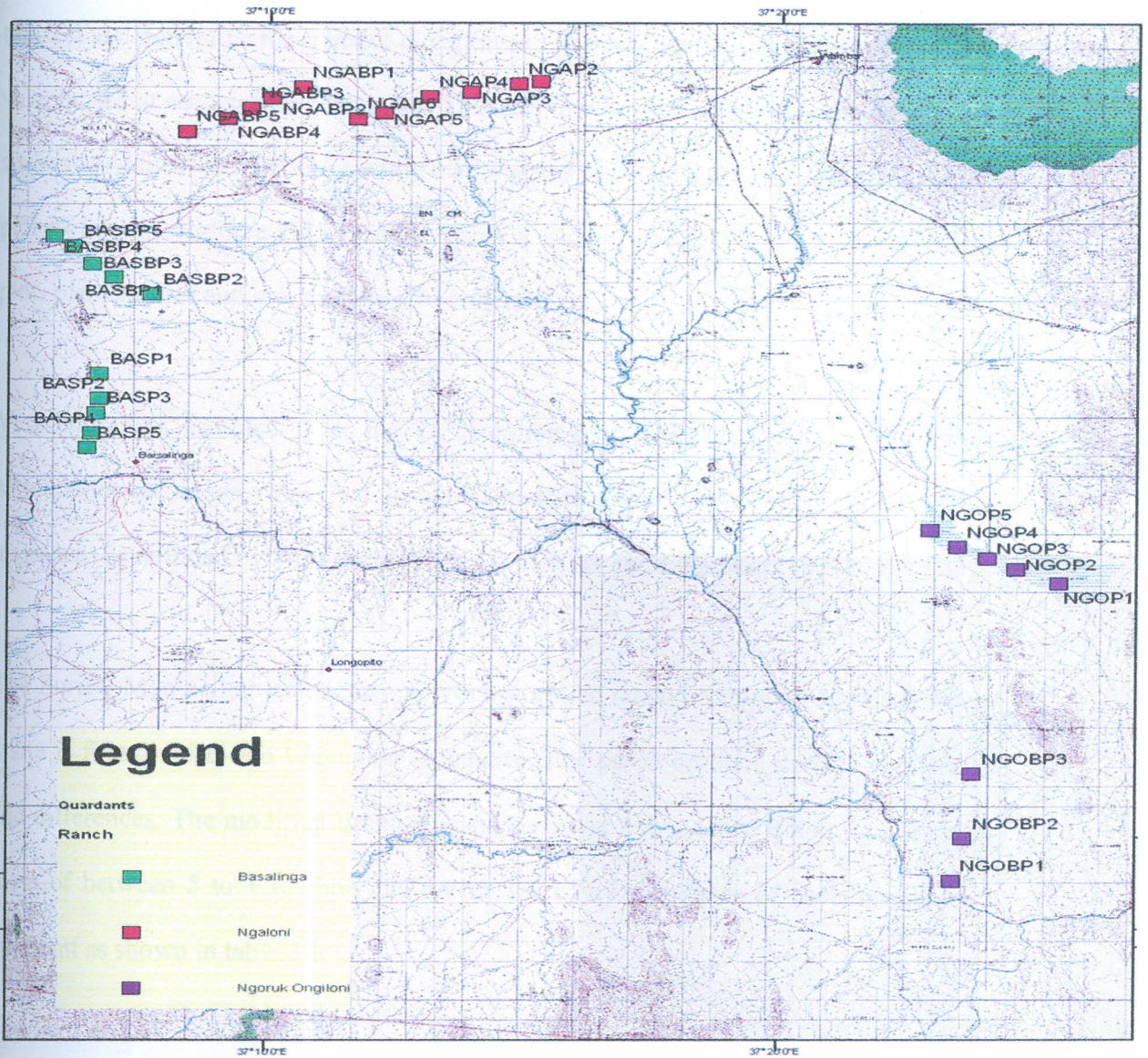


Figure 3.3 Distribution of sample points as superimposed on a topographic map (Source: Author 2005).

The origin and orientation of each line transect were determined by the visual vegetation homogeneity while the length was maintained as one kilometers. To ensure stratification, 2 transects were placed in grazing and settlement areas in each of 3 community ranches under study area (Figure 3.2). Five plots were randomly placed along each transect. To obtain random sample plots, 100 small papers numbered 1 to 100 were put in a paper bag from where they were randomly picked after being shaken well. A hand held Global

positioning system was used to measure the distance between the plots along the line transect and determine the transect direction and bearing. Markers made of painted rocks were buried at each corner of the plot. This was to reinforce GPS location data when the site was revisited. In addition, a white marking was made on a centrally placed tree in the plot to further reinforce GPS reading; given a varying accuracy $\pm 10\text{m}$. In each of the plots plant species and soil samples was collected.

Vegetation was sampled from the 29 sampling plots (Figure 5), using the Zurich–Montpellier technique (Modified Braun-Blanquet Cover /Abundance Rating method approach) as outlined by Shimwell (1971) and Mueller and Ellenberg (1974).

The Zurich–Montpellier technique involves a stratified random sampling approach where a site is first divided into vegetation ‘compartments’ based on their floristic similarities and differences. The modified Braun-Blanquet Cover /Abundance Rating uses a rating scale of between 5 to + to show the percentage cover/abundance of each species in a quadrant as shown in table 3.1.

Table 3.1. Modified Braun-Blanquette Cover /Abundance Rating

Symbol	Cover/Abundance
5	Any number of individuals, with a cover of more than 75 % of plot area.
4	Any number of individuals, with a cover of 50 % - 75 % of plot area.
3	Any number of individuals, with a cover of 25 % -50 % Of plot area.
2	Any number of individuals, with a cover of 5 % -25 % of plot area.
1	Numerous individuals, but with a total cover of less than 5 % of plot area.
r	Few individuals, with small cover
+	Solitary individual, with small cover.

Composition of plant species was based on plant species present on sampling plots and the composition was based on the different life forms as shown in table 3.2.

Table 3.2 Life form classes/ stratum symbols

SYMBOL	STRATUM
T	Tree - any woody plant with a height of more than 5m
S	Shrub - any woody plant with a height of 0.5m to 5 m
H	Plant with a height of less than 0.5m
V _w	Woody vine
W _H	Herbaceous vine

The life form symbols were added on the transect plot code in recording all the species, and a number used to indicate the count of the species in the same stratum collected in a given plot.

Twenty nine soil samples were collected from randomly selected points in the plot. Using the soil auger, samples were taken at surface level (0-10cm) and 50 cm depth (Plate 2). A total of 56 samples were take from the two levels and later mixed to make 29 composite samples.

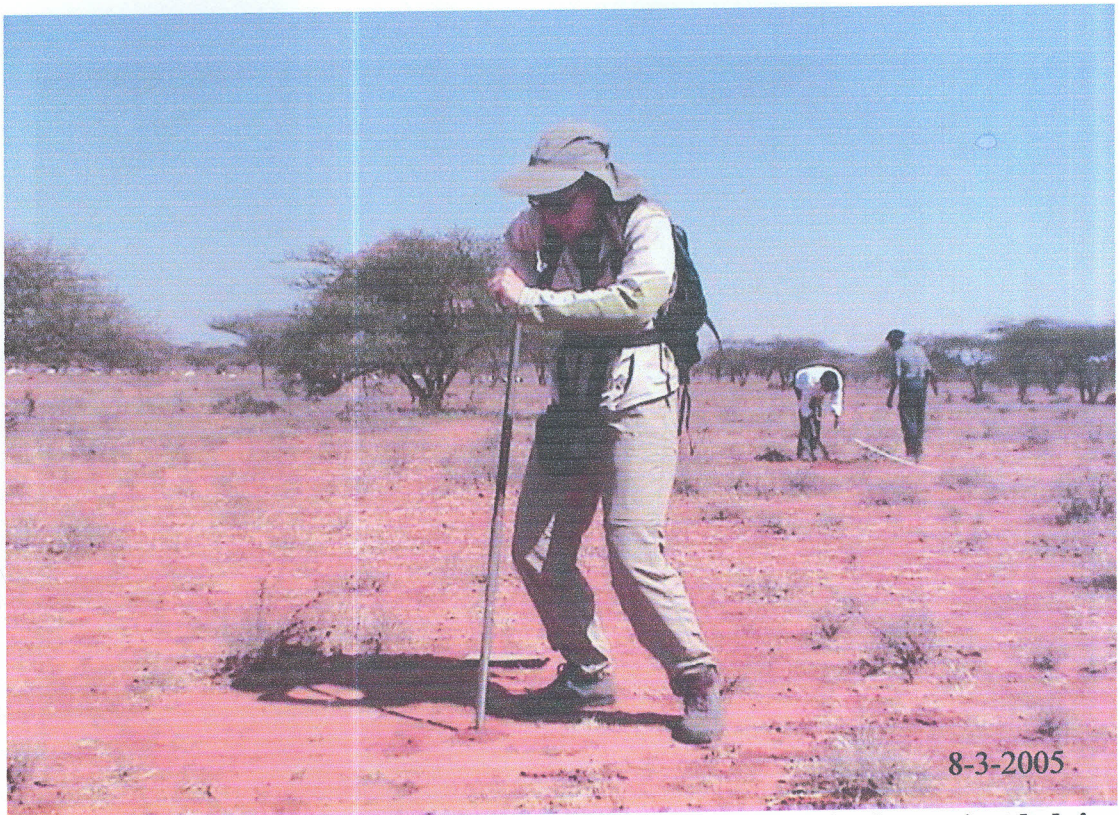


Plate 2. Soil sample collection using soil augers a volunteer in the project helping in collection of the soil sample; (Author 2005)

3.3 Data analysis methods

3.3.1 Species identification

Species identification was done in the field, and species that could not be identified in the field were recorded to the nearest possible family or genera. In addition to plant species coding (Plate 3), identification by local names was done with the assistance of community guide, Morans and herders. The local names were later counter checked with scientific names as given by Herlocker (1993). Where positive identifications could not be made, specimens were sent to the National Herbarium at the National Museums of Kenya for further identification.

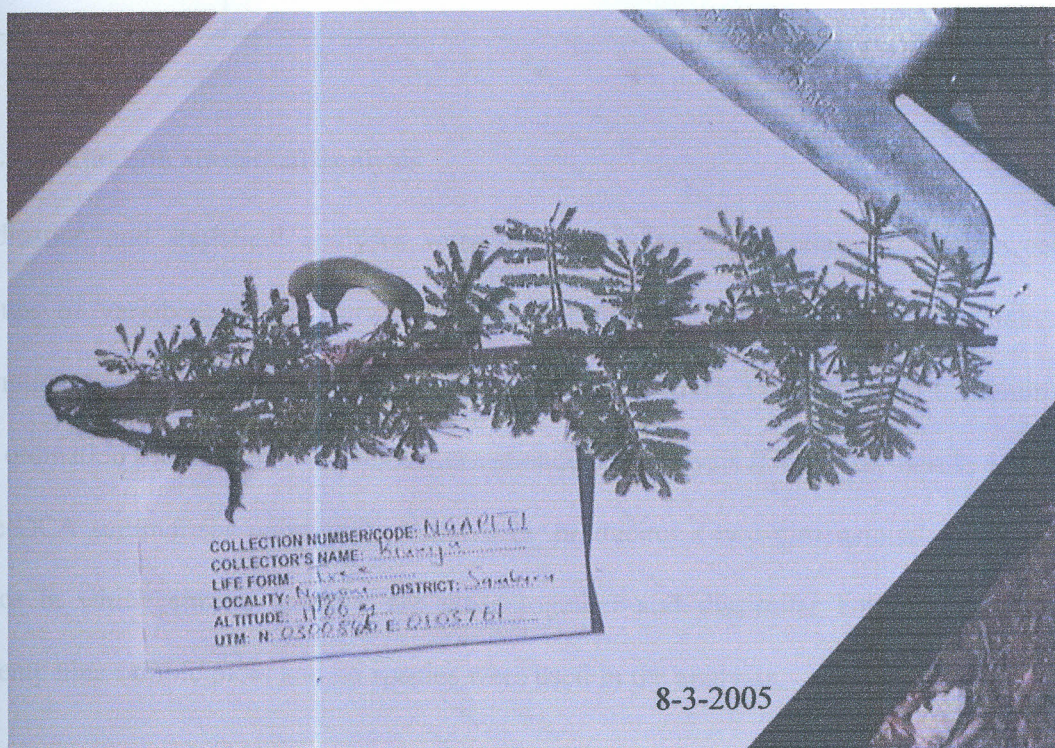


Plate 3: Coded plant species (Author 2005)

3.3.2 Soil data analysis

Laboratory soil analyses were done following **standard procedures** (Gupta, 2000) The specific test for each soil variable is as shown on table 3.3.

Table 3.3 Laboratory chemical soil analyses

Element to analyze	Test
% Organic carbon;	Walkey-Black method
% Total Nitrogen	Kjedahl method
Available nutrients	Extraction by shaking with 0.1N HCl/0.025 N H ₂ SO ₄ (at ratio of 1:5) Ca ²⁺ , K, and Na, were determined with a flame photometer; while P and Mn was determined calorimetrically.

3.3.3 Ordination statistical analysis

Ordination and statistical analyses were used to examine the relationships between groups of variables as put forward in the hypothesis. The results from vegetation sampling were processed using the software package CANOCO (Version 4) containing the ordination programme Detrended Correspondence Analysis (DCA) (ter Braak, 1987). The DCA summarises community patterns by producing a two-dimensional ordination space in which similar samples are close together and dissimilar entities far apart. Twenty nine sample plots and 86 species were used in the analysis.

Detrended canonical correspondence analysis (DCCA) was used to show the relationship between species, plots and the soil chemical characteristics distribution. DCCA is one of the canonical analyses designed to detect patterns of variation in species data that can be explained by the observed environmental variables. The resulting ordination diagram expresses a pattern of variation in species composition and the main relations between the species and each environmental variable. The Corel Quattro Pro software package was used to plot the ordination diagrams.

CHAPTER 4

4.0 RESULTS AND DISCUSSION

Result obtained from the field observation and measurements, laboratory, DCA and DCCA analysis are outlined in this chapter. The chapter is divided into two main sections dealing with aspects related to objectives and hypothesis formulated for the study.

4.1 Land use Management Practice and Social Economic Infrastructure

Results on grazing and settlement show that land zonation as a range management practice is deeply rooted in the community traditions. The study identified two zones, i.e. grazing and settlement zones. Grazing zones included floodplains and hills with undulating slopes and these are used for grazing during the dry seasons. Traditionally, animals are not allowed to graze in these areas during the wet season. The areas identified include Mathews range, Ndikiri hills and Ngojek flood plains (Table 4.1).

Settlement zones were mainly on the plain land, and animals were grazed in this zone during the wet seasons. Manyattas (Samburu homestead) were observed to have circular fences made of thorny tree branches (see Plate 4). Some portions of areas surrounding the homestead were secured for the young animals, in what is known as *Lokere*, and these are secured with tree branches to prevent other mature livestock from entering. The two zones were characterised by tree canopies with little or no undergrowth and eroded bare grounds (Plate 5), whereby rill erosion and gully erosion were observed (Plates 6 & 7).

Table 4.1 Characteristics of the Land Zone

	Zones	
	Grazing zone	Settlement zones
Topography	Hilly and flood plains E.g. Mathews range, Ngojek flood plain	Plains
Observed characteristics	Tree canopy with bare ground ; little or no undergrowth <ul style="list-style-type: none"> • Numerous cattle trails • Gully erosion • No homesteads 	<ul style="list-style-type: none"> • Homesteads present • Numerous cattle trails radiating from the manyatta • Bare grounds around the home stead • Rill and gully erosion

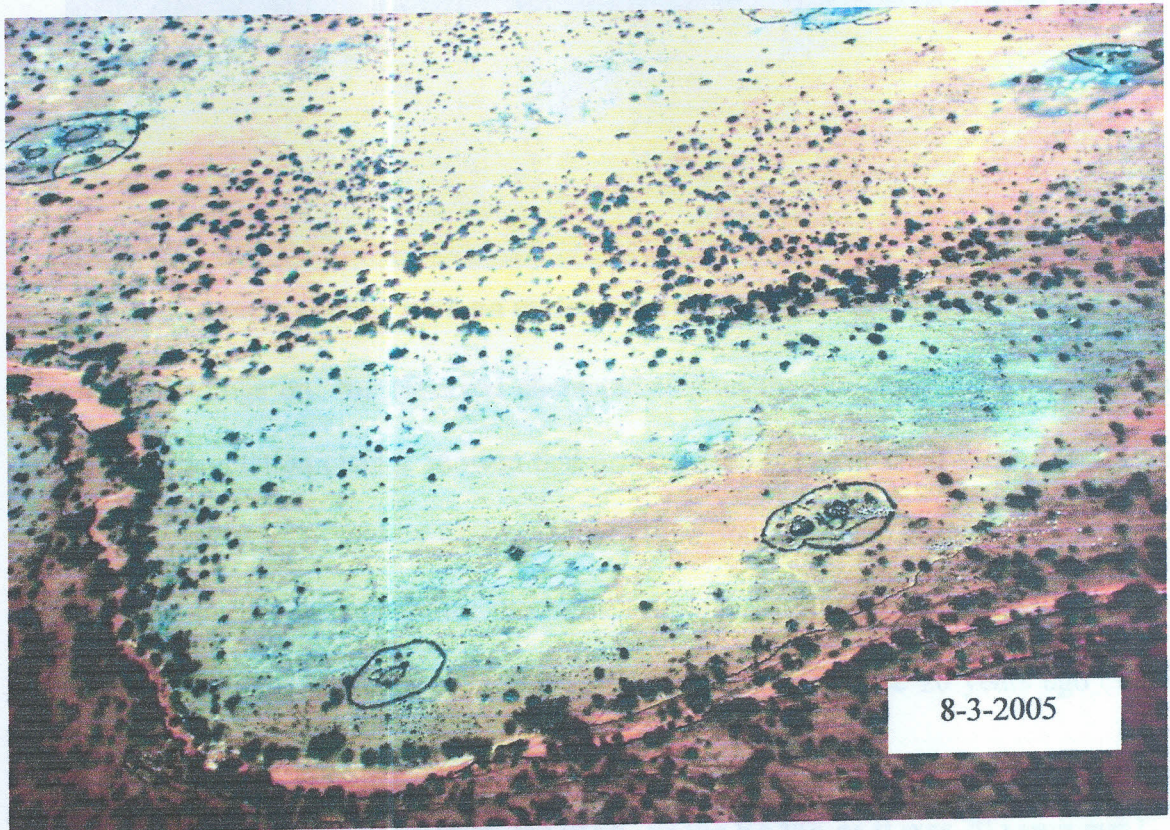


Plate 4. Rings of the homestead known as Manyatta surrounded with tree branches (Author 2005).

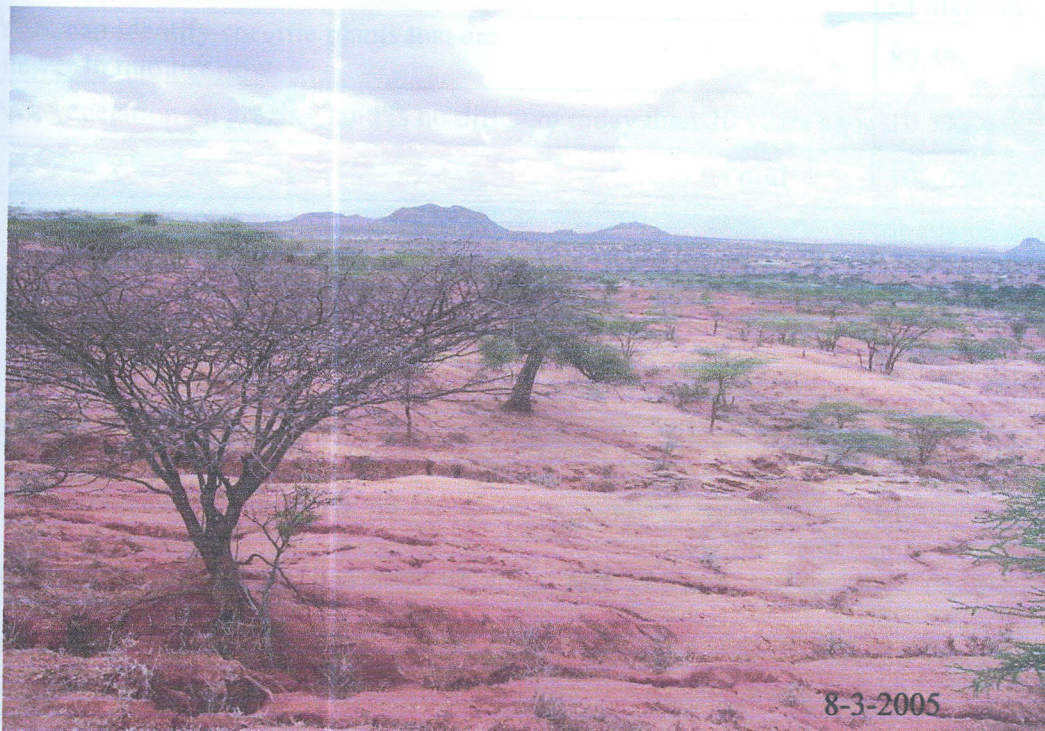


Plate 5. Acacia canopy with no under growth (Author 2005)

The study findings on the observed characteristics on the two land use zones were an indicator of vegetation change showed that grazing land had worsened than it used to be about a generation ago (Table 4.2). Moreover, vegetation change on specific plant species was reported to have occurred over the years, with almost 90% of respondents affirming that there were plant species that numbered fewer today than were 20 years ago (Table 4.3).

Table 4.2 Is grazing land BETTER, WORSE, or the SAME as it was 20 years ago?

	Percentage of mention
WORSE	75.1%
BETTER	14.0%
SAME	10.9%
Total	100.0%

Table 4.3 Are there SPECIFIC PLANTS that are FEWER now than 20 years ago?

	Percentage of mention
YES, can identify specific plants that are Fewer in number now.	89.5%
NO, vegetation on grazing land is no different today than 20 years ago.	10.5%
Total	100.0%

Water availability is an indicator that determines the plant species richness. In order to gain some historical perspective on physical changes in water supply and quality, the survey asked for factual information about what water sources, if any, have dried up over the past generation (Table 4.4). 68.5% of the respondents reported that at least one water source in their community had dried up in the past 20 years. Furthermore, reports from respondents revealed that water availability had worsened over the past 20 years (Table 4.5).

Table 4.4 Have any water sources dried up completely in the past 10 or 20 years?

	Number of responses	Percentage of mention
YES, at least one	87	68.5%
NO	40	31.5%
Total	127	100.0%

Table 4.5 Has water availability gotten better or worse over the past 20 years?

	Number of responses	Percentage of mention
WORSE	78	61.4%
BETTER	44	34.7%
SAME	5	3.9%
Total	127	100.0%

An examination on the range management practices in order to know understand herding is done to ensure continuous availability of the resources revealed that skills relating to herding included livestock diversification, herd splitting and task sharing. Livestock diversification is a practice whereby pastoralist rear more than one animal type. Results on livestock composition showed that 90% of the respondents owned cows, 100% goats and donkeys, 60% owned camels and 30% chicken (Figure 4.1).

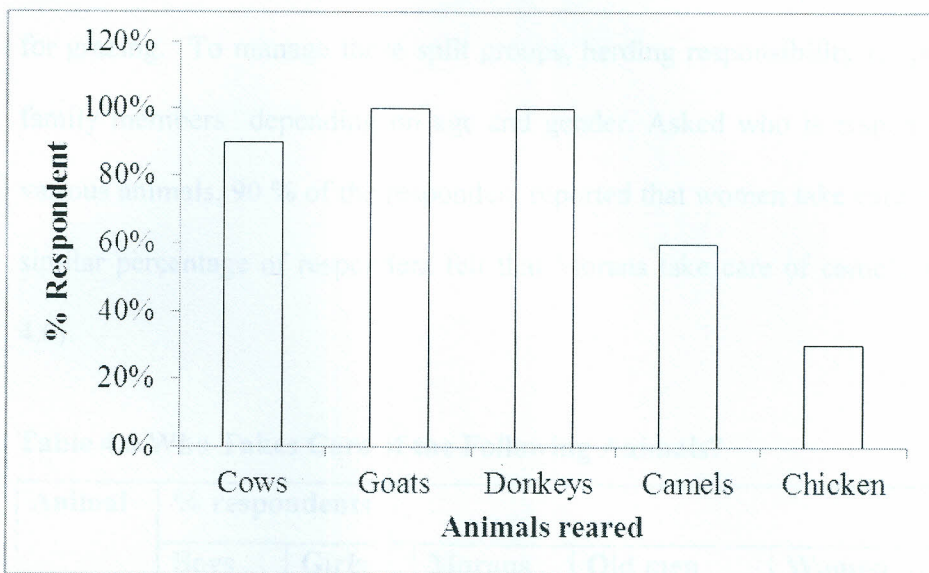


Figure 4.1 Animals kept by respondents

This confirms Herlocker (1999) conclusion about Samburu people having introduced camels to cater for milk. Herlocker (1999) argued that adaptations of the camels to the harsh condition was a great motivation and are left providing milk while cows are taken to far grazing fields during the drought seasons. Though a taboo for Samburu people to feed on birds, chicken were reared for a quick source of income. Cows, goats and donkeys have been reared by Samburu people all along. However, their population of

cows was decreasing over time (Herlocker, 1999) may be due to harsh conditions or livestock diseases.

This study also observed that Samburu people manage the diverse herd of livestock through splitting depending on various factors. All respondent indicated that a diverse herd of livestock is managed through splitting based on type (goats, camels, cows and donkeys), age (old and young), health (pregnant, sick milking) and distance from home for grazing. To manage these split groups, herding responsibility is spread to different family members depending on age and gender. Asked who is responsible for herding various animals, 90 % of the respondent reported that women take care of donkeys while similar percentage of respondent felt that Morans take care of camels and cows (Table 4.6).

Table 4.6 Who Takes Care of the Following Animals?

Animal	% respondents				
	Boys	Girls	Morans	Old men	Women
Cows	10	0	90	0	0
Goats	16	49	4	0	31
Donkeys	0	10	0	0	90
Camels	9	21	30	0	40

An exploration on animal watering skills in addition to range and herding skills identified revealed that the distribution and abundance of watering points in these arid and semi arid lands is dependent on the season. During the wet season watering points are more compared to during the dry seasons. It was observed that Samburu people mostly depend

on water in dry lagas (Plate 8). A narrow deep vertical hole for drawing water is sunk on sand filled lagas during the dry season.

The art of watering livestock was observed to be a perfected skill which was time bound and animal dependent. Time bound as animals are generally watered once or twice per week depending on their type, health and age. Milking animals especially cows were watered twice a week. Cattle trails and heavy erosion was a characteristic observed radiating from almost all watering points.

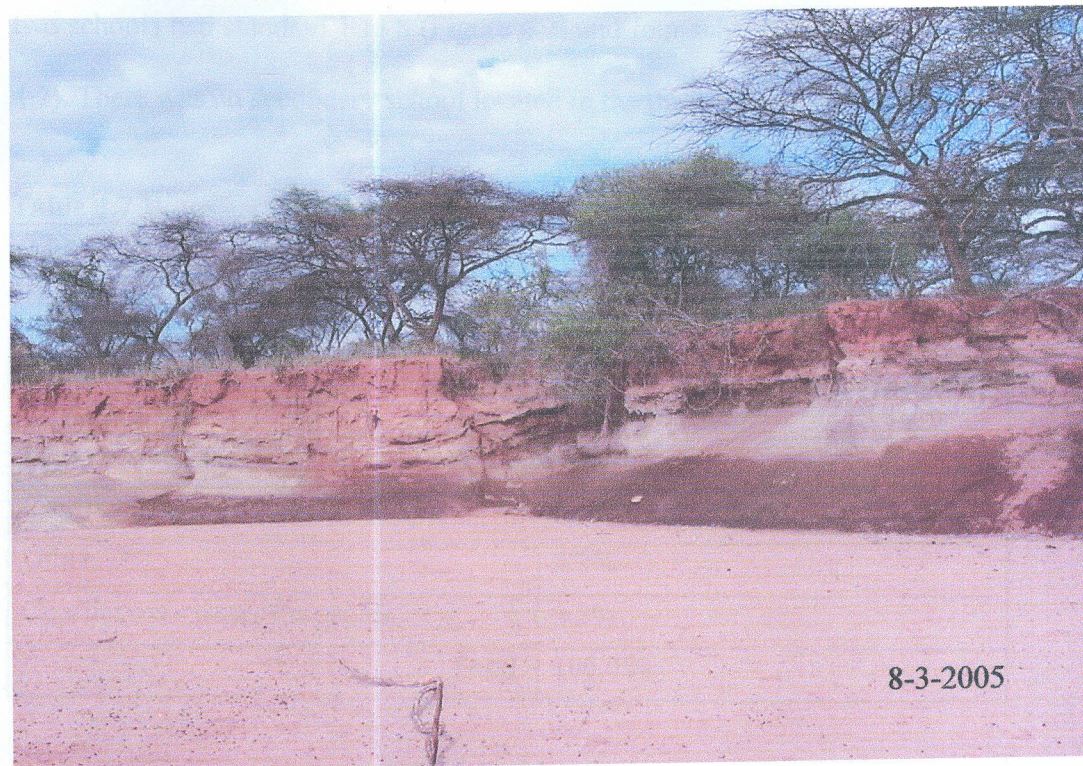


Plate 6: Eroded laga banks (Author2005)

Other questions in the survey purposed to crosscheck and add to the depth of the responses on water resource. A distinct majority of people, 39.2% of the respondent, pointed 'distance to water points' as one of the greatest threats to their water supply

(Table 4.6. In fact, almost twice the number of people responded ‘distance’ as compared to the next frequently identified threat, overpopulation, which was mentioned by 21.9% of the respondents. About a quarter of respondents mentioned a basic lack of water for human and livestock consumption. A further 8.7% of the respondents referred to conflicts over a limited water supply for both humans and livestock (Table 4.6).

The study reveals a notable increase in the social economic points. School which doubled as clinic and church points have increased in the recent past. The study used the school level; Nursery level, class 1-3, class 1-8 and secondary to examine school distribution over the years. The study revealed that 12 schools in the study areas had nursery, only two schools had standard 1 to 8 (Figure 4.2) and four schools had standard 1 to 3 (Table 4.7). There was no secondary school located in the three community ranches.

Table 4.7 What are the Biggest Threats to Your Water Supply?

Threat	Percentage of mention
Distance to water points	39.2%
Too many people	21.9%
Lack of water for people	13.8%
Lack of water for livestock	12.2%
Conflict over water for livestock	5.5%
Other	4.2%
Conflict over water for people	3.2%
Total	100.0%

The school buildings were noted to be also used for clinic and church assembly points. The main shopping centres were observed to be Wamba town, Basalinga and

Lodungokwe. Other small shops were observed near the schools and along the Wamba-Maralal road and Wamba - West gate road.

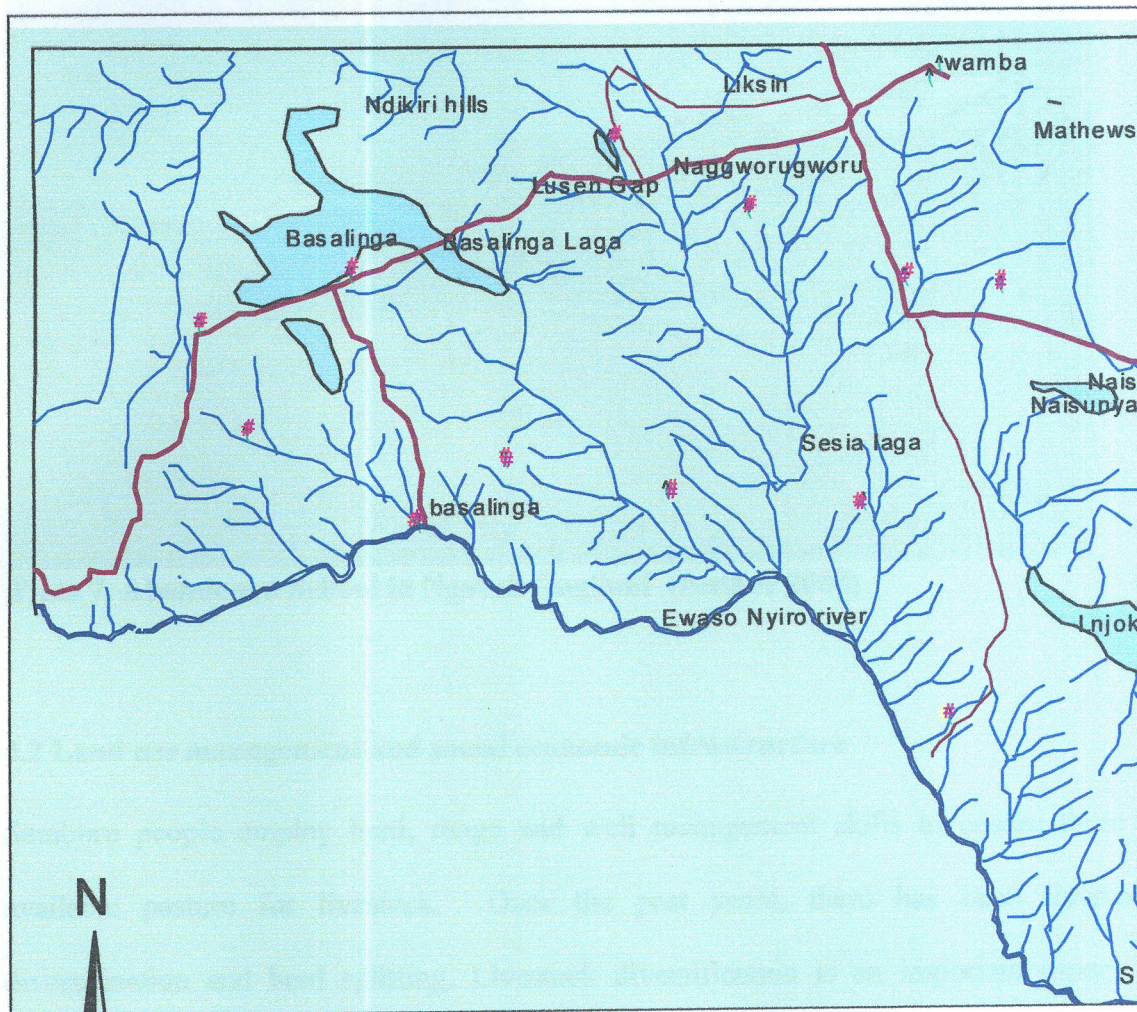


Figure 4.2. Distribution of schools, churches and clinics indicated by the red sharps. (Source: Author 2005)

Table 4.8. Distribution of Schools

Study area	Levels			
	Nursery	1-3 class	1-8 class	Secondary
Ngaloni	4	1	1	0
Ngotuk Ongiloni	4	1	0	0
Basalinga	4	2	1	0

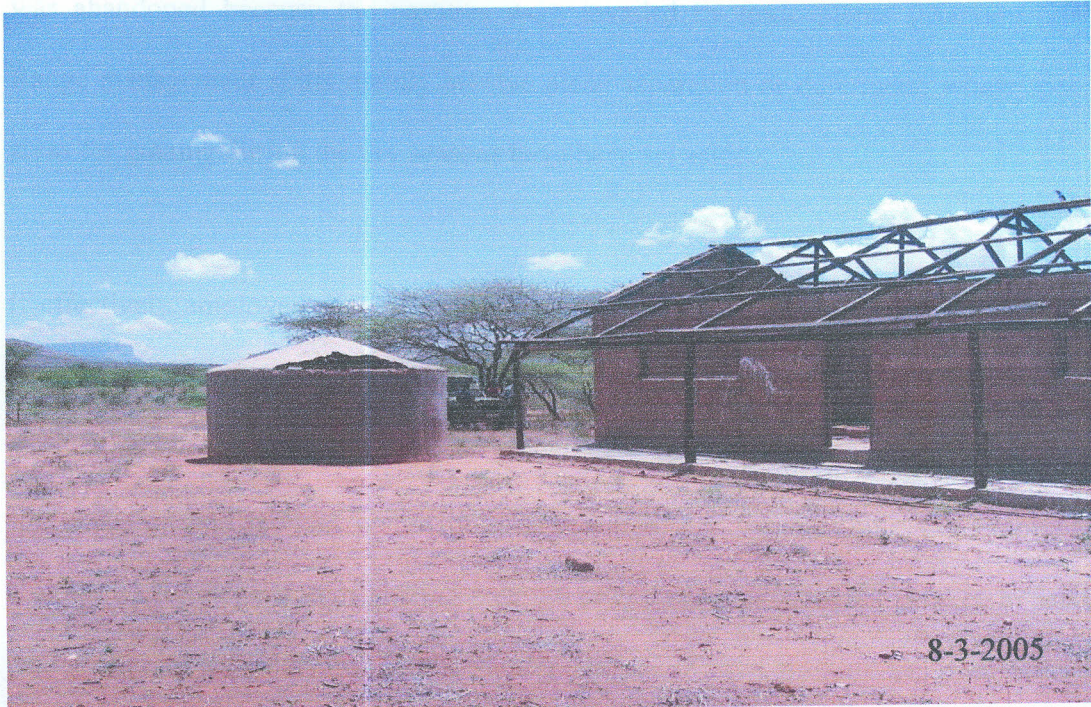


Plate 7. Abandoned School in Ngotuk Ongiloni (Author 2005)

4.2 Land use management and social economic infrastructure

Samburu people employ herd, range and well management skills to ensure there is available pasture for livestock. Over the past years, there has been livestock diversification and herd splitting. Livestock diversification is an important aspect in ensuring that a variety of animals are maintained throughout the year regardless of the harsh conditions in the rangelands. This allows different animals feed at different levels of the resource thus reduces competition.

Traditionally, Samburu community set hilly and flood plain areas for grazing during dry season. The practice of land zone is also common among Sukuma people of the southern Lake Victoria and Barbers of Morocco (Maryam, 2008). These communities reserve

areas for the drought years. A similar practices was carried out by Tilemsi of Mali but was abandoned because the pastures were invaded by toxic plants (Maryam, 2008). Range management skills mainly involve niche separation or deferment, where specific areas for grazing during the dry seasons have been set aside.

If effectively employed, herd diversity and splitting are techniques that maintain long-term productivity of the rangeland. The techniques ensure sustainable livestock production at a comparatively low cost. Herd splitting results in increased niche specialization and reduces competition among livestock for the same vegetation. This also allows for dispersion of grazing pressure as each type of livestock is taken to pasture which suits it best (Maryam, 2008). Similar practice of herd splitting has been observed among Rendille people who herd camels together with sheep and cattle with goats.

Vegetation change is apparent in the study area despite Samburu people having maintained their management skills. From respondent reports, it is notable that the vegetation change has occurred over their life time. However, observation on the *lokere*, an area secured by tree branches in the settlement area for young animals showed vegetation cover contrasting the neighbourhood that were characterized by bare grounds. Furthermore, Ngotuk Ongiloni flood plain was cited to be insecure due to cattle rustling had tall grass compared with vegetation found in flood plain and around social amenities such as schools in other ranches that were characterized by bare grounds where there was intense grazing. FAO (2007) showed that land with intense utilization such as settlement area, watering point, schools and churches were more prone to vegetation change. The

high number of schools at nursery level may be an indication of community changing from nomadic way of life to a more sedentary life style over the past few years.

4.3 Vegetation Clusters

A total of 86 plant species were collected. The life form composed 58% herbs of less than 0.5m tall, 28% Shrubs of height between 0.5 to 5m while trees with height of more than 5 meters accounted 6% of all species collected. Woody vine and herbaceous vines accounted for 7% and 1% respectively (Figure 8 and Table 13). Braun Blanquette cover abundance rating reveals that the vegetation growth form in the study area have the plants with less than half a meter tall having the highest abundance.

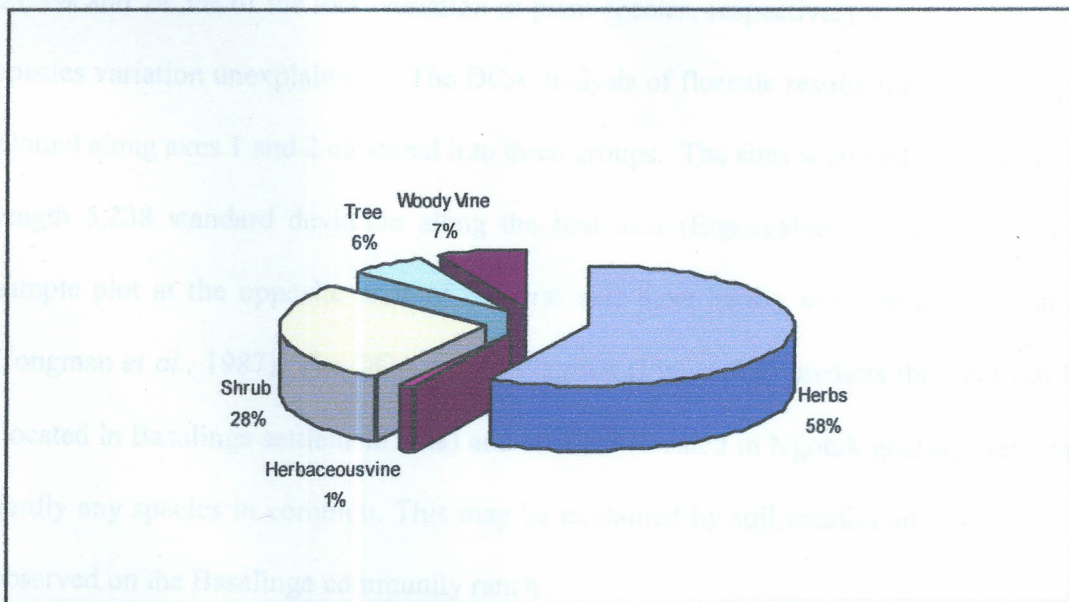


Figure 4.3 Plant Life in Percentage

Table 4.9 Percentages of vegetation life form classes

Life form Count	Layer Type	SYMBOL	Stratum characteristics
5	Tree	T	Tree – any woody plant with a height of more than 5m
51	Herbs	S	Shrub - any woody plant with a height of 0.5m to 5 m
22	Shrubs	H	Plant with a height of less than 0.5m
4	Woody Vine	V _w	Woody vine
1	Herbaceous Vine	W _H	Herbaceous vine

The four Detrended correspondence analysis (DCA) axes explained 12.6%, 18.2%, 21.9% and 24.3% of the total variation in plant species, respectively leaving 30% of the species variation unexplained. The DCA analysis of floristic results for the 29 samples plotted along axes 1 and 2 clustered into three groups. The sites scattered to a gradient of length 5.238 standard deviation along the first axis (Eigenvalues = 0.803) indicating sample plot at the opposite ends of the first axis have hardly any species in common (Jongman *et al.*, 1987). The DCA scatter diagram (Figure 4.4) predicts that plot BASP2 (located in Basalinga settlement area) and NGOP2 (located in Ngotuk grazing area) have hardly any species in common. This may be explained by soil erosion and over grazing observed on the Basalinga community ranch.

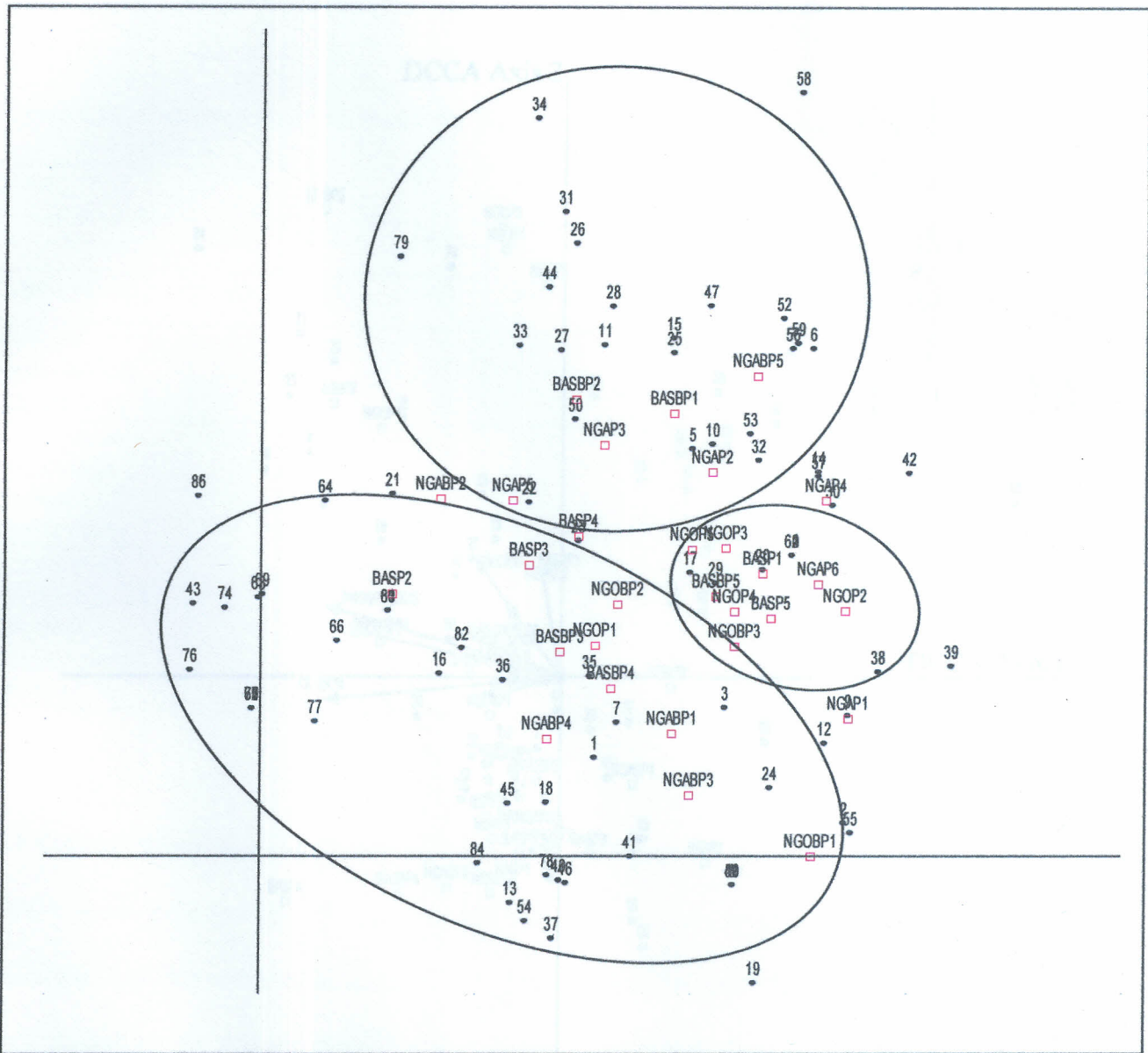


Figure 4.4. DCA scatter diagram. Plots and plant species are indicated by open box and dot respectively

Other plots were assorted in the two clusters. E.g. in cluster 2, plots NGAP3, NGAP2, BASBP1 were on transects on the settlement areas and are clustered together with plot NGABP5, NGOP5, NGOP3 placed on grazing area transect. Floristic clusters reveals that land use zones based on the grazing and settlement areas does not influence the floristic

characteristic of the study area but other factors such as climatic and competition may be responsible for the clustering.

Table 4.10 Comparison of the result for the first four ordination axes of DCA and DCCA

Axes	1		2		3		4	
	DCA	DCCA	DCA	DCCA	DCA	DCCA	DCA	DCCA
Eigen values	.803	.500	.362	.350	.234	.243	.156	.563
Species-environment correlations		.877		.914		.919		.000
Cumulative percentage variance of species data	12.6	7.8	18.2	13.3	21.9	17.1	24.3	25.9
Cumulative percentage of species-environment relation		23.8		23.8		52.0		.0

4.4 Vegetation-Soil Relationship

DCCA result indicated that plant species had a 64.1 % relationship with measured soil variables. The first two axes explained 23.8% and 40.4% of the total variation that could be explained by the soil variables. The DCCA ordination scatter diagram (Figure 4.10) shows DCCA axis 1 as of Sodium-Carbon gradient while axis 2 as Calcium-pH gradient. All sample plots (NGOP1, NGOP2, NGOP3 and NGOP5) in Ngotuk Ongiloni grazing area, had positive relationship Calcium and Sodium unlike plots in grazing area of Ngaloni and Baslinga community ranches.

whose vegetation was not disturbed are clustered together as was the case in the DCA results.

4.5 Discussion on vegetation clustering and vegetation-soil relationship

Detrended correspondence analysis (DCA) of the floristic sample data set reveals a continuous decrease in Eigenvalues for the four DCA axes, an indication that the data collected was well structured (El-Ghani and Marel, 2006). The high Eigenvalues of the first DCA axis indicate a greater proportion of variation in the species composition among the sample stands.

DCA analysis of floristic results for the 29 samples plotted along axes 1 and 2 clustered into three groups. The sites scattered to a gradient of length 5.238 standard deviation along the first axis (Eigenvalues = .803), an indication that sample plot at the opposite ends of the first axis have hardly any species in common (Jongman *et al.*, 1987). Sample plots collected in Ngotuk Ongiloni grazing area, a flood plain whose vegetation was not disturbed (overgrazed) were clustered together. It may be argued then that Ngotuk Ongiloni flood plain had near similar floristic characteristics (Jongman *et al.*, 1987). However, Plot BASP5 and BASB1 though located in Basalinga settlement areas had similar floristic characteristic as Plot BASBP5 located in Basalinga grazing area. It is worth noting that Basalinga grazing and settlement areas had similar observed characteristics of acacia canopy with no undergrowth and open bare land.

The DCCA Eigenvalues were lower than those of DCA analysis (see Table 14 above). El-Ghani and Marel (2006), Franklin and Merlin (1992) and McDonald *et al.*, (1996)

argued that this is an indication that important explanatory variables were not measured and included in the analysis or some of the variations were not explained by the soil chemical variables measured. Therefore, other than soil chemical variables, factors such as soil structure, carrying capacity and climatic variables could be influencing vegetation changes in the study area.

DCCA results revealed that Calcium influences the dissimilar floristic characteristics observed for Plots NGOP2 and BASP2 in DCA results. The similar patterns of DCA and DCCA suggest that sodium-carbon gradient influence the distribution of the floristic characteristic.

Detrended canonical correspondence analysis (DCCA) was used to examine the relationships between plant species and soil chemical variables measured (Ter Braak and Prentice, 1988). DCCA has some advantage over the other ordinations in that it makes the interpretation of the axes easier (Ter Braak, 1986). However, for the species-environment relationship, the first two axes explained more than half (23.8% +40.4%) of the total variation that could be explained by the soil variables. The DCCA ordination scatter diagram (Figure 4.5) shows DCCA axis 1 as of Sodium-Carbon gradient while axis 2 as Calcium-pH gradient. All sample plots (NGOP1, NGOP2, NGOP3 and NGOP5) in Ngotuk Ongiloni grazing area, had positive relationship Calcium and Sodium unlike plots in grazing area of Ngaloni and Basalinga community ranches.

DCCA vegetation-soil correlation result was high (.877, .914, .919) as expected in constrained ordination. The analysis maximizes the relationship between species and environmental variables even for random data (Jongman *et al.*, 1987). Sum of all unconstrained Eigenvalues for both the DCA and DCCA were similar (2.725) as expected in normal (unconstrained) correspondence analysis. DCCA Eigen values are normally lower than Eigen value of DCA when important explanatory variables are not measured and included in the analysis or some of the variations are not explained by the environmental variables measured (Franklin and Merlin, 1992).

From the findings of this study, the following conclusions can be drawn:

- One of the most significant findings in energy than the other is that the people employ rain to herd and water management skills to ensure the availability of forage for their livestock throughout the year. This is due to the fact that there has been an increase in the development of the roads and other infrastructures in the area. The result indicates that despite the high population density being pastoralists, their movement is more and more dependent on the availability of the water resources.
- The Braun-Blanquet cover-abundance index reveals that plants less than a half cover had the highest abundance. It also reveals a clear floristic clustering in the distribution of plant species within each vegetation.
- Detrended canonical correspondence analysis (DCCA) indicated that there is a 68.1% relationship with measured soil variables.
- The sum of all unconstrained Eigen values for both DCA and DCCA were similar and had similar value of 2.725 as expected in normal (unconstrained) correspondence analysis.

CHAPTER 5

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

This study set to; first determine the past and current land use management practices among the Samburu people in context of the social economic infrastructure development in the area. Secondly, determine if there is clustering in the spatial distribution of plant species and finally determine if there is plant-soil relationship in the study area.

From the findings of this study, the following conclusions can be drawn:

- One of the most significant finding to emerge from this study is that Samburu people employ range, herd and wells management skills to ensure there is availability of forage for their livestock throughout the year. The study also shows that there has been an increase in the development of the social economic infrastructures in the area. The result indicates that despite the Samburu community being pastoralists, their movement is more and more constrained by the availability of the social amenities.
- The Braun Blanquette cover abundance rating reveals that plants less than a meter tall had the highest abundance. DCA results confirm floristic clustering in spatial distribution of plant species in Samburu eco-region.
- Detrended canonical correspondence analysis (DCCA) indicated plant species had 68.1% relationship with measured soil variables.
- The sum of all unconstrained Eigen values for both DCA and DCCA in this study had similar value of 2.725 as expected a normal (unconstrained) correspondence

analysis. This implies that important explanatory variables were measured and included in the analysis.

5.2 Recommendations

For further understanding of the land use and vegetation condition in Samburu eco-region, it is recommended that further research be undertaken in the following area;

- There is need to determine the forage value of the vegetation in the study area. How well the available plants provide nutrients to the grazing animals?
- Sedentary lifestyle need to be supported by other benefits obtained from rangeland as current change in land use may not sustainably support pastoralism for long. Studies on payment for ecosystem services need to be explored to support local community
- Government and policy makers should engage the local communities to through training on need to understand the new constitution spirit of benefit sharing with responsibility. This will enable community to participate in conservation efforts as they become beneficiary of the tourism activities in their locality.
- To understand the problem of vegetation change and find solutions deteriorating rangelands, further studies are required on methods to control soil erosion
- Need for further studies on the effectiveness of the other livelihood such as poultry and beekeeping on the study area.

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APPENDICES

APPENDIX 1: INTERVIEW DISCUSSION GUIDE

1. Do you keep any of the following animals? *Tick where appropriate*

Cows

Goats

Donkeys

Camels

Chicken

2. In most cases, who take care of the following animals? *Tick where appropriate*

	Boys	Girls	Morans	Old men	Women	Others
Cows						
Goats						
Donkeys						
Camels						
Chicken						

3. In the following areas (*read out names from the provided topographic map*) which ones do you generally use for

A) Grazing

B) Settlement

4. Are there SPECIFIC PLANTS that are FEWER now than 20 years ago? *Tick where appropriate*

YES, at least one	
NO	

5. Is grazing land BETTER, WORSE, or the SAME as it was 20 years ago?

Tick where Appropriate

WORSE	
BETTER	
SAME	

6. Have any water source dried up completely in the pas 10 or 20 years?

Yes

No

7. Has water availability gotten better or worse over past 20 years?

Better

Worse

8. What are the biggest threats to your water supply ?

Distance to water p

Too many people

Lack of water for people

Lack of water for livestock

Conflict over water for livestock

Other

Conflict over water for people

9. Describe the watering pattern? Watering schedules

APPENDIX 3: DCCA OUT PUT

Program CANOCO Version 4.0 April 1998 - written by Cajo J.F. Ter Braak
Copyright (c) 1988-1998 Centre for Biometry Wageningen, CPRO-DLO
Box 100, 6700 AC Wageningen, the Netherlands.
CANOCO performs (partial) (detrended) (canonical) correspondence analysis,
principal components analysis and redundancy analysis.
CANOCO is an extension of Cornell Ecology program DECORANA (Hill,1979)

For explanation of the input/output see the manual or
Ter Braak, C.J.F. (1995) Ordination. Chapter 5 in:
Data Analysis in Community and Landscape Ecology
(Jongman, R.H.G., Ter Braak, C.J.F. and Van Tongeren, O.F.R., Eds)
Cambridge University Press, Cambridge, UK, 91-173 pp.

*** Type of analysis ***

Model	Gradient analysis		
	indirect	direct	hybrid
linear	1=PCA	2=RDA	3
unimodal	4=CA	5=CCA	6
„	7=DCA	8=DCCA	9
	10=non-standard analysis		

Type analysis number
Answer = 8

*** Data files ***

Species data : SAMSSP
Covariable data :
Environmental data : SAMENV
Initialization file: CANOCO.INI

Forward selection of envi. variables = 0
Scaling of ordination scores = 2
Diagnostics = 3

File : SAMSSP
Title : SAMBURU JAN 2005 VEG DATA
Format : (I5,1X,6(I6,F5.1))
No. of couplets of species number and abundance per line : 6

No samples omitted
Number of samples 29
Number of species 86
Number of occurrences 342

File : SAMENV
Title : SAMBURU SOILS DATA
Format : (I5,1X,4(I6,F9.3))
No. of environmental variables : 8

No interaction terms defined

No transformation of species data
No species-weights specified
No sample-weights specified
No downweighting of rare species

No. of active samples: 29
No. of passive samples: 0
No. of active species: 86

Total inertia in species data=
Sum of all eigenvalues of CA = 6.39776

***** Check on influence in covariable/environment data *****

The following sample(s) have extreme values

Sample Environmental Covariable + Environment space
variable Influence influence influence

2 2 30.9x
9 4 6.3x
15 3 7.5x
24 7 20.1x
25 8 7.7x
26 5 5.4x

***** End of check *****

MESSAGE

No detrending with respect to term AX2*AX3

1

**** Weighted correlation matrix (weight = sample total) ****

SPEC AX1	1.0000								
SPEC AX2	.0043	1.0000							
SPEC AX3	.0692	-.0272	1.0000						
SPEC AX4	.4254	-.0013	.2226	1.0000					
ENVI AX1	.8767	.0000	.0000	.0000	1.0000				
ENVI AX2	.0000	.9140	.0000	.0000	.0000	1.0000			
ENVI AX3	.0000	.0000	.9195	.0000	.0000	.0000	1.0000		
ENVI AX4	.0000	.0000	.0000	.0000	.0000	.0000	.0000	1.0000	
1	.5673	.1558	-.1173	.0000	.6471	.1704	-.1276	.0000	
2	.3724	-.0913	.7561	.0000	.4248	-.0999	.8223	.0000	
3	.1644	.4647	.2875	.0000	.1875	.5084	.3127	.0000	
4	.2105	.1796	-.1179	.0000	.2401	.1964	-.1282	.0000	
5	.1665	.4111	.1128	.0000	.1900	.4498	.1227	.0000	
6	.1883	-.1342	.0619	.0000	.2148	-.1468	.0673	.0000	
7	-.1337	-.0600	.2348	.0000	-.1525	-.0656	.2554	.0000	
8	.5417	.2957	-.0636	.0000	.6179	.3236	-.0692	.0000	

SPEC AX1	SPEC AX2	SPEC AX3	SPEC AX4	ENVI AX1	ENVI AX2	ENVI AX3	ENVI AX4
1	1.0000						
2	.0057	1.0000					

3	.6887	.1372	1.0000					
4	.1192	-.0274	-.1961	1.0000				
5	.6811	.1428	.8113	.0682	1.0000			
6	.4478	.0863	.3807	.3087	.5336	1.0000		
7	.2022	.0719	.3017	-.1944	.2463	.1869	1.0000	
8	.1230	.2511	-.1056	.5927	-.0062	.2263	-.1519	1.0000

1 2 3 4 5 6 7 8

N	name	(weighted) mean	stand. dev.	inflation factor
1	SPEC AX1	.0000	1.1407	
2	SPEC AX2	.0000	1.0940	
3	SPEC AX3	.0000	1.0876	
4	SPEC AX4	.0000	1.0000	
5	ENVI AX1	.0000	1.0000	
6	ENVI AX2	.0000	1.0000	
7	ENVI AX3	.0000	1.0000	
8	ENVI AX4	.0000	.0000	
1	1	3.3150	3.0509	2.3861
2	2	.6613	.2941	1.2098
3	3	.1077	.2481	4.3450
4	4	13.9040	11.2588	2.1131
5	5	21.4753	17.9019	4.0650
6	6	6.9845	.9051	1.6292
7	7	12.8030	27.9715	1.1620
8	8	2.3136	2.7575	1.8541

**** Summary ****

Axes	1	2	3	4	Total inertia
Eigenvalues :	.500	.350	.243	.563	6.398
Species-environment correlations :		.877	.914	.919	.000
Cumulative percentage variance					
of species data :	7.8	13.3	17.1	25.9	
of species-environment relation:	23.8	40.4	52.0	.0	

Sum of all unconstrained eigenvalues 6.398

Sum of all canonical eigenvalues 2.105

APPENDIX 4: DCA OUT PUT

Program CANOCO Version 4.0 April 1998 - written by Cajo J.F. Ter Braak
Copyright (c) 1988-1998 Centre for Biometry Wageningen, CPRO-DLO
Box 100, 6700 AC Wageningen, the Netherlands.
CANOCO performs (partial) (detrended) (canonical) correspondence analysis,
principal components analysis and redundancy analysis.
CANOCO is an extension of Cornell Ecology program DECORANA (Hill,1979)

For explanation of the input/output see the manual or
Ter Braak, C.J.F. (1995) Ordination. Chapter 5 in:
Data Analysis in Community and Landscape Ecology
(Jongman, R.H.G., Ter Braak, C.J.F. and Van Tongeren, O.F.R., Eds)
Cambridge University Press, Cambridge, UK, 91-173 pp.

*** Type of analysis ***

Model Gradient analysis
indirect direct hybrid
linear 1=PCA 2=RDA 3
unimodal 4=CA 5=CCA 6
„ 7=DCA 8=DCCA 9
10=non-standard analysis
Type analysis number
Answer = 7

*** Data files ***

Species data : SAMSSP
Covariable data :
Environmental data :
Initialization file: CANOCO.INI

Number of segments = 26
Nonlinear recaling of axes
Rescaling threshold = .00
Number of axes in biplot = 2

Diagnostics = 2

File : SAMSSP
Title : SAMBURU JAN 2005 VEG DATA
Format : (15,1X,6(16,F5.1))
No. of couplets of species number and abundance per line : 6

No samples omitted
Number of samples 29
Number of species 86
Number of occurrences 342

No transformation of species data
No species-weights specified
No sample-weights specified
No downweighting of rare species

No. of active samples: 29
 No. of passive samples: 0
 No. of active species: 86

Total inertia in species data=
 Sum of all eigenvalues of CA = 6.39776

**** Summary ****

Axes	1	2	3	4	Total inertia
Eigenvalues	: .803	.362	.234	.156	6.398
Lengths of gradient	: 5.238	3.498	2.671	2.460	
Cumulative percentage variance of species data	: 12.6	18.2	21.9	24.3	
Sum of all unconstrained eigenvalues					6.398

APPENDIX 5: SPECIES LIST

Species DCCA number	SPECIES CODE	Local Name	SPECIES
1	BASBP1H1		
2	BASBP1H2		
3	BASBP1H3		
4	BASBP1H4		
5	BASBP1H5		
6	BASBP1H6		
7	BASBP1VW1		
8	BASBP2H2		
9	BASBP2VW1		
10	BASBP3H1		
11	BASBP3H2		
12	BASBP3T1		
13	BASP2T1		
14	BASP2T2		
15	NGABP1H2		
16	NGABP1H3		
17	NGABP1S1		
18	NGABP2H2	narturot	
19	NGABP2H5		
20	NGABP3H1		
21	NGABP3S1		
22	NGAPIH1	nairobaba	Leonitis sp.
23	NGAPIH2	narerrepicho	Achyranthes aspera
24	NGAPIH3		
25	NGAPIH4		Sansevieria volkensii
26	NGAPIH5		Reullia patula
27	NGAPIH6	naropili	Becium filamentosum
28	NGAPIH7		Ruellia patula
29	NGAPIH8	ndapash	Hibiscus caryphyllas
30	NGAPIH9		
31	NGAPIS1		
32	NGAPIS2		Abutilon figarianum.
33	NGAPIS3		solanum incanum
34	NGAPIS4		Solanam reinschii
35	NGAPIS5	naiyobi	Abutilon sp.
36	NGAPI1T1	ltepes	Acacia tortilis
37	NGAPI1VW1		Salvadora persica
38	NGAPI1WH1		
39	NGAP2H1		Aristida kenyesis
40	NGAP2H2		Eragrostis sp.
41	NGAP2H3	lmarag	Brepharis edulis
42	NGAP2H4		Tetrapogon cencrifomis

43	NGAP2H5		Solanam coagulans
44	NGAP2H6		Sericocompisis hildebrandtii
45	NGAP2H7		Ocimum americanum
46	NGAP2H8		Sericocompisis hildebrandtii
47	NGAP2S1	lokitengi	Ipomea spathulata
48	NGAP2S2		Hibiscus micranthus?
49	NGAP2VW1		
50	NGAP3H1		
51	NGAP3H2	suchai kinilnkoko	Barleria sp.
52	NGAP3H3		
53	NGAP3S1	ngamei	Asparagus africana?
54	NGAP3VW1		
55	NGAP4H1		Indigofera spinosa
56	NGAP4S1		Solanam reinschii
57	NGAP5H1		
58	NGAP6H1		
59	NGAP6H2		
60	NGAP6H3		
61	NGAP6S1		Boscia sp.
62	NGOP1H1		
63	NGOP1H2		
64	NGOP1H3		
65	NGOP1S1		
66	NGOP1S2		
67	NGOP1S3		
68	NGOP1S4		
69	NGOP1S5	lchurai	
70	NGOP1S6	itarai	indigofera arrecta
71	NGOP1S7		
72	NGOP1S8		
73	NGOP1S9		
74	NGOP1T1	ltepess	
75	NGOP1vw1		
76	NGOP2H1	lemonenei	
77	NGOP2H2	loipip	
78	NGOP2H7		
79	NGOP3H1	nchenebor	
80	NGOP4H1	nayasio	
81	NGOP4H2		
82	NGOP4H3	lekindogo	
83	NGOP4H4		
84	NGOP4H5	longorereki	
85	NGOP5S1	limunyanyi	
86	NGOP5S2	nchenienkare	