LAND USE CHANGE AND ITS EFFECTS ON SOIL AND VEGETATION DEGRADATION IN KIBWEZI DISTRICT.

BY

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A thesis submitted in partial fulfillment for the degree of Master of Science in Biology of Conservation, University of Nairobi, 2006

DECLARATION

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

Muthoni .... 29/03/2010..........

Purity Muthoni Njoki **Date**

This thesis has been submitted for examination with our approval as the University supervisors.

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DEDICATION

This thesis is dedicated to my parents, Mr. Bramwell Njagi and Mrs. Mary Njagi for seeing me this far in education, and to my husband Mr. Samuel Kanyari, our son Elian Njori and daughter Sheila Wangechi.

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LIST OF ABBREVIATIONS

PCQ	Point Centered Quarter
ANOVA	Analysis of Variance
ASALs	Arid and Semi-Arid Lands
KMC	Kenya Meat Commission
GPS	Global Positioning System
GoK	Government of Kenya

ABSTRACT

Land degradation is caused by removal of vegetation cover and subsequent fertility loss. Frequent assessment of land use changes and their effects on soil and vegetation in ranches is critical to their conservation. This study, carried out in four selected ranches in Kibwezi District is important because previous studies in the area have mainly dwelt on soil erosion and no research has been done on effects of land use changes on soil quality in terms of organic carbon, total nitrogen and vegetation cover. The objectives of the study were to determine plant species density and diversity; assess soil quality in terms of total nitrogen content and organic carbon; and determine the relationship between abundance of plant species and soil characteristics to ascertain levels of soil and vegetation degradation. This study was intended to shed light on the impacts of land use changes on the productivity of rangelands in relation to soil quality and vegetation cover.

Transects measuring 200m traversing cultivated farms and grazing areas were established within the study sites namely Kiu, Ngaamba, Ulu/Aimi and Konza South ranches. Data was collected in three seasons. Phase one and three during the wet seasons and phase two in the dry season. Trees and herbaceous plants species were sampled using the Point Centered Quarter method (PCQ) and $1m^2$ quadrat respectively. Where shrubs were encountered a 5m x10m quadrat was used. Soil samples were collected from a monolith measuring 10cm x 10cm x 30cm at the centre of each $1m^2$ quadrat.

Total nitrogen was determined using the Wet Digestion method, Organic carbon using Walkley-Black method and soil texture by Bouyoucos or hydrometer method. Soil moisture was determined using Anderson and Ingram method while for soil pH 50ml of deionised water was added to 20 ± 0.1g soil measured on 2.5:1 water to soil suspension.

A total of five species belonging to four families were recorded during the study. *Acacia tortilis* had the highest density across seasons (291.4 trees per hectare) and *Lannea schwanfurthii* (8.25 trees per hectare) the least. Diversity indices of trees revealed a significant difference in species richness among the ranches ($F_{[3, 16]} = 5.066$, $P < 0.05$) with Konza ranch recording the highest diversity index. ANOVA test revealed a significant difference in the mean abundance of tree stumps among the ranches ($F_{[3, 6]} = 159.458$, $P < 0.05$) where Ulu/Aimi ranch contributed the highest number of tree

stumps in the study area while Ngaamba had the least. ANOVA test revealed a significant difference in the mean abundance of shrubs species among the ranches ($F_{[3, 126]} = 0.993$, $P < 0.05$) with Ulu ranch recording the least abundance. There was also a significant difference in the mean abundance of grass species among the ranches ($F_{[3, 169]} = 21.504$, $P < 0.05$).

Results of ANOVA test revealed significant differences in the mean abundance of forbs species among the ranches ($F_{[3, 214]} = 5.792$, $P < 0.05$). ANOVA test results for soil analysis revealed no significant differences between the ranches in terms of both total nitrogen ($F_{[3, 5]} = 3.262$, $p > 0.05$) and organic carbon ($F_{[3,5]} = 1.763$, $p > 0.05$) in the soil. The broad ratings of carbon and nitrogen confirmed that the four ranches had very low levels of both organic carbon and total nitrogen.

Both grass and forbs species had no significant correlations with pH ($r = 0.24$, $p > 0.05$ and 0.2, $p > 0.05$ respectively), while shrubs showed significant correlation ($r = -0.4$, $p < 0.05$). Shrubs ($r = 0.61$, $p > 0.05$; 0.42, $p > 0.05$ and 0.06, $p > 0.05$ respectively) and forbs ($r = -0.02$, $p > 0.05$; -0.18, $p > 0.05$ and -0.17, $p > 0.05$ respectively) had no significant correlation with organic carbon, total nitrogen and moisture respectively while grass had a significant correlation with moisture (-0.53, $p < 0.05$) but no significant correlation with organic carbon ($r = -0.35$, $p > 0.05$) and total nitrogen (-0.25, $p > 0.05$).

The results of the study showed that there was a decline in plant species diversity, this probably being as a result of increased human activities in the ranches. It is therefore important to sensitize farmers on the need to plant and maintain trees as they play an important role in recycling leached nutrients and tapping new nutrient stocks from deeper soil layers. Cover crops should also be planted on the terraces to increase vegetation cover.

CHAPTER ONE

INTRODUCTION, LITERATURE REVIEW, JUSTIFICATION AND OBJECTIVES

1.0 Introduction

Kenya's land surface area is largely (80%) Arid and Semi-Arid Lands (ASALs) that support about two-thirds of the country's livestock and wildlife, the cornerstone of the tourism industry (Government of Kenya, 1990). The South Kenya rangelands hold some of country's major wildlife protection areas such as Tsavo National Park; Shimba Hills National Reserve; Chyullu Hills National Reserve and Kiboko National Reserve. However in the past two decades the rangelands, which include Kibwezi district, have undergone rapid land use changes characterized by sub-division of communal group ranches and fragmentation of large land parcels. Coupled with this is a rapidly increasing human population and expanding cultivation (Kimani & Pickard, 1998). This is to a large extent attributed to immigration of farming communities into semi-arid areas from the congested high potential areas (World Bank, 1994). The displaced and immigrant populations are settled on relatively small land units in settlement schemes.

Different types of land use have varying impacts on the vegetation such as encroachment of bushes; spread of unpalatable grass species; replacement of perennial grasses by annual herbs and loss of woody layer. In Kenya trees are extensively used for fuel and construction. However, closed canopy forests cover less than 3% of the country, highlighting the importance of the ASALs wood layer. Among the many tree uses in the study area are charcoal, wood and souvenir production which directly generates income and employment (Marshall & Jenkins, 1994). The charcoal is consumed in urban centers especially Nairobi while the souvenirs are sold in the tourism sector (GoK, 1994).

Land degradation is caused by removal of vegetation cover and subsequent fertility loss (Negassi, Bein, Ghebru & Tengnas, 2002). Loss of vegetation threatens biodiversity and habitats for other species. Removal of the protective cover of vegetation, in turn can be driven by a number of factors, alone or in combination, such as tillage for agriculture; removal of crop residues for livestock feeding /construction use; deforestation for construction materials (Secretariat of the Convention on Biological

Diversity, 2005). Level of organic matter in the soil influences availability of nutrients and its depletion results in loss of nutrients through leaching. Land use changes, alter the pattern of decomposition, nutrient release and affects the relative proportions of soil organic matter. This may be due to changes in soil structure caused by continuous cultivation. The magnitude of this loss depends on intensity of cultivation and the quantity of organic residues returned to the soil (Kenya Agricultural Research Institute, 2003).

Clearing land for cultivation and preparing soil for planting presents a major external event that radically re-structures and disrupts a previously stabilized ecosystem. The disturbed ecosystem immediately begins a process of ecological succession where plant species adapted to the sunny conditions and the broken soil rapidly invade the site and become established. Within any community some species may decrease abundance over time, or they may vanish from the ecosystem all together. Similarly, over time, other species within the community may become more abundant, or new species may invade the community from adjacent ecosystems. In semi-arid areas of Kenya several invasive species that have been identified include *Ipomea* species, *Lantana camara* and *Tagetes minuta* (Elizabeth & Scott, 2000).

Four ranches, Konza South, Ngaamba, Kiu and Ulu were for decades managed as livestock enterprises, with a ready market at the Kenya Meat Commission (KMC). The collapse of KMC and down turn in the agricultural and livestock sectors over the past two decades rendered ranching an unprofitable business and a number of ranches such as Ngaamba (3240 acres) and Ulu (12,200 acres) were subdivided and completely settled by cultivators. In Konza South Ranch, the remaining 8145 acres are being subdivided among the shareholders. Kiu ranch, which covers 7000 acres is partly subdivided and is currently being settled.

Population growth, poor livestock sector returns, political expediency, livelihood and demographic pressures have led to subdivision. This directly determines the amount of pressure exerted by farmers on soil and vegetation. It is thus important to know the quality of soil in terms of organic carbon and total nitrogen (constituents of organic matter) and diversity of plant species to understand the effects of cultivation and make decisions on land use changes.

1.1 Literature review

1.1.1 Land use trends in Kenya Arid and semi-arid lands

Land use changes in the study area are mainly related to changes in the tenure system, increasing cultivation by pastoralists and immigrant farmers and delineation of conservation areas. The range Management Division was created in 1963 and it quickly embarked on designing a program that would commercialize the nomadic subsistence production system of pastoral communities through the group ranch concept. The group ranch concept was to -reduce stocking rates hence land degradation, facilitate the development of infrastructure such as dips and boreholes through loans and guard against landlessness among the pastoralists (Galaty, 1980). The concept was welcomed by pastoralists because by getting group title deeds their land was protected against encroachment and the risk of further loss to game parks.

By 1980's it was evident that the group ranch concept had failed due to poor management, the desire by members to have individual title deeds and adjudication to ecological and economically unviable units. Sub-division commenced in the early 1980's and by 1998 over 20% of the group ranches had finalized sub-division and many more were in various stages of sub-division (Kimani & Pickard, 1998). Sub-division has been followed by rapid fragmentation as individual pastoralists divided and sold their allocation parcels to mainly new comers. With sub-division and fragmentation the median plot sizes have decreased while cultivation has increased. The rate of decline in plot size as fragmentation continues is related to the distance of the area from Nairobi, annual rainfall and number of years since sub-division (Kimani & Pickard, 1998).

Establishment of settlement schemes in semi-arid areas by the government to settle landless people mainly from highly potential areas also plays a critical role. One such scheme is Ulu settlement scheme which is part of the investigation in this study.

1.1.2 Vegetation of semi-arid areas

Vegetation changes in semi-arid areas have direct impacts on species composition. The mechanisms and factors that govern vegetation changes under different environments are still poorly understood especially in African drylands. The era of intensive research in vegetation community dynamics was initiated by Clements when he pioneered the organismic view of plant communities in his manuscript on plant succession. Gleason (1926) who advocated the individualistic view published early objections to the Clements view. Connell & Slayter (1977) suggested three models of seral sequence in succession, labeled 'facilitation', 'tolerance and 'inhibition'. Due to poor understanding of mechanisms responsible for vegetation change, confusion surrounds the definition and application of critical terms such as 'degradation' and 'carrying capacity' (Behnke, Scoones & Kerven, 1993).

The mechanism that govern shrubs versus grass balance in savanna ecosystems have been the subject of a lot of debate. Bush encroachment, replacement of perennial grasses by annuals and land bareness are factors that have rendered wide areas of African drylands almost useless to livestock production (Pratt & Gwyenne, 1977; Archer, Boutton & Hibbard, 2000). Several mechanisms have been suggested as being responsible for bush invasion; for example Sudan Government, 1944 hypothesized a Grass-Acacia cycle which entailed the existence of natural cycles of 'trees' and grasses'. Commonly the increase in shrubs is thought to be a result of the physical effects of herbivory and fire (Heady, 1975). The two layered model (Skarpe, 1990) has also been used to explain tree to grass balance. In this theory, the relative availability of soil moisture and nutrients is responsible for increase of shrubs where grasses have been depleted by over-grazing.

The role of soil moisture has been shown to be the most important factor governing the structure and function of savannas (Walker, Ludwing & Holling, 1981). In other cases cultivation activities have also been shown to alter vegetation structure (Reid, Wilson, Krusker & Woudyalew, 1997). After disturbance in semi-arid ecosystems recovery is slow especially under the recurring effects of drought and heavy grazing (Mworia, Mnene, Musembi & Reids, 1997).

In grasslands, as in most plant community types, soil disturbance creates openings for establishment, frequently of weedy or ruderal species. Where such disturbance has long been a component of the ecosystem, there is likely to be a substantial fraction of the flora that is specialized or adapted for establishment there. Thus in the Mediterranean region, where human agricultural and other activity has long created such soil disturbance, there is a large and successful group of weedy species (Naveh, 1967; Hobbs & Hopkins, 1990). Plowing is said to diminish species richness, especially that of dicots, in lowland grasslands (Fuller, 1987). Disturbance may act primarily by providing a rougher surface on which seeds can lodge (Hobbs & Atkins, 1988).

The densities of woody species in heavily grazed areas were attributed to the effects of herbivory and probably lack of fire. Fire has been shown to alter vegetation structure in Southern Kenya rangelands (Coughenour & Ellis, 1993). Herbivore pressure also changes the composition of herbaceous layer favoring unpalatable and chemically defended species (Augustine & McNaughton, 1998). Beneficial effects of trees in drylands have been documented (Kinyamario, Trlica & Njoka, 1995; Belsky, Amundson, Duxbury, Riha, Ali, & Mwonga, 1989). They include improved microclimate leading to increased biomass production of grasses under their canopy in semi-arid lands. They also recycle leached nutrients, tap new nutrient stocks in deeper soil layers and build-up a nutrient pool for the following cropping period (Schmohl, 2003).

1.1.3 Effects of cultivation on soil quality in terms of organic carbon and total nitrogen

Inappropriate cultivation has been cited as one of the principle causes of deterioration in rangeland conditions in Eastern Africa (Herlocker, 1999). Expansion of cultivating farms fragments rangeland landscapes, when farmers convert rangeland into cropland. The on-going sub-division of group ranches into small individual ranches of between 10 and 60 ha has had a negative impact on the vegetation resources.

Cultivation is practiced for numerous reasons and has a myriad of consequences. Cultivation is undertaken for weed control; to increase water and air permeability; to improve seed- zone micro environment; to incorporate fertilizers, pesticides, crop residues, manures, and other amendments into the soil; and for other specialized reasons. Seldom is tillage practiced for the direct enhancement of nutrient availability, even though this is frequently a major consequence of such activity. However, the direct effects of cultivation are frequently factors that help to regulate soil nutrients availability (Clark & Rosswall, 1981).

Cultivation usually affects soil water content by several mechanisms. Stirring the soil during cultivation increases the surface area of soil particles and aggregates exposed to the soil-atmosphere interface thereby increasing the potential for evaporation and water loss (Larson & Gill, 1971).

Soil water content affects nitrogen-availability by affecting microbial activity and the transport of soluble nitrogen-containing compounds. Generally, microbial activity increases as soil water content increases from approximate wilting point to near field capacity, and then decreases as saturation is approached (Campbell, 1978; Sommers & Biederbeck, 1973). However, different groups of microorganisms predominate at different soil water tensions. Actinomycetes and fungi are most common in drier soils.

Placement of residues with respect to the soil surface is normally achieved through tillage. With the wide variety of cropping systems and tillage implements in use, a number of methods of residue placement may be encountered. These range from no residues returned (harvested for food, feed or fuel, or burned), through complete incorporation (mould-board ploughing) or partial incorporation (discs and chisels), to no incorporation (subsurface tillage and, ultimately, no tillage). Thus, both the position and the quantity of residues are affected by the tillage practices employed. These different methods of handling residues affect the availability of nitrogen (Power & Legg, 1978).

The consequences of continued complete removal of crop residues, without returning significant quantities of organic materials or nitrogen fertilizers, are evident from the history of early agricultural civilizations. Complete residue removal has been practiced in parts of North Africa, Western Asia, and elsewhere for centuries, and the accompanying soil deterioration is well known. It is evident from these experiments, as well as from numerous field experiments, that continued removal of crop residues depletes the soil organic nitrogen reservoir, and results in eventual loss of productivity (Clark & Rosswall, 1981).

The total nitrogen in the soil ranges from 0.02% to more than 2.5% in peat and 0.02% to 0.4% in plough layer of most cultivated soils (Brady, 1990). Nitrogen is an essential nutrient element for plant growth and therefore needed in adequate supply for normal development of crops. However, nitrogen is the most deficient nutrient in cultivated soils (Jones, 1982), the element that most frequently limits yield in the tropics (Sanchez, 1976) and generally the first element to become deficient in semi arid and arid regions (Hagin & Tucker, 1982). Nitrogen usually occurs in small amounts ranging from 0.02 to 0.4% by weight in the plough layer of majority of cultivated soils (Barber, 1984). Unfortunately, most of this nitrogen is not available to crops at any one particular time because most of it is organically bound (Jones, 1982).

Generally, soil organic matter and organic nitrogen content decreased for the first 25 to 50 years after natural grasslands were put under cultivation in Mississippi. The rate of decrease usually depended upon the cropping system and tillage practices used (Bauer & Kucera, 1978).

The amount of organic carbon in the soil is very variable. Climate and vegetation are the most important factors affecting the soil organic carbon content under natural conditions (Stevenson, 1974). Organic carbon in the soil is a major factor contributing to aggregation of soil particles and favours soil structure by increasing total porosity and percent of macro-pores, decreases crust formation and reduces susceptibility to erosion (Sanchez, 1976).

Cunningham (1963) pointed out that organic carbon in tropical soils under forest is delicately balanced; the continuous addition of fresh material being offset by decomposition. Exposure of soil due to vegetation removal reduces organic carbon. The decline can greatly be attributed to two cases. First, clearing and cultivation of land results in reduced rate of addition of vegetation organic material (Greenland & Nye, 1959) and secondly, the rate of decomposition of the soils organic carbon is accelerated as a result of a combination of factors favoring increased mineralization after clearing and cultivation (Lal, Wilson & Okigbo, 1979). It has been confirmed that sites with abundant vegetation have relatively more organic matter. Also trees/bush sites have consistently higher organic content, while bare ground has the least (Kironchi, 1992).

1.1.4 Justification

Research work done in the Athi-Kapiti plains, mainly emphasizes on livestock, wildlife and overgrazing. Less work has been done in the Kapiti Plains and concentrated mainly on effects of grazing and cultivation on soil erosion in the Machakos hills (Moore, 1979). Gachimbi (1990) conducted similar research in Kibwezi and dwelt more on soil conservation techniques to prevent soil erosion.

Little attention has been paid to effects of land use changes on soil quality and plant species abundance and diversity. This study was intended to shed light on the impacts of land use changes on the productivity of rangelands in relation to soil quality and vegetation cover. Nitrogen and carbon humus is important in aggregation (structure formation) and increases water holding capacity of the soil (Landon, 1984).

The study focused on Ulu, Ngaamba, Kiu and Konza South ranches due to their transformation from commercial ranching to agro-pastoralism at different times and therefore the quality of soil and plant species diversity was assumed to differ with time of transformation. The plant species diversity and soil quality are important aspects in decision making towards future management options of the remaining ranches as well as management interventions towards the effects that might result from the human activities in the study area, following the transformations.

1.1.5 Objectives: The objectives were to determine:

1. The diversity of plant species in the cultivated farms and the grazing area, and tree density in the four selected ranches in Kibwezi District.
2. The soil quality in terms of organic carbon and total nitrogen content in the four ranches.
3. If a relationship exists between richness of herbaceous plants species and soil characteristics.

1.1.6 Hypotheses

1. Diversity of plant species differ significantly in the cultivated farms and the grazing areas.
2. Soil quality in terms of organic carbon and total nitrogen content varies among the four selected ranches.

CHAPTER TWO

THE STUDY AREA

2.1 Physical location

The study was conducted in Kilome Division of Kibwezi District in Eastern Province, Kenya. The area is situated between 37^0 9' E longitudes and 1^0 38'S latitude. The mean altitude is 1837m above sea level. The study sites which included Kiu, Ngaamba, Konza South ranches as well as Ulu settlement (Figure 1), are located around Salama town which is about 150km South East of Nairobi along Mombasa road.

2.2 Geology and Soils

The physiography of the study area is strongly influenced by the geology. The distribution of soil types is largely determined by parent material and physiography. Soils are Ferral-Chromic Luvisols (Touber, 1983) which are well drained, moderately deep, dark reddish brown soils, with well developed A-horizons. The A-horizons have a characteristic dark reddish brown colour and sandy clay loam to sandy clay texture (soil analysis results). The major land form in the study area includes Kyundu hill in Konza South ranch and Mawa hill in Ngaamba ranch which are highland ranches. Kiu ranch and Ulu settlement are in lowland areas.

2.3 Climate

Rainfall in the study area is bimodal with long rains from March to May and short rains from November or December to early January (Kenya Meteorological Department), as illustrated in Figure 2. The short rains are more reliable in time than long rains and therefore most important. There is a lot of variability in rainfall amounts both in time and space and its reliability is low (Okoola & Ambenje, 2003). In the tropics a "wet" month has been defined as that receiving at least 50mm of rainfall with high-rainfall months defined as those months receiving more than 200mm.

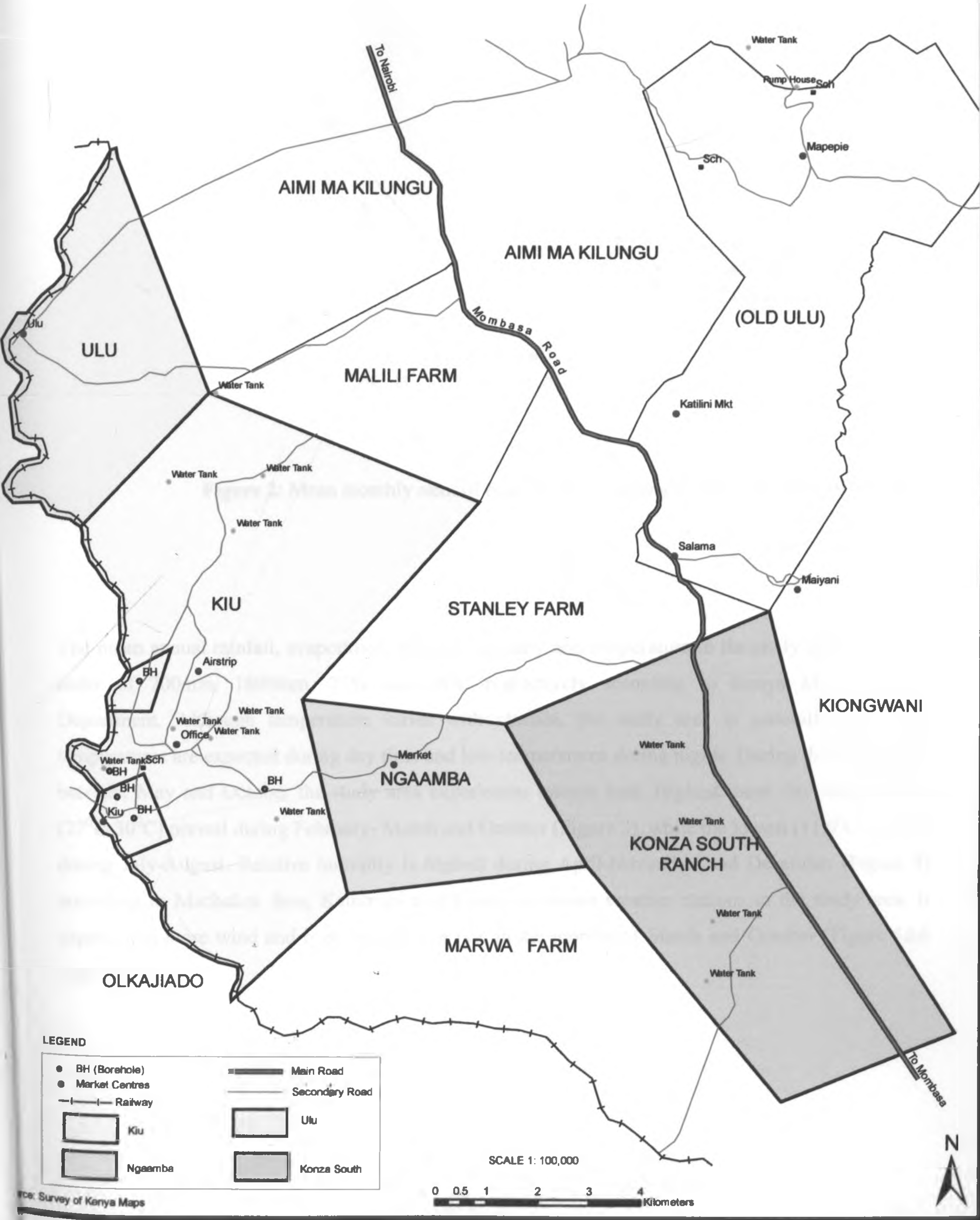


Figure 1: Map of the study sites

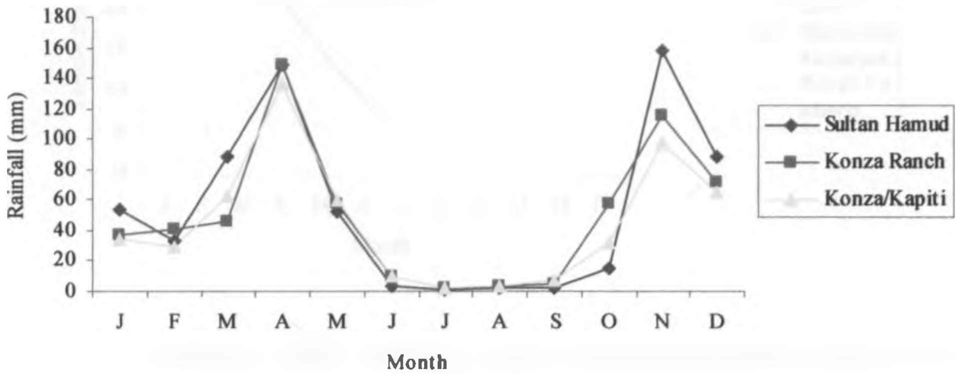


Figure 2: Mean monthly rainfall from weather stations in the study area (1978-2007)

The mean annual rainfall, evaporation, relative humidity and temperature in the study area are in the order of 700mm, 1800mm, 77% and 26^0C respectively according to Kenya Meteorological Department. Although temperature varies with altitude, the study area is generally hot. High temperatures are expected during day time and low temperatures during nights. During the dry periods between May and October the study area experiences intense heat. Highest mean day temperatures (27^0C-30^0C) prevail during February- March and October (Figure 3), while the lowest (11.9^0C-12.4^0C) during July-August. Relative humidity is highest during April-November and December (Figure 4) according to Machakos dam, Katumani and Kampi ya mawe weather stations in the study area. It experiences more wind and high evaporation rate in the months of March and October (Figure 5&6 respectively).

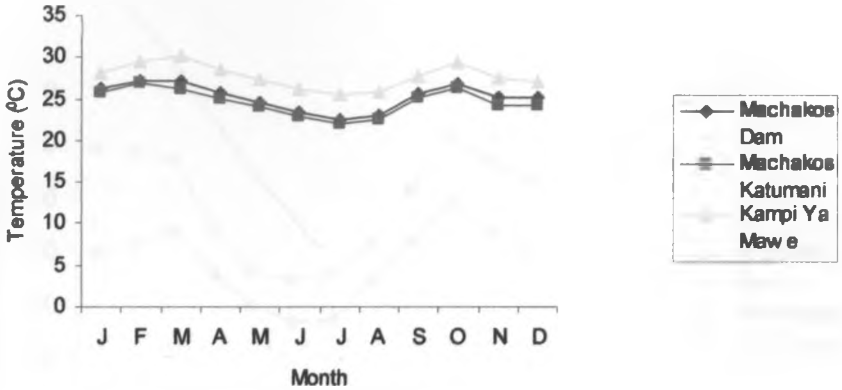


Figure 3: Mean monthly temperature from weather stations in the study area (1972-1980)

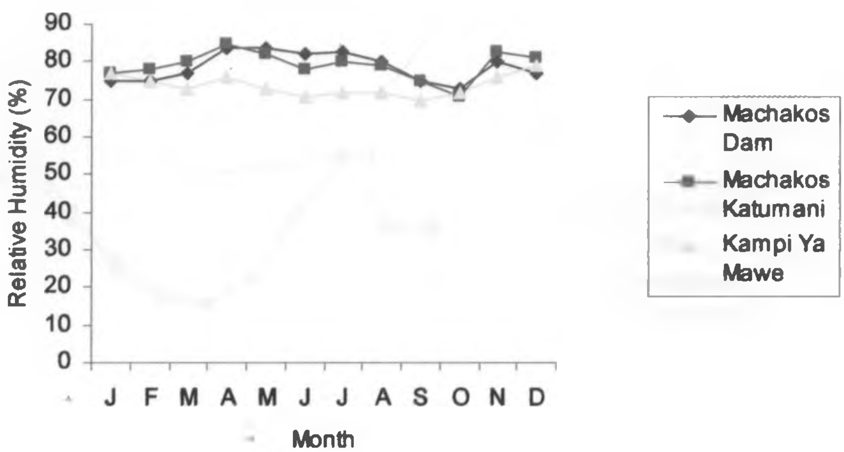


Figure 4: Mean monthly relative humidity from weather stations in the study area (1972-1980)

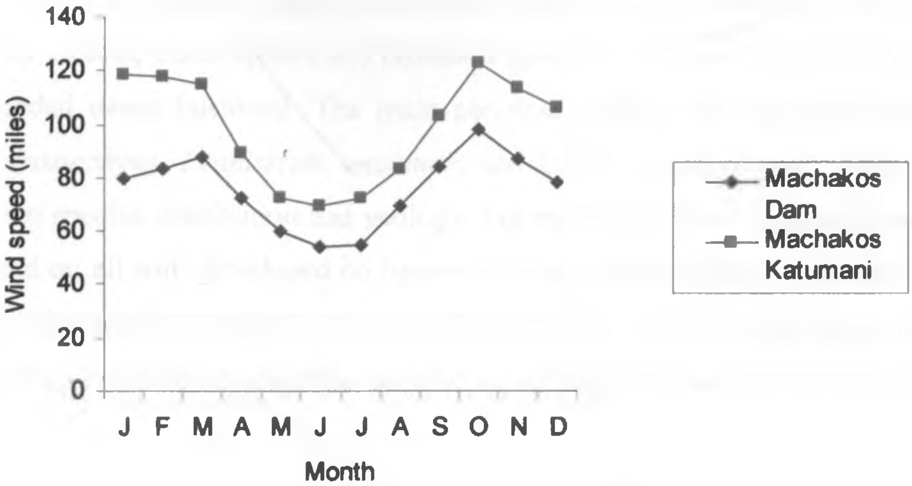


Figure 5: Mean monthly wind run from weather stations in the study area (1974-1980)

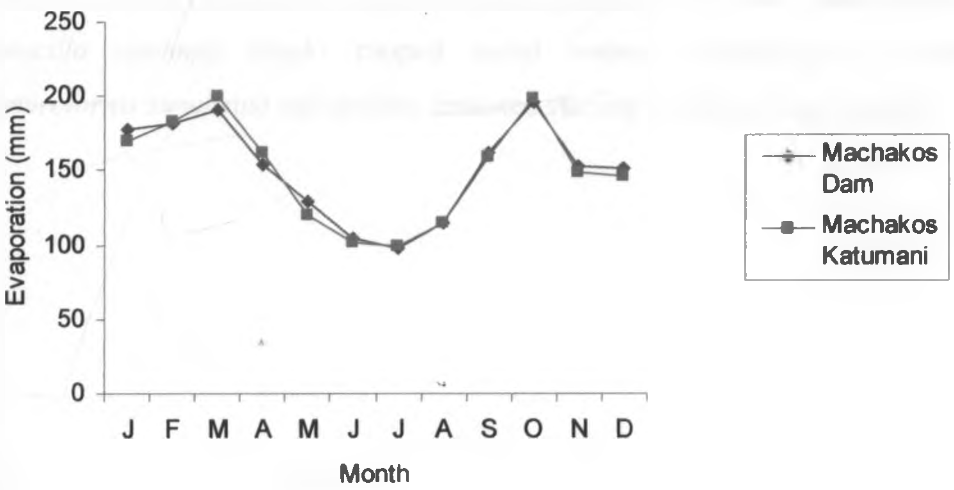


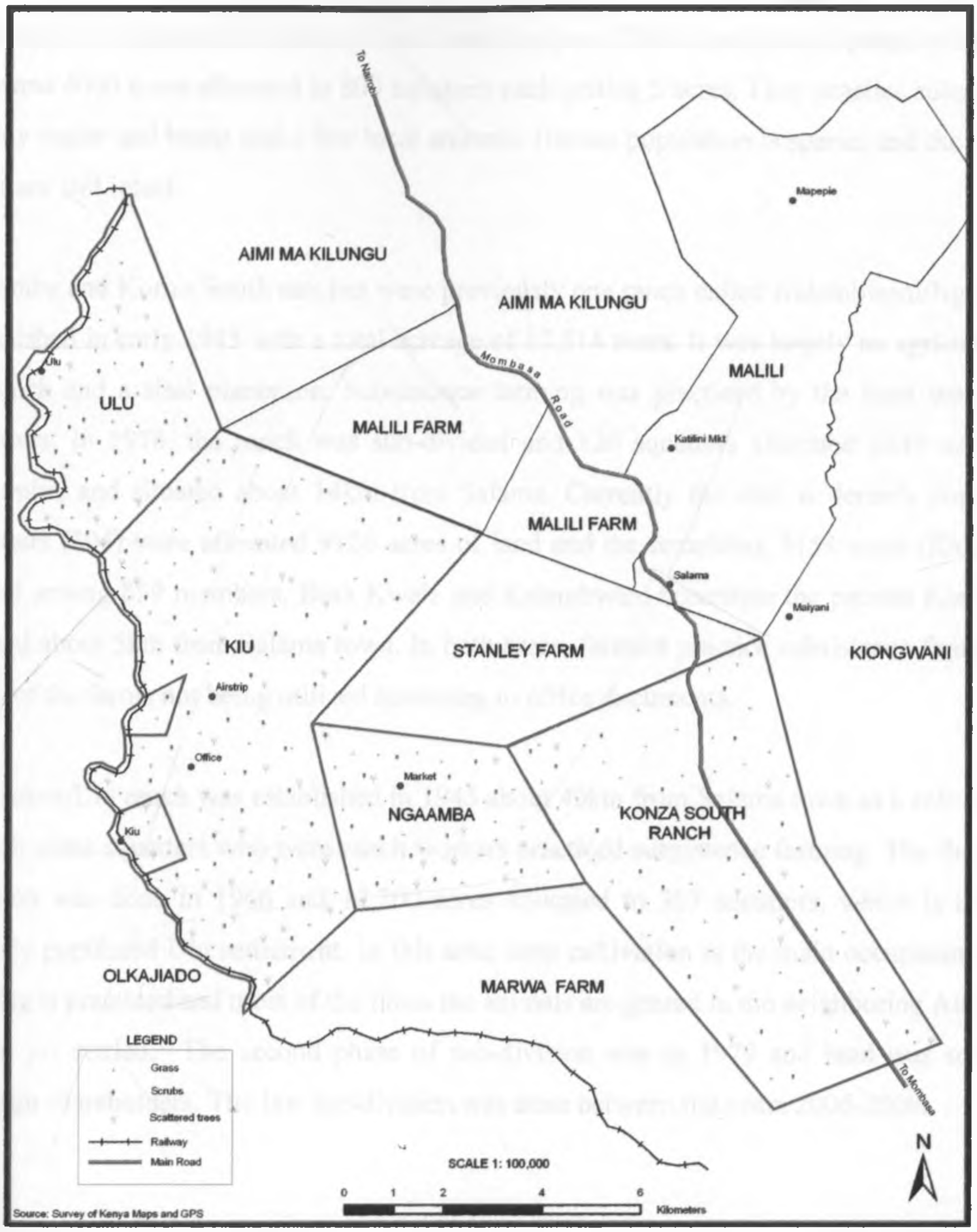
Figure 6: Mean monthly evaporation from weather stations in the study area (1965-1980)

2.4 Vegetation

The vegetation of the study area is related to soils and climate, and is generally bushed grassland to bushland of mainly Acacia, Commiphora and Balanites species. High rainfall on the Chyulu hills has resulted in a wooded dense bushland. The main perennial grasses species are *Cenchrus ciliaris, Enteropogon macrostachyus, Pennisetum mezianum* and *Chloris roxburghiana.* There is a general correlation between species distribution and geology. For example *Chloris roxburghiana* a dominant grass is widespread on all soils developed on basement system rocks while poorly drained areas and cracking clays are dominated by *Pennisetum mezianum* (Touber, 1983). Preliminary observation of vegetation in the study sites showed the area consists of scattered trees, scrubs and grasses (Figure 7).

2.5 Wildlife

The study sites were in the past frequented by wildlife from game reserves during the dry spells, and presently quite a number of animals such as Thomson gazelles (*Gazella thomson),* Maasai giraffes (*Giraffa camelopardalis),* common zebras (*Equus quagga),* cape buffalos (*Syncerus caffer),* and cheetah (*Acinonyx jubatus)* still visit the ranches during the dry seasons. Also found in the ranches are a number of birds such as cattle egrets (*Egretta garzetta),* hoopoe (*Upupa epops),* African pied wagtail (*Motacilla aguimp),* black- capped social weaver (*Pseudonigrita cabanisi),* superb starling (*Lamprotornis superbus)* and golden- breasted starling (*Cosmopsarus regius*).



Compiled by: Ms Purity Njoki

Figure 7: Vegetation map for the study sites

2.6 Study sites

Kiu ranch is 22km from Salama town and was established in 1945 as a sole livestock ranch, covering 7000 acres. It remained a livestock ranch until the year 2000 when the first phase of sub-division was done and 4000 acres allocated to 800 squatters each getting 5 acres. They practice subsistence farming, mainly maize and beans and a few local animals. Human population is sparse, and the remaining 3000 acres are still intact.

Ngaamba and Konza South ranches were previously one ranch called Kalembwani/Ngaamba, and was established in early 1945 with a total acreage of 17,514 acres. It was largely an agricultural farm with livestock and a sisal plantation. Subsistence farming was practiced by the farm workers who were squatters. In 1976, the ranch was sub-divided and 120 squatters allocated 3240 acres, now called Ngaamba, and situated about 14km from Salama. Currently the area is densely populated. Kwale squatters (304) were allocated 9120 acres of land and the remaining 5154 acres (Kalembwani farm) shared among 859 members. Both Kwale and Kalembwani constitute the present Konza South ranch located about 5km from Salama town. In both areas, farmers practice subsistence farming, with some areas of the farms not being utilized according to office documents.

Machakos/Ulu ranch was established in 1945 about 40km from Salama town as a sole livestock ranch, though some squatters who were ranch workers practiced subsistence farming. The first phase of sub-division was done in 1966 and 12,200 acres allocated to 305 squatters, which is now the present densely populated Ulu settlement. In this area, crop cultivation is the main occupation, although zero grazing is practiced and most of the times the animals are grazed in the neighboring Aimi ranch, which is not yet settled. The second phase of sub-division was in 1979 and land was sold to Aimi ma Kilungu shareholders. The last sub-division was done between the years 2006-2008.

CHAPTER THREE

MATERIALS AND METHODS

3. 1 Establishment of transects

A preliminary survey was conducted in November/December 2007 to understand the vegetation structure and identify the various ranches. Suitable sampling sites were identified in the four ranches and their GPS points recorded. The GPS points aided in tracing the selected sampling areas during the subsequent sampling.

Transects measuring 200m traversing cultivated farms and grazing areas were established randomly within the study sites namely Kiu, Ngaamba, Ulu/Aimi and Konza South ranches depending on the cooperation of the farmers since most land is individually owned. Five transects were established in each ranch (Figure 8 below) with the help of a GPS receiver at a distance of 1-3 kilometres and data collected in three seasons. Phase one and three during the wet seasons and phase two in the dry season.

3.2 Determination of tree density and plant species diversity

3.2.1 Woody plants

Woody plants were sampled in twenty transects using the Point Centered Quarter (PCQ) Method. A PCQ sample unit was placed at the GPS point (50m interval) along the transect and the area around each point split into four quadrants. The nearest tree was sought in each quarter, and the Point to plant distance measured and recorded.

The mean point to individual plant distances were first summed for all species at all points and the mean point to individual distances calculated. This value squared gave the mean area per plant. The density of plants per hectare in the area sampled was then obtained by dividing the mean area per plant by 10,000m^2. Thus, the Average Density = 10,000 / (mean distance in m^2).

$$\text{Total density of all species} = \frac{10{,}000\,m^2}{(\text{Mean-point-to individual distance (m)})^2}$$

Density by species was determined by counting the number of individuals in a sample for each species and recording. The total number of individuals counted (4 times the number of points sampled) was then determined. Thus, for each species,

$$\text{Relative density} = \frac{\text{Number of individuals of a species}}{\text{Total individuals of all species}} \times 100$$

$$\text{Density} = \frac{\text{Relative density of a species} \times \text{Total density of all species}}{100}$$

Tree species abundance was assessed as present/absent data, where only the occurrence of a species within a quadrat was noted (Martin & Paddy, 1992) and richness was determined using the Shannon-Weiner diversity index calculated as;

$$H' = -\sum (pi \log pi)$$

The Shannon-Weiner diversity index assumes that all individuals are randomly sampled from an infinitely large population and that all species from the community are included in the sample. The indices gave information about both the number of species in a community and the distribution of individuals among those species.

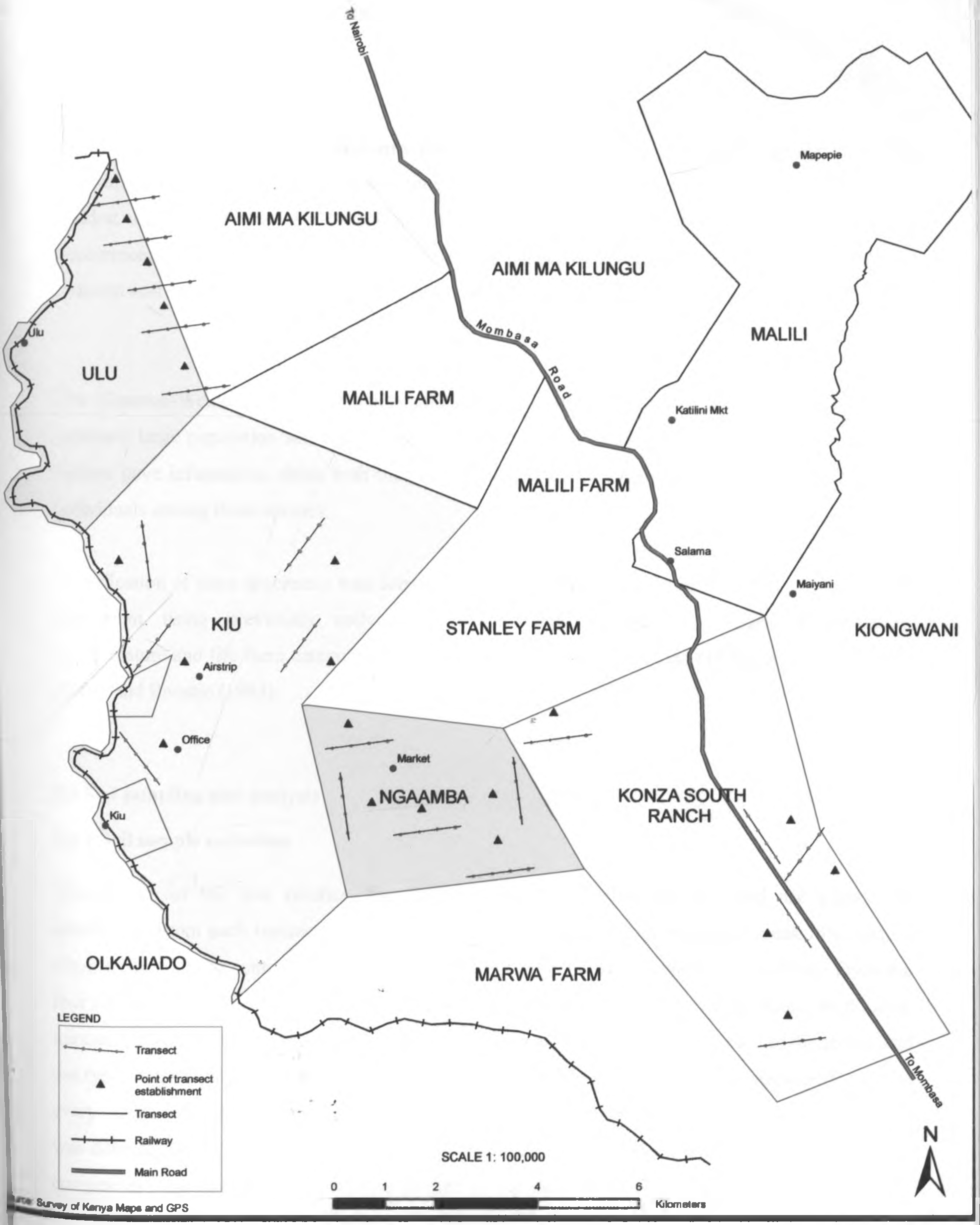


Figure 8: Map showing the layout of transects in the study sites

3.2.2 Herbaceous layer

Herbaceous layer were sampled in twenty transects using a $1m^2$ quadrat within the same points (50m interval) as the woody plants. Where shrubs were encountered within the same points, a 5m x10m quadrat was used. Plants species abundance was assessed as present/absent data, where only the occurrence of a species within a quadrat was noted and its cover recorded (Martin & Paddy, 1992) and richness was determined using the Shannon-Weiner diversity index calculated as;

$$H' = -\sum (pi \log pi)$$

The Shannon-Weiner diversity index assumes that all individuals are randomly sampled from an infinitely large population and that all species from the community are included in the sample. The indices gave information about both the number of species in a community and the distribution of individuals among those species.

Identification of plant specimens was done with the help of a taxonomist at the University of Nairobi Herbarium using previously collected specimens and photographic images. Identification, nomenclature and life form categorization of plants was guided by Bogdan (1976); Agnew & Shirley (1994) and Beentje (1994).

3.3 Soil sampling and analysis

3.3.1 Soil sample collection

Within each of the four ranches, five 200m transects traversing the two land use types were established. From each transect, four soil samples were collected from monoliths measuring 10cm x 10cm x 30cm at the centre of each $1m^2$ quadrat used for sampling herbaceous vegetation. From the four samples, two were obtained from cultivated farms and two from grazing areas. Within each ranch, ten samples were obtained from cultivated farms, and ten from grazing areas. In each of the above land use types, the samples were mixed to form a composite and in effect, two composites were formed in every ranch, making a total of eight composites, each weighing 500g in all the ranches. Soil analysis was done for composites due to time, distances between the ranches and available resources. These composites were taken to the Soil Science laboratories at the University of Nairobi for analysis.

3.3.2 Soil Nitrogen determination

Total nitrogen was determined using the Wet Digestion method in which the sample is digested for several hours with concentrated sulphuric acid so that all the nitrogen is converted to ammonium. This method was first described by Kjeldahl in 1883 because of its simplicity, speed and completeness of the conversion of nitrogen to ammonium, it is still the basic method for nitrogen determination, though several modifications have been introduced.

The Kjeldahl method gives very satisfactory, reproducible results provided that the digestion procedure is continued long enough. Almost all combined forms of nitrogen are converted to ammonium though the nitrite and nitrate in the soil is not included unless the method is modified. In most soils the amounts of nitrite and nitrate present at any one time are generally too small to have any appreciable effect on the result.

3.3.3 Organic carbon determination

Organic carbon was determined using Walkley- Black method. Here oxidizable matter in a soil sample is oxidized by Dichromate ion ($Cr_2O_7^{2-}$), and the reaction is facilitated by the heat generated when 2 volumes of Sulphuric acid (H_2So_4) are mixed with 1 volume of Potassium dichromate ($K_2Cr_2O_7$) solution. The excess $Cr_2O_7^{2-}$ is determined by titration with standard Iron (11) Sulphate ($FeSo_4$) solution, and the quantity of substances oxidized is calculated from the amount of $Cr_2O_7^{2-}$ reduced.

The highest temperature attained by the heat-of-dilution reaction produced upon addition of the H_2So_4 is approximately 120^0C, which is sufficient to oxidize the active forms of soil organic carbon, but not the more inert forms of carbon that may be present. This method oxidizes a lower percentage of the total carbon present in the soil and, moreover, gives a wider range of carbon recovery than the Schollenberger method which involves the external application of heat.

3.3.4 Soil pH determination

For soil pH, 50ml deionised water was added to 20 ± 0.1g soil measured on 2.5: 1 water to soil suspension. The mixture was stirred for 10 minutes and allowed to stand for 30 minutes and stirred again for 2 minutes. The pH of the soil suspension was measured and the suspension allowed to settle for 1 hour before determining the conductivity of the supernatant liquid. Electroconductivity of the dissolved salts was measured using an electroconductivity bridge meter.

3.3.5 Soil texture determination

Bouyoucos or hydrometer method (Bouyoucos, 1927) was used for soil texture. Here, 50g of soil air-dried for 2 minutes was weighed into a beaker. The soil was then saturated with distilled water, 10ml of 10% calgon solution was added and solution allowed to stand for 10 minutes. 300ml of tap water was added and shaken overnight on reciprocating shaker. The suspension was transferred into a graduated cylinder, a hydrometer was inserted, water added to 1130ml and hydrometer removed. The cylinder was covered with a tight fitting rubber bung and the suspension mixed by inverting the cylinder carefully ten times. The time was noted and 2-3 drops of amyl alcohol added and hydrometer placed into the column after 20 seconds. After 40 seconds, hydrometer reading was made and temperature of the suspension measured. Mixing of the soil suspension was repeated 120 times and cylinder allowed to stand undisturbed for 2 hours.

The hydrometer and temperature readings were then made again. After 40 seconds sand had settled and the hydrometer reading reflected the grams of silt + clay in 1 litre of the suspension. To calculate the amount of sand present in 1 litre of the suspension, this value was subtracted from the original sample weight. The percentage sand was calculated by dividing the sand content by the total (50g) and multiplying by 100. After 2 hours, silt had settled and the hydrometer reading reflected the clay content of the original suspension. The silt content was calculated by subtracting the sum of the clay and sand contents form 100 %. Soils were then assigned to textural classes based on particle size distribution using the soil textural triangle.

3.3.6 Soil moisture determination

Anderson & Ingram (1993) method was used to determine soil moisture. About 1±0.001 g of prepared air-dry soil was put into a dry container of known weight (W1). Weight 2 was recorded (W2) and dried at 105°c for 2 hours, then allowed to cool in desiccators and weighed (W3). All data was corrected to dry weight basis by multiplying with (100/dry soil in %).

$$\text{Soil moisture (\%)} = (W3 - W1 \times 100] / (W2 - W1)$$

3.4 Data analysis

Data for plants species diversity was analyzed using the computer program "PC-ORD 5.0" (Shannon's diversity index). Pearson correlation analysis was used to establish if there was a relationship between abundance of plant species and soil characteristics. One way ANOVA was used to analyze variations in soil quality in terms of organic carbon and total nitrogen in the four ranches. ANOVA test was also used to compare means of plants species abundance within and between the ranches. Chi-squared test was applied to analyze variations in tree species richness between the ranches. Means were separated using Student-Newman-Keul's (S-N-K) post hoc test to establish which means actually differed from each other and results were presented in graphs showing error bars. Both correlation and ANOVA were done using the SPSS computer program.

CHAPTER FOUR

RESULTS

4.0 Tree species density and diversity of plant species in the study area

4.1 Tree species density in the ranches and across seasons

A total of five species belonging to four families were recorded during the study. *Acacia tortilis* had the highest density across seasons (291.4 trees per hectare) and *Lannea schwanfurthii* (8.25 trees per hectare) the least as indicated in Table1.

Table 1: Tree species density across seasons

Family	**Species**	**Season and density/ha**			
Leguminosae		Wet 1	Dry	Wet 2	Mean density
	Acacia tortilis	328.9	291.8	253.4	291.4
	Acacia kirkii	178.4	168.9	157.3	168.2
Burseraceae	*Commiphora africana*	107.5	100.1	80.3	96
Balanitaceae	*Balanites aegypitiaca*	192	178.8	178.4	183.1
Anacardiaceae	*Lannea schwanfurthii*	8.9	8.18	7.68	8.25

The highest tree density was recorded in Konza ranch where all the five species were present. Ngaamba and Ulu/ Aimi ranches recorded two species each and tree densities were almost equal in the two ranches. Kiu ranch recorded the least tree diversity as only one species was recorded as shown in Table 2.

Table 2: Tree species density/ha in the ranches

SPECIES	Kiu	Ngaamba	Ulu/Aimi	Konza
Acacia tortilis	49.95		62.18	48.34
Balanites aegypitiaca		62.57		46.39
Commiphora africana			42.85	18.55
Acacia kirkii		49.95		55.66
Lannea schweinfurthii				4.64

4.2 Diversity of plant species in the study area

4.2.1 Tree species richness and abundance in the ranches

Diversity indices of trees revealed a significant difference in species richness among the ranches ($F_{[3, 16]} = 5.066$, $P < 0.05$) with Konza ranch recording the highest diversity index and Kiu ranch the least as shown in Figure 9.

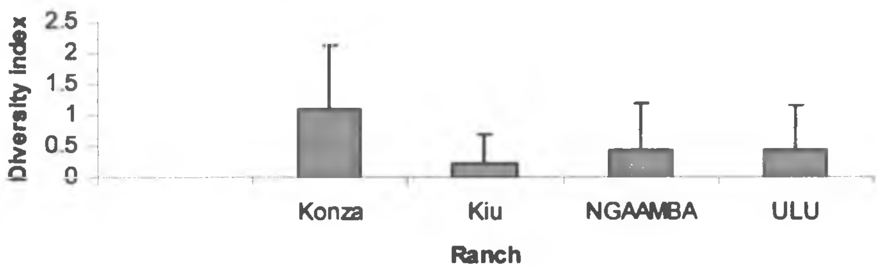


Figure 9: Diversity index ± SE of tree species richness

ANOVA test revealed a significant difference in the mean abundance of tree stumps among the ranches ($F_{[3, 6]} = 159.458$, $P < 0.05$) where Ulu/Aimi ranch contributed the highest number of tree stumps in the study area while Ngaamba had the least as indicated in Figure 10.

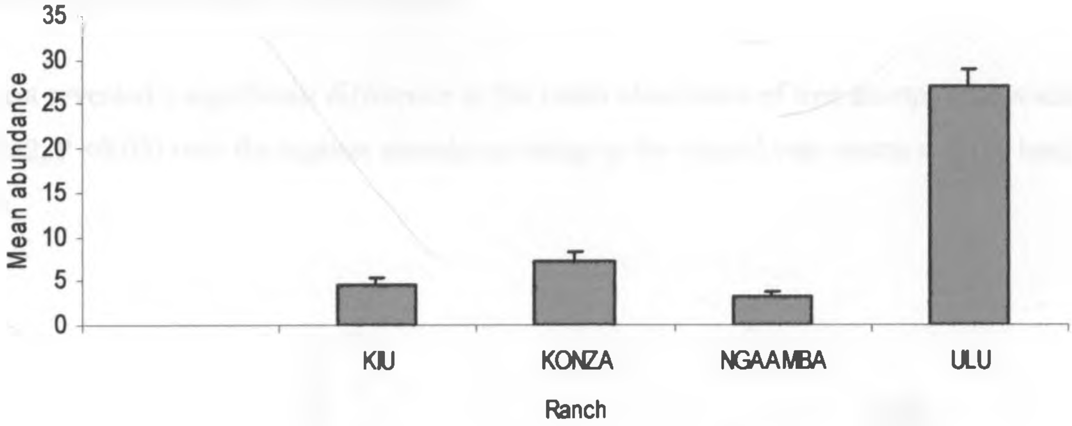


Figure 10: Mean ± SE abundance of tree stumps in different ranches

Acacia tortilis was recorded in three of the four ranches namely Konza, Ulu and Kiu. Anova results indicated a significant difference in its mean abundance among the ranches ($F_{[2, 28]} = 22.879$, $P < 0.05$). There was no significant difference in the mean abundance of *Balanite aegypitiaca* between Konza and Ngaamba ranches ($F_{[1, 16]} = 0.006$, $P > 0.05$). There was also no significant difference in the mean abundance of *Commiphora africana* ($F_{[1, 11]} = 0.014$, $P > 0.05$) between Konza and Ulu ranches. However there was a significant difference in the mean abundance of *Acacia kirkii* ($F_{[1, 15]} = 5.934$, $P < 0.05$) between Konza and Ulu ranches as shown in Table 3.

Table 3: Mean ± SE abundance of tree species in the ranches

Species	Ranch	Mean ± SE	Abundance
Acacia tortilis	Konza	2.667 ± 0.398	12
	Ulu	1.222 ± 0.441	10
	Kiu	4.933 ± 0.356	15
Balanites aegypitiaca	Konza	3.000 ±0.421	9
	Ngaamba	3.044 ±0.36	13
Acacia kirkii	Konza	4.333 ±0.621	9
	Ngaamba	2.333 ±0.537	12
Commiphora africana	Konza	2.000 ±0.191	6
	Ulu	1.972 ±0.143	11

4.2.2 Tree species abundance across seasons

ANOVA test revealed a significant difference in the mean abundance of tree stumps across seasons ($F_{[2, 6]} = 16.952$, $P < 0.05$) with the highest abundance being in the second wet season and the least in first wet season.

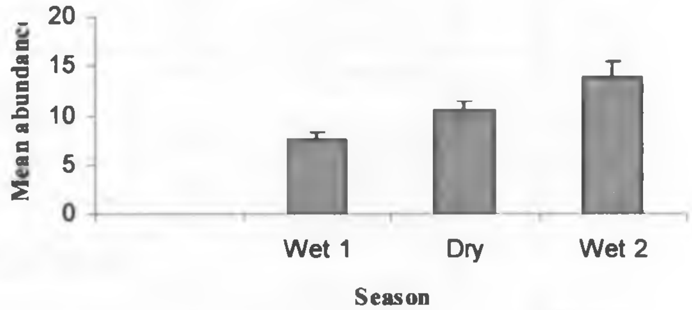


Figure 11: Mean ± SE abundance of tree stumps across seasons

ANOVA test revealed no significant difference in the mean abundance of *Acacia tortilis* across seasons ($F_{[2, 28]} = 1.706$, $P > 0.05$). There were also no significant differences in the mean abundance of *Balanites aegypitiaca* ($F_{[2, 16]} = 0.075$, $P > 0.05$), *Acacia kirkii* ($F_{[2, 15]} = 0.041$, $P > 0.05$) and *Commiphora africana* ($F_{[2, 11]} = 1.249$, $P > 0.05$) respectively as shown in Table 4.

Table 4: Mean ± SE abundance of tree species across seasons

Species	Season	Mean ± SE	Abundance
Acacia tortilis			
	Wet 1	3.506 ± 0.407	13
	Dry	2.833± 0.407	12
	Wet 2	2.483 ± 0.384	12
Balanites aegypitiaca			
	Wet 1	3.167±0.515	8
	Dry	3.000 ±0.461	8
	Wet 2	2.900 ±0.461	6
Acacia kirkii			
	Wet 1	3.417 ±0.711	7
	DRY	3.417 ±0.711	7
	Wet 2	3.417 ±0.711	7
Commiphora africana			
	Wet 1	2.250±0.203	6
	Dry	1.875 ±0.203	6
	Wet 2	1.833±0.214	5

4.3 Shrubs species abundance and richness in the ranches

Table 5 shows species recorded in the various ranches, their distribution and percentage cover. A total of 18 species of shrubs were recorded during the study, with *Lantana camara* and *Solanum incanum* being the most common shrubs in the ranches. Konza ranch had the highest species richness (17 species) with *Lantana camara* recording the highest cover (32%) in Ngaamba, Konza and Kiu ranches respectively. Ngaamba, Kiu and Ulu/Aimi ranches recorded five; four and two species respectively. ANOVA test revealed a significant difference in the mean abundance of shrubs species among the ranches ($F_{[3, 126]} = 0.993$, $P < 0.05$) with Ulu ranch recording the least abundance as shown in Table 6.

Table 5: Shrubs species recorded in different ranches and their percentage cover

	Ranch			
Species	Konza	Ngaamba	Kiu	Ulu
Solanum incanum	22	18	15	10
Lantana camara	32	35	32	22
Melhania velutina	5	4	8	0
Abuliton mauritianum	5	4	0	0
Ocimum kilimandscharicum	8	13	0	0
Aspilia pluriseta	2	0	0	0
Microglossa pyrifolia	10	0	0	0
Tridax procumbeas	3	0	0	0
Pycnostachys umbrosa	22	0	0	0
Asparagus falcatus	10	0	0	0
Ormocarpum kirkii	2	0	0	0
Indigofera ambelacensis	12	0	0	0
Phyllanthus sepialis	3	0	0	0
Combretum collinum	3	0	0	0
Terminalia brownii	1	0	0	0
Ocimum grutissimim	8	0	0	0
Hibiscus micranthus	17	0	0	0
Ipomea hildebrandtii	0	0	13	0

Table 6: Mean ± SE abundance of shrubs species in the ranches

Ranch	Mean ± SE	Abundance
Konza	2.179 ± 0.174	70
Ulu	1.000 ± 0.340	3
Kiu	1.493 ± 0.108	30
Ngaamba	1.471 ± 0.096	38

4.3.1 Shrubs species abundance in each ranch across seasons

There were no significant differences in the mean abundance of shrub species between seasons ($F_{[2, 126]} = 0.113$, $P > 0.05$) as indicated in Table 7.

Table 7: Mean ± SE abundance of shrubs species across seasons

Season	Mean ± SE	Abundance
Wet 1	1.692 ± 0.175	50
Dry	1.698 ± 1.698	47
Wet 2	1.603 ± 0.177	44

Konza ranch recorded seventeen species during the first wet season and thirteen species in both dry and second wet seasons. *Melhania velutina*; *Abuliton mauritianum*; *Aspilia pluriseta* and *Microglossa pyrifolia* dried up during the dry season and did not re-emerge during second wet season. Ngaamba recorded five species, Kiu four species and Ulu ranch two species, all of which emerged during the three seasons. Anova results revealed no significant differences in the mean abundance of shrub species among the ranches during the first wet season ($F_{[3, 45]} = 0.563$, $P > 0.05$); dry season ($F_{[3, 42]} = 0.567$, $P > 0.05$) and second wet season $F_{3, 39]} = 0.121$, $P > 0.05$) respectively as indicated in Table 8.

Table 8: Mean ± SE abundance of shrubs species in the ranches across seasons

Season	Ranch	Mean± SE	Abundance
Wet1	KIU	1.600 ± 0.186	11
	KONZA	2.196 ± 0.301	24
	NGAAMBA	1.467 ± 0.152	15
	ULU	1.000 ± 0.589	1
Dry	KIU	1.545 ± 0.177	10
	KONZA	2.182 ± 0.301	23
	NGAAMBA	1.583 ± 0.17	12
	ULU	1.000 ± 0.589	1
Wet2	KIU	1.333 ± 0.196	9
	KONZA	2.159 ± 0.301	23
	NGAAMBA	1.364 ± 0.177	11
	ULU	1.000 ± 0.589	1

4.3.2 Shrubs species abundance between land use types

Konza and Ngaamba ranches recorded two species each in the cultivated farms while Kiu and Ulu ranches recorded none. However, there was more cover in grazing areas (74%; 90%) than cultivated farms (2%; 10%) in Ngaamba and Konza ranches respectively. Kiu grazing areas recorded 68% cover while Ulu recorded only 32% shrubs cover. ANOVA results revealed a significant difference in the mean abundance of shrub species recorded in grazing areas and those that were found in cultivated farms in the study area ($F_{[1, 126]} = 22.348$, $p < 0.05$) as shown in Table 9. However, no meaningful analysis was done between land use types in each ranch as the species were either too few or absent.

Table 9: Mean ± SE abundance of shrubs species between land use types

Land use type	Mean ± SE	Abundance
Grazing areas	1.333 ± 0.094	138
Cultivated farms	3.000 ± 0.340	3

4.4 Herbaceous plants species diversity

4.4.1 Grass species richness and abundance in the ranches

Table 10 shows species recorded in the various ranches, their distribution and cover. A total of 20 species of grass were recorded during the study. Konza ranch had the highest species richness (thirteen species) with *Panicum coloratum* having the highest cover (17%). Ngaamba ranch recorded three species with *Cenchrus ciliaris* (50%) having the highest cover.

Five species of grass were recorded in Kiu ranch with *Cynodon dactylon* having the highest cover (40%), while Ulu/Aimi ranch recorded three species with *Brancharia nigropedata*having the highest cover (50%). Three species were found to be unpalatable and included *Perotis patens* (5% cover); *Eragrostis heteromera* (5% cover) and *Panicum coloratum* (17% cover) all recorded in Konza ranch.

Table 10: Grasses species recorded in different ranches and their cover

	Ranch			
Species	Konza	Ngaamba	Kiu	Ulu
Cenchrus ciliaris	5	50	0	0
Eragrostis heteromera	5	0	0	0
Eragrostis superba	10	0	0	3
Perotis patens	5	0	0	0
Panicum coloratum	17	0	0	0
Cynodon ulemfuensis	3	0	0	0
Digitaria milanjiana	1	0	0	0
Cyperus rubicundus	0.3	0	0	0
Cyperus niveus	0.3	0	0	0
Pennisetum mezianum	5	0	0	0
Bothriochloa insculpta	5	0	0	0
Brachiaria leersiodes	5	0	0	0
Dactyloctenium aegyptium	5	0	0	0
Eragrostis cilianensis	0	3	7	0
Sporobolus pyramidalis	0	0	17	20
Brancharia nigropedata	0	0	0	50
Eriochloa meyerana	0	0	10	0
Cynodon dactylon	0	0	40	0
Chloris roxburghiana	0	0	15	0
Harpachne schimperi	0	0	10	0

There was a significant difference in the mean abundance of grass species among the ranches ($F_{[3, 169]} = 21.504$, $P < 0.05$) as indicated in Table 11.

Table 11: Mean ± SE of grass species abundance in the ranches

RANCH	Mean ± SE	Abundance
KIU	1.366 ± 0.074	67
KONZA	1.917 ± 0.135	43
NGAAMBA	1.793 ± 0.088	43
ULU	2.240 ± 0.103	52

4.4.1.1 Grass species abundance in each ranch across seasons

There were no significant differences in the mean abundance of grass species between seasons ($F_{[2, 169]} = 0.245$, $P > 0.05$) as indicated in Table 12.

Table 12: Mean ± SE abundance of grass species across seasons

Season	Mean ± SE	Abundance
Wet 1	1.773 ± 0.095	75
Dry	1.924 ± 0.088	60
Wet 2	1.803 ± 0.082	70

In Konza ranch thirteen species were recorded during the first wet season (and nine species in both dry and second wet seasons respectively. *Cynodon ulemfuensis*; *Digitaria milanjiana*; *Cyperus rubicundus* and *Cyperus niveus* dried up during the dry season and did not re-emerge during the second wet season. Of the three species recorded in Ngaamba ranch only *Cenchrus ciliaris* emerged as a perennial grass during the three seasons. Out of the six species recorded in the first season, only two survived the dry season (*Cynodon dactylon* with 25% cover and *Chloris roxburghiana* with 10% cover) and of the four that dried up, only *Eragrostis cilianensis* did not re-emerge during the second wet season. Ulu ranch recorded three species and only one (*Eragrostis superba*) did not emerge in the subsequent seasons. Six species were recorded in Kiu ranch and of the three which dried up during the dry season only one (*Eragrostis cilianensis*) did not re-emerge in the second wet season.

Results of analysis revealed significant differences in the mean abundance of grass species among the ranches during the first wet season ($F_{[3, 62]} = 5.965$, $P<0.05$); dry season ($F_{[3, 49]} = 11.133$, $P <0.05$) and second wet season $F_{[3, 58]} = 6.938$, $P <0.05$) respectively as indicated in Table 13.

Table13: Mean ± SE abundance of grass species in the ranches across seasons

Season	Ranch	Mean± SE	Abundance
Wet1	KIU	1.444 ± 0.134	24
	KONZA	1.905 ± 0.266	16
	NGAAMBA	1.750 ± 0.160	13
	ULU	1.938 ± 0.174	22
Dry	KIU	1.364 ± 0.136	20
	KONZA	1.875 ± 0.216	13
	NGAAMBA	1.889 ± 0.151	15
	ULU	2.889 ± 0.185	12
Wet2	KIU	1.291 ± 0.116	23
	KONZA	1.972 ± 0.215	14
	NGAAMBA	1.739 ± 0.145	15
	ULU	2.211 ± 0.174	18

4.4.1.2 Grass species abundance between land use types

Konza ranch recorded three species in the cultivated farms while Ngaamba, Kiu and Ulu ranches recorded one species each. There was more cover in grazing areas (53%) than cultivated farms (3%) in Ngaamba ranch. Konza ranch grazing areas recorded more cover (57%) compared to cultivated farms (11%). Kiu ranch grazing areas recorded 92% cover and cultivated farms 7%, while Ulu ranch grazing areas recorded 73% cover and cultivated farms 13% grass cover. Anova results revealed significant differences in the mean abundance of grass species between land use types in the study area ($F_{[1, 169]}$ = 31.408, $P < 0.05$) as indicated in Table 14.

Table 14: Mean ± SE abundance of grass species between land use types

Land use type	Mean ± SE	Abundance
Grazing areas	1.821 ± 0.057	108
Cultivated farms	1.159 ± 0.085	58

There were no significant differences in the mean abundance of grass species between grazing areas and cultivated farms in both Kiu ($F_{[1, 58]} = 20.17$, $P > 0.05$) and Konza ($F_{[1, 34]} = 9.697$, $P > 0.05$) ranches. However there were significant differences in Ngaamba ($F_{[1, 34]}$ 7.456, $P < 0.05$) and Ulu ($F_{[1, 43]}$ 18.732, $P < 0.05$) ranches respectively as indicated in Table 15.

Table 15: Mean ± SE abundance of grass species between land use types in the ranches

Land use type	Ranch	Mean± SE	Abundance
Cultivated farm	KIU	1.000 ± 0.124	21
	KONZA	1.670 ± 0.226	9
	NGAAMBA	1.194 ± 0.141	16
	ULU	1.333 ± 0.160	12
Grazing area	KIU	1.284 ± 0.104	30
	KONZA	1.584 ± 0.102	31
	NGAAMBA	2.028 ± 0.141	16
	ULU	2.387 ± 0.100	31

4.4.2 Forbs species richness and abundance in the various ranches

Results of ANOVA test revealed significant differences in the mean abundance of forbs species among the ranches ($F_{[3, 214]} = 5.792$, $P < 0.05$) as indicated in Table 16.

Table16: Mean ± SE abundance of forbs species in the ranches

RANCH	Mean ± SE	Abundance
KIU	1.542 ± 0.070	59
KONZA	1.908 ± 0.097	67
NGAAMBA	1.574 ± 0.097	84
ULU	1.347 ± 0.087	38

A total of thirty four species of forbs were recorded during the study, with ***Commelina benghalensis***; *Oxygonium sinuatum* and *Indigofera tanganyikensis* being the most common forbs as they were recorded in all the ranches. Konza ranch recorded the highest species richness (25 species) with *Trichodesma zeylanicum* (10%) and *Launaea cornuta* (10%) having the highest cover. Ngaamba ranch recorded twenty two species; Kiu ranch ten species; and Ulu ranch eleven species with *Indigofera tanganyikensis* (18%; 13% and 28%) recording the highest cover in the three ranches respectively as indicated in Table 17.

Table 17: Forbs species recorded in different ranches and their cover

Forbs species	Ranch			
	Konza	Ngaamba	Kiu	Ulu
Commelina benghalensis	2	8	8	5
Oxygonium sinuatum	1	8	2	10
Indigofera tanganyikensis	4	18	13	28
Ocimum obovatam	3	2	0	0
Ipomea obscura	3	2	0	0
Sonchus oleraceus	1	3	0	3
Bidens pilosa	2	7	0	3
Leucas grandis	3	2	2	0
Glycine wightii	1	2	0	0
Solanum renschii	2	0	0	0
Ageratum conyzoides	0.3	0	0	0
Monechma debile	0.3	0	0	0
Justicia striata	0.3	0	0	0
Phyllamitius spatensi	0.3	0	0	0
Crossandra subacaulis	1	2	0	0
Orthosiphon parvifolium	1	5	0	3
Trichodesma zeylanicum	10	2	0	0
Emilia coccinea	3	8	0	0
Launaea cornuta	10	2	0	0
Tagetes minuta	1	3	0	0
Indigofera spinosa	1	0	0	0
Leucas micranthus	0.3	6	0	3
Abutilon fruticosum	2	0	2	0
Achyranthus asperagus	0.3	3	7	0
Leucas pratensis	0	5	3	5
Endostemon tereticaulis	0	1	1	0

Portulaca oleracea	0	3	0	0
Asystasia schimperi	0	2	0	0
Euphorbia hirta	0	0	0	2
Commelina africana	0	0	0	3
Gynandropsis gynandra	0	0	3	0
Tribulus cistoides	0	0	0	0
Justicia exigua	0	0	0.3	0
Cleome monophylla	0	0	0.3	0

4.4.2.1 Forbs species abundance in each ranch across seasons

There were no significant differences in the mean abundance of forbs species between seasons ($F_{[2, 214]} = 0.245$, $P > 0.05$) as indicated in Table 18.

Table 18: Mean ± SE abundance of grasses species across seasons

Season	Mean ± SE	Abundance
Wet 1	1.583 ± 0.066	109
Dry	1.488 ± 0.100	58
Wet 2	1.637 ± 0.064	81

Konza ranch recorded twenty four species during the first wet season of data collection, and ten of them dried up and were therefore not recorded during the dry season. During the second wet season eleven species were recorded some of which had not been recorded in the previous seasons and included *Indigofera spinosa.* In Ngaamba ranch, of the seventeen species recorded in the first wet season eight dried up and were not recorded in the subsequent seasons (dry and second wet seasons). Of the eleven species recorded during the dry season, *Emilia coccinea* was the only new species not sampled before. 16 species were sampled in the second wet season and included four new species not recorded in the previous seasons (*Ipomea obscura*; *Sonchus oleraceus*; *Leucas grandis* and *Glycine wightii*). Kiu ranch recorded eight species in the first wet season four of which dried up during the dry season. Of the six species recorded in the second wet season *Leucas grandis* and *Leucas pratensis* were new emergences. Ulu ranch recorded eleven species in the first wet season, of which seven dried up during the dry season. Some re-emerged in the second wet season and were among the eight species recorded. Three species dried up completely and included *Gynandropsis gynandra*; *Tribulus cistoides* and *Emilia coccinea*.

Results of Anova revealed no significant differences in the mean abundance of forbs species among ranches in the first wet season ($F_{[3, 97]} = 0.497$, $P > 0.05$). However there were significant differences in the mean abundance of forbs species during the dry ($F_{[3, 48]} = 6.973$, $P < 0.05$) and second wet ($F_{[3, 69]} = 4.421$, $P < 0.05$) seasons respectively as indicated in Table 19.

Table19: Mean ± SE abundance of forbs species in the ranches across seasons

Season	Ranch	Mean± SE	Abundance
Wet1	KIU	1.621 ± 0.105	27
	KONZA	1.463 ± 0.134	33
	NGAAMBA	1.574 ± 0.134	32
	ULU	1.674 ± 0.153	17
Dry	KIU	1.667 ± 0.242	12
	KONZA	1.148 ± 0.189	16
	NGAAMBA	1.533 ± 0.112	24
	ULU	1.833 ± 0.205	6
Wet2	KIU	1.433 ± 0.120	20
	KONZA	1.429± 0.122	18
	NGAAMBA	1.519 ± 0.117	28
	ULU	2.167 ± 0.152	15

4.4.2.2 Forbs species abundance between land use types

Konza ranch recorded eighteen species in the grazing areas and fourteen species in the cultivated farms while Ngaamba recorded six species in the grazing areas and 12 species in the cultivated farms. Kiu ranch recorded four species in the grazing areas and six species in the cultivated farms, while Ulu ranch recorded two species in the grazing areas and ten species in the cultivated farms. Ngaamba ranch grazing areas had 30% cover and cultivate farms 48% cover. Konza ranch grazing areas recorded 21% cover and cultivated farms 35% cover. While Kiu and Ulu ranches recorded (19%; 30% cover) and (22.3%; 38% cover) in grazing areas and cultivated farms respectively. Anova results revealed no significant difference in mean abundance of forbs species between land use types in the study area ($F_{[1,214]}$ =2 8.415, P >0.05) as indicated in Table 20.

Table 20: Mean ± SE abundance of forbs species between land use types

Land use type	Mean ± SE	Abundance
Grazing areas	1.336 ± 0.067	99
Cultivated farms	1.245 ± 0.050	113

There were no significant differences in the mean abundance of forbs species between grazing areas and cultivated farms in Kiu ($F_{[1, 50]}$ = 17.006, P >0.05); Konza ($F_{[1, 58]}$ = 3.898, P >0.05) and Ngaamba ranches ($F_{[1, 75]}$ =24.292, P >0.05) respectively. However there was a significant difference in Ulu ranch ($F_{[1, 31]}$ =4.419, P <0.05) as indicated in Table 21.

Table 21: Mean ± SE abundance of forbs species between land use types in the ranches

Land use type	Ranch	Mean± SE	Abundance
Cultivated farm	KIU	1.238 ± 0.097	30
	KONZA	1.225 ± 0.107	23
	NGAAMBA	1.210 ± 0.081	41
	ULU	1.386 ± 0.116	19
Grazing area	KIU	1.083 ± 0.196	13
	KONZA	1.148 ± 0.092	37
	NGAAMBA	1.083 ± 0.086	34
	ULU	2.028 ± 0.131	15

4.5 Organic carbon and total nitrogen contents in the study area

ANOVA test revealed no significant differences in organic carbon among the ranches ($F_{[3, 5]} = 1.763$, $P > 0.05$). There was also no significant difference in organic carbon between the land use types ($F_{[1, 3]} = 4.689$, $P > 0.05$). There was no significant difference in total nitrogen among the ranches ($F_{[3, 5]} = 3.262$, $P > 0.05$). There was also no significant difference in total nitrogen between the land use types ($F_{[1, 3]} = 3.454$, $P > 0.05$) as shown in Tables 22 and 23 respectively. Since values of both organic carbon and total nitrogen were percentages, data was first transformed using logarithmic transformation (log10(x)). Transformation was also necessary since some observed values were small.

Table 22: Mean ± SE of soil organic carbon in the ranches

	Log10(x)	
Ranch	Mean ± SE	Re-transformed values
Kiu	0.356 ± 0.055	1.3
Konza	0.215 ± 0.045	0.6
Ngaamba	0.348 ± 0.055	1.2
Ulu	0.348 ± 0.055	1.0
Land use type	Mean ± SE	
Cultivated	0.356 ± 0.055	1.3
Grazing area	0.313 ± 0.05	0.9

Table 23: Mean ± SE of soil total nitrogen in the ranches

	Log10(x + 1)	
Ranch	Mean ± SE	Re-transformed values
Kiu	0.043 ± 0.01	0.1
Konza	0.023 ± 0.008	0.1
Ngaamba	0.062 ± 0.01	0.2
Ulu	0.031 ± 0.01	0.1
Land use type	Mean ± SE	
Cultivated	0.024 ± 0.009	0.1
Grazing area	0.078 ± 0.01	0.1

4.6 Relationship between soil characteristics and richness of herbaceous plants species

4.6.1 Soil results

Results of soil characteristics analyzed from soil samples collected from the field are shown in Table 24 below. The pH in water varied from 5.93 to 7.02. These values were rated as moderate, slightly acidic to neutral and the highest values were in both Konza grazing areas (7.02) and cultivated farms (7.01) implying that the ranch was neutral. Kiu ranch soils were moderately acidic with a range of 5.93-6.06 in the cultivated farms and grazing areas respectively. Ngaamba and Ulu ranches recorded slightly acidic soils in both grazing (6.37 & 6.93 respectively) and cultivated (6.99 & 6.44 respectively) farms respectively.

The soil organic carbon in the ranches ranged from 0.69-1.02% in the grazing areas and 0.83-1.86% in the cultivated farms an indication that all the soils had very low organic carbon (<2%). Total nitrogen content in the ranches ranged from 0.07 -0.2 in the cultivated farms and 0.05-0.11 in the grazing areas indicating that only Ngaamba cultivated farms had low soil nitrogen (0.2%). The rest had very low (<0.1%). Both carbon and nitrogen are components of soil humus which is known to increase the water holding capacity of the soil.

Moisture content was higher in cultivated farms (6.31-9.99%) than grazing areas (1.08-5.06%) except in Ulu cultivated farm which recorded 2.21%. Konza South (9.99%) and Ngaamba cultivated farms (9.16%) recorded the highest moisture content. In Konza grazing areas two gullies were noted in two transects and rill erosion was evident in Ulu/Aimi ranch grazing areas due to exposure of soil through overgrazing. This may have affected moisture content in the grazing areas of the two ranches.

Soil water content affects nitrogen-availability by affecting microbial activity and by the transport of soluble nitrogen-containing compounds. Soil texture was sandy clay loam (SCL) in all the ranches except some sections of Konza South ranch (Konza reserve) cultivated farms which was found to have sandy clay. This section was found to have been cultivated for over 30 years and the only vegetation that was found to survive there were two species of grass; *Eragrostis heteromera* and *Perotis patens*.

Table 24: Summary of soil characteristics analyzed

LAND USE TYPE	pH Water	% C	% N	% Moisture	% Sand	% Silt	% Clay	Soil texture
Kiu cultivated farm	5.93	1.86	0.14	6.31	66	9	25	Sandy clay loam
Kiu grazing area	6.06	0.8	0.07	4.6	64	13	23	"
Ngaamba cultivated farm	6.99	1.46	0.2	9.16	63	12	25	"
Ngaamba grazing area	6.37	1.02	0.11	5.06	65	11	24	"
Ulu cultivated farm	6.44	1.13	0.07	2.21	69	10	21	"
Aimi grazing area	6.93	0.94	0.08	1.08	70	7	23	Sandy clay loam
Konza South cultivated farm	7.01	0.83	0.07	9.99	63	12	25	Sandy clay loam
Konza South grazing area	7.02	0.69	0.05	3.97	64	10	26	"
Konza reserve					49	10	41	Sandy Clay

4.6.2 Correlation results

The richness of grasses, forbs and shrubs species in the study sites was correlated with that of pH, total nitrogen, organic carbon and moisture. There was no significant correlation between soil pH and grass species richness ($r = 0.24$; $n=21$, $p > 0.05$). There were also no significant relationships between organic carbon ($r = -0.35$; $n=21$, $p > 0.05$) and total nitrogen ($r = -0.25$; $n=21$, $p > 0.05$) with grass species richness. However, soil moisture had a significant relationship with grass species richness ($r = -0.53$; $n=21$, $p < 0.05$).

There were no significant relationships between forbs species richness and soil pH ($r = 0.2$; $n=35$, $p>0.05$); organic carbon ($r = -0.02$; $n=35$, $p>0.05$); total nitrogen ($r = -0.18$; $n=35$, $p>0.05$) and soil moisture ($r = -0.17$; $n=35$, $p>0.05$). .ANOVA results revealed a significant relationship between soil pH and shrubs species richness ($r = -0.4$; $n=18$, $p<0.05$). However the relationships between shrubs species richness and organic carbon ($r= 0.61$; $n=18$, $p>0.05$); total nitrogen ($r = 0.42$; $n=18$, $p>0.05$) and soil moisture ($r = 0.06$; $n=18$, $p>0.05$) were not significant.

CHAPTER FIVE

DISCUSSIONS

5.1 Density of trees and plants species diversity in the study area

During the study, results of ANOVA revealed a significant difference in the mean abundance of tree stumps among the ranches with Ulu/Aimi ranch recording the highest abundance (Figure 10). There was also a significant difference in tree stumps abundance across the seasons with second wet season recording the highest abundance (Figure 11). This was an indication that trees were being lost in all the ranches through cutting, thus signifying vegetation degradation in terms of wood layer. From my observations no trees were recorded in the cultivated farms, and no grazing areas were remaining in Ulu ranch which is fully settled and intensive cultivation is practiced. This could be attributed to the fact that Ulu was the first ranch to be settled in 1966 and population has grown over time increasing demand for food, thus more cultivated farms. It was also observed that farmers in Ulu ranch reared animals which grazed in the neighboring Aimi ranch which had not yet been settled. Tree cutting in Aimi ranch was intensive probably by Ulu settlers for wood fuel.

Tree densities were also noted to decrease with seasons. It was observed that during the dry season farmers cut down trees for wood fuel and also to expand cultivating farms since during the second wet season, areas where trees were cut were found to have been dug and planted. These observations agree with findings of the study done by Mworia, Kinyamario & Kiringe (2001) in Kiboko where they observed that small scale farms in the settlements led to high stocking densities, intensive cultivation and heavy use of trees for fuel wood, charcoal and souvenir production whose end result was a shift in the wood layer structure to a lower relative dominance and abundance.

Presence of vast covers of shrubs and forbs species in the study area is an indication of vegetation degradation. This observation has been made in other studies (Pratt & Gwyenne, 1977; Archer *et al.,* 2000) where bush encroachment, replacement of perennial grasses by annuals and land bareness are factors that have been found to have rendered wide areas of African drylands almost useless to livestock production. This observation also agrees with those of Heady (1975) where increase in shrubs is thought to be a result of the physical effects of herbivory and fire and Skarpe (1990) where relative availability of soil moisture and nutrients are said to be responsible for increase of shrubs where grasses have been depleted by over-grazing. In other cases cultivation activities have also been shown to alter vegetation structure (Reid *et al.,* 1997). According to research conducted in Mashuru division of Kajiado district by Macharia (2005), vegetation degradation occurs where indigenous shrubs and trees encroach onto former grassland areas changing them to various forms of shrubbed grasslands.

Konza ranch had the highest shrubs species richness (17 species). Ngaamba, Kiu and Ulu/Aimi ranches recorded five; four and two species respectively. ANOVA test revealed a significant difference in the mean abundance of shrubs species among the ranches with Konza ranch recording the highest abundance and Ulu/Aimi ranch the least. *Lantana camara* and *Solanum incanum* were the most common shrubs in the ranches and also had the highest cover. This could be interpreted to mean that the two shrub species were indicators of degradation due to their vast covers. Ulu/Aimi ranch recorded least abundance because grazing areas were in Aimi ranch which is the most recently sub-divided ranch and so was the case with Kiu ranch whose sub-division was done in the year 2000. High abundance in Konza and Ngaamba ranches could be as a result of their sub-division and settlement in 1976 leading to overgrazing thus establishment of bushes.

Skarpe (1990) observed that relative availability of soil moisture and nutrients are said to be responsible for increase of shrubs where grasses have been depleted by over-grazing. This could be said to be true for both Konza and Ngaamba ranches whose moisture contents were found to be high and this could be attributed to the presence of Kyundu and Mawa hills respectively. Seasons were also found to play part in the establishment of shrubs abundance and cover. During the dry season abundance and cover decreased but increased in the second wet season though the recovery was slow. Thus, Konza and Ngaamba ranches were the most degraded in relation to the time of their sub-division and settlement.

Results of ANOVA test revealed significant differences in the mean abundance of grass species among the ranches with the highest abundance being recorded in Ulu/Aimi (52) and Kiu (67) ranches respectively. There were no variations between Konza and Ngaamba ranches. Anova results also indicated more abundance in Ulu/Aimi grazing areas than cultivated farms. This could be attributed to the fact that Aimi ranch being the most recently sub-divided and yet to be settled, and Kiu ranch having been settled for the last 5 years, have not yet lost the perennial grass species thus, the vast covers. Konza and Ngaamba ranches had more species but mainly annuals (*Cyperus rubicundus*; *Cyperus niveus* and *Eragrostis cilianensis*) and so they were affected by seasons. Others were unpalatable to the animals such as *Eragrostis heteromera*; *Perotis patens* and *Panicum coloratum*.

Therefore Konza and Ngaamba ranches could be said to be more degraded due to the establishment of annuals as well as unpalatable species in relation to the time of their settlement. This observation has been made in other studies (Augustine & McNaughton, 1998) where they observed that herbivore pressure also changes the composition of herbaceous layer favoring unpalatable and chemically defended species. It is also supported by observations made in other studies (Pratt & Gwyenne, 1977; Archer *et al.,* 2000) where replacement of perennial grasses by annuals has been found to have rendered wide areas of African drylands almost useless to livestock production.

Results of ANOVA test showed significant differences in the mean abundance of forbs species among the ranches with Ulu/Aimi ranch recording the least abundance (38) followed by Kiu (59) ranch. Both Konza (67) and Ngaamba (84) had high abundance. There were no significant differences in the mean abundance of species between grazing areas and cultivated farms in Konza, Ngaamba and Kiu ranches. However there was a significant difference in the two land use types in Ulu/Aimi ranch with cultivated areas being more abundant. This confirmed observations made in other studies (Naveh, 1967; Hobbs & Hopkins, 1990) that in grasslands, as in most plant community types, soil disturbance creates openings for establishment, frequently of weedy or ruderal species. Where such disturbance has long been a component of the ecosystem, there is likely a substantial fraction of the flora that is specialized or adapted for establishment there. Thus in the Mediterranean region, where human agricultural and other activity has long created such soil disturbance, there is a large and successful group of weedy species. Low forbs abundance in Ulu ranch could be as a result of over cultivation due to its settlement in 1966, a fact that could be supported by observations made by Fuller (1987) that plowing diminishes species richness, especially that of dicots, in lowland grasslands.

Seasons also affected forbs species among the ranches with Kiu and Ulu/Aimi ranches being the most affected. This could be attributed to the fact that they are lowland ranchs with low moisture content as supported by the soil analysis results. This could also be supported by observations made by Larson & Gill (1971) that stirring the soil during cultivation increases the surface area of soil particles and aggregates exposed to the soil-atmosphere interface thereby increasing the potential for evaporation and water loss. More abundance in Konza and Ngaamba ranches could be associated with the time of their settlement which could have led to the replacement of perennial grasses by annual plants (Pratt & Gwyenne, 1977; Archer *et al.,* 2000).

From the findings, Konza ranch registered the highest diversity and abundance of trees, shrubs and forbs species followed by Ngaamba ranch. This could have been linked to high moisture content as a result of high rainfall infiltration since the two ranches are highland ranches and the presence of Kyundu and Mawa hills may have contributed to the spread of rainfall in the dry season thus supporting proliferation of species that dried in the lowland ranches where moisture diminished in hot weather. This observation concurs with findings of Skarpe (1990) where relative availability of soil moisture and nutrients were responsible for increase of shrubs where grasses have been depleted by over-grazing and Walker *et al* (1981) where the role of plant available moisture has been shown to be the most important factor governing the structure and function of savannas. More grasses abundance than forbs was evident in both Ulu/Aimi and Kiu ranches. Their grazing areas were more abundant with grasses than forbs and cultivated farms more abundant with forbs than grasses. Konza and Ngaamba ranches had more forbs abundance than grasses. This could be attributed to the time of their settlement.

5.2 Organic carbon and total nitrogen content in the study area

Results of ANOVA test revealed no significant differences in organic carbon among the ranches. There were also no significant differences in organic carbon between the land use types across the ranches. There were no significant differences in total nitrogen among the ranches and there were also no significant difference in total nitrogen between the land use types across the ranches

According to the broad ratings of carbon/nitrogen (Landon, 1984) the ranches were deficient in both elements. This could be as a result of exposure of soil due to vegetation removal reducing organic carbon. The decline can greatly be attributed to two cases. First, clearing and cultivation of land results to reduced rate of addition of vegetation organic material (Greenland & Nye, 1959) and secondly, the rate of decomposition of the soils organic carbon is accelerated as a result of a combination of factors favoring increased mineralization after clearing and cultivation (Lal & Okigbo, 1979). Nitrogen usually occurs in small amounts ranging from 0.02 to 0.4% by weight in the plough layer of majority of cultivated soils (Barber, 1984). Unfortunately, most of this nitrogen is not available to crops at any one particular time because most of it is organically bound (Jones, 1982).

In Konza grazing areas two gullies from surface runoff were noted in two transects and rill erosion was evident some transects of grazing areas in Ulu/Aimi ranch due to overgrazing. This may have affected moisture content in the grazing areas of the two ranches through soil exposure. Moisture content was also very low in Ulu/Aimi cultivated farms and this could be attributed to several events such as; it is the oldest settlement scheme (1966) and cultivation is so intense that tillage is done by ploughing; it is a lowland ranch where rainfall is minimal. This concurs with observations of the study done by Larson & Gill (1971) that cultivation usually affects soil water content by several mechanisms. Stirring the soil during cultivation increases the surface area of soil particles and aggregates exposed to the soil-atmosphere interface thereby increasing the potential for evaporation and water loss. Kyundu and Mawa hills may have contributed to the high moisture content in Konza and Ngaamba ranches respectively as they are highland ranches. Rainfall was also observed to have spread into the dry months of January-early March in the same ranches, thus contributing to wetness in dry season.

Soil water content affects nitrogen-availability by affecting microbial activity and by the transport of soluble nitrogen-containing compounds. Generally, microbial activity increases as soil water content increases from approximate wilting point to near field capacity, and then decreases as saturation is approached (Campbell, 1978; Sommers & Biederbeck, 1973). However, different groups of microorganisms predominate at different soil water tensions. Actinomycetes and fungi are most common in drier soils.

The consequences of continued complete removal of crop residues, without returning significant quantities of organic materials or nitrogen fertilizers, are evident from the history of early agricultural civilizations. Complete residue removal has been practiced in parts of North Africa, Western Asia, and elsewhere for centuries, and the accompanying soil deterioration is well known. It is evident from these experiments, as well as from numerous field experiments, that continued removal of crop residues depletes the soil organic nitrogen reservoir, and results in eventual loss of productivity (Clark & Rosswall, 1981). . This was observed in almost all the cultivated farms of the study sites.

Generally, soil organic matter and organic nitrogen content decreased for the first 25 to 50 years after natural grasslands were put under cultivation in Mississippi. The rate of decrease usually depended upon the cropping system and tillage practices used (Bauer & Kucera, 1978). This observation however contradicts my results as Kiu ranch was put under cultivation for last 7 years and therefore should not be depleted of both organic carbon and total nitrogen. However, I did not carry out investigations on cropping systems and tillage practices to ascertain their contribution in degradation of soil organic carbon and total nitrogen content.

5.3 Relationship between soil characteristics and diversity of herbaceous plants species

From the findings, it was observed that soil characteristics influence plant species either significantly or insignificantly, among them organic carbon, total nitrogen, soil pH and moisture. These parameters determine plant species abundance and richness. The results showed that grasses had no significant correlation with soil pH since pH is known to be a consequence of grass abundance and probably this explains why high pH (7.02) was recorded in Konza ranch grazing areas whose species richness was high compared to grazing areas of the other ranches. This could be attributed to high moisture content retained in the grass cover causing species proliferation.

However, soil moisture was found to have a significant correlation with grass species richness. This could be attributed to the ability of grasses to retain moisture owing to vast cover and abundance. The fact that Konza and Ngaamba ranches are highland ranches could also have contributed to high moisture content leading to high species richness. Organic carbon and total nitrogen were not found to have significant correlation with grass species richness. This concurs with earlier findings by Walker *et al* (1981) where the role of plant available moisture has been shown to be the most important factor governing the structure and function of savannas.

Soil pH was however, found to have a significant correlation with shrubs species. This is true for Konza ranch where high pH was recorded and also highest number of shrubs species. Soil moisture, organic carbon and total nitrogen had no significant correlations with shrubs species richness. This is not true for Konza ranch with regard to soil moisture content as most species were recorded during the first wet season. Shrubs species abundance was also seen to increase with increase in soil moisture content. It also contradicts the findings of Skarpe (1990) where relative availability of soil moisture and nutrients were responsible for increase of shrubs where grasses have been depleted by over-grazing. It also contradicts observations made by Stevenson (1974) that the amount of organic carbon in the soil is very variable and climate and vegetation are the most important factors affecting the soil organic carbon content under natural conditions. It has also been confirmed that sites with abundant vegetation have relatively more organic matter. Also trees/bush sites have consistently higher organic content, while bare ground has the least (Kironchi, 1992).

There were no significant correlations between soil pH; soil moisture; organic carbon and total nitrogen content and forbs species. This contradicts the findings of my research where more forbs species were recorded in Konza ranch grazing areas (14 species) and cultivated farms (18 species) as well as in Ngaamba ranch cultivated farms (12 species) whose pH values were higher than in other ranches. Konza ranch had pH values of 7.01 and 7.02 in grazing areas and cultivated farms respectively while Ngaamba cultivated farms had pH value of 6.99. Forbs species were more during the first wet season of data collection. Their abundance was also noted to increase during the wet seasons. It also contracts the fact that Konza and Ngaamba are highland ranches with high moisture contents, thus high species richness and abundance.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1: Conclusion

Ulu ranch was confirmed to be the most degraded in terms of trees and forbs species abundance and richness having been transformed in 1966 from a livestock only ranch to a settlement that solely concentrates on crop cultivation and rearing of a few animals. All the trees have been cut to pave way for cultivation and grazing areas completely eliminated such that farmers have turned to the neighboring Aimi ranch for grazing and wood fuel. The cultivated farms recorded only invasive species whose abundance and richness was low a confirmation that plowing diminishes species richness, especially that of dicots, in lowland grasslands (Fuller, 1987).

Konza ranch was found to be the second most degraded ranch in terms of encroachment by invasive species both of forbs and shrubs whose abundance surpassed that of indigenous grasses. Forbs and shrubs invaded both grazing areas and cultivated farms. It is in this ranch that 3 species of unpalatable grasses were recorded, 2 (*Perotis patens* and *Eragrostis heteromera*) in an area whose soil texture was found to be sandy clay, and confirmed to be unproductive after 30 years of cultivation. *Panicum coloratum* was found in the grazing areas which could have been a result of overgrazing due to reduced grazing areas arising from increased population resulting in small pieces of land per family (1 acre). It was subdivided in 1976 together with Ngaamba ranch whose findings were not very different from those of Konza ranch.

Aimi ranch was included in the study due to lack of grazing areas in Ulu and was being subdivided by the time of data collection (2006-2008) therefore vegetation degradation in terms of perennial grasses was minimal and it was the only ranch with vast areas of grass cover. It was encroached by two species of shrubs (*Lantana camara* and *Solanum incanum*) and 2 forbs species (*Indigofera tanganyikensis* and *Oxygonium sinuatum*) the latter being annual.

Despite different times of transformation, all the ranches were found to have very low quantities of both organic carbon and total nitrogen. There were no significant differences in organic carbon and total nitrogen between land use types among the ranches. Konza ranch was confirmed to be the richest ranch in both tree and herbaceous species. This could be attributed to high moisture content and high pH values contrary to the correlation results which showed otherwise. Both Konza and Ngaamba ranches are highland ranches where moisture content was high and also where most species richness and high abundance were found. It could not be established whether vast covers of shrubs in Konza ranch were a result of lack of herbivory or overgrazing since no grazing was witnessed in most of the grazing areas as some areas are yet to be settled. Where tethering of animals was witnessed, effects of overgrazing were live such as presence o*f Panicum coloratum.*

In relation to cover, shrubs species with vast covers can be said to be indicators of degradation since grasses were observed to have been eliminated in areas they occupied in the study area and they include; *Solanum incanum*; *Lantana camara*; *Ocimum kilimandscharicum*; *Microglossa pyrifolia*; *Pycnostachys umbrosa*; *Indigofera ambelacensis*; *Hibiscus micranthus* and *Ipomea hildebrandtii.* In grasslands, grasses should be perennial and palatable to livestock.

Therefore, those that can be grouped as indicators of degradation due to their annual nature include; *Digitaria milanjiana*; *Cyperus rubicundus*; *Cyperus niveus*; *Eragrostis cilianensis* and *Eragrostis superba.* Those that can grouped as indicators of degradation due to their unpalatability include; *Perotis patens*; *Eragrostis heteromera* and *Panicum coloratum.* Forbs species to be included in the list of indicators of degradation due to their unpalatability and replacement of grasses include; *Indigofera tanganyikensis*; *Portulaca oleracea*; *Asystasia schimperi* and *Euphorbia hirta.*

6.2: Recommendations

Grasslands are known to play important role in the survival of both livestock and wildlife. Grasslands are also known to be habitats for many other animals including birds as was witnessed in the ranches under investigation. These animals are crucial to the growth of our economy. The results of this study clearly demonstrates that trends of degradation of the ranches in South East Kenya are on the increase due to the continuing fragmentation of commercial ranches, a factor seen to be having effects on the neighboring unfragmented ranches.

Therefore the following points need to be put into consideration.

- The ranches were found to be frequented by wildlife and were also habitats to many species of birds a factor that calls for immediate conservation measures of the remaining ranches and game reserves to avert extinction of wildlife.
- There is a looming danger of desertification in the ASALs if the trend of tree cutting without replacement continues as was witnessed in the settled areas.
- There is a looming danger of human wildlife conflict either by farmers invading grazing areas in the neighboring game reserves or wildlife invading farms once the ranches are fully settled and cultivated.
- Since it is known that arid and semi- arid soils are low in fertility and that soil organic carbon and total nitrogen content decreased in the first 25 to 50 years after natural grasslands have been put under cultivation (Bauer & Kucera, 1978), it is important to sensitize farmers on the need for residue placement to increase soil organic matter.
- More research needs to be done in the study area to confirm that sites with abundant vegetation have relatively more organic matter and that trees/bush sites have consistently higher organic content, while bare ground has the least (Kironchi, 1992), since I was not able to investigate owing to time, distances between the ranches and available resources.
- Further investigations on cropping systems and tillage practices to ascertain their contribution in degradation of soil organic carbon and total nitrogen content in the study area should be done.

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APPENDICES:

Appendix 1: Broad ratings of nitrogen and carbon

N. Content

Kjeldahl method

Nitrogen (total)

(% soil by weight)	Rating
>1.0	Very high
0.5-1.0	High
0.2-0.5	Medium
0.1-0.2	Low
<0.1	Very low

Organic C content

Walkley-Black method

(% soil by weight)	Ratings
>20	Very high
10-20	High
4-10	Medium
2-4	Low
<2	Very low

Modified by (Landon, 1984).

Appendix 2: Shrub species recorded in various ranches, their distribution across seasons and different land use types

Konza ranch

	Percentage cover in each season		
Species	Wet 1	Dry	Wet 2
Solanum incanum	30	15	20
Lantana camara	40	25	30
Melhania velutina	15	0	0
Abuliton mauritianum	15	0	0
Ocimum kilimandscharicum	10	5	8
Aspilia pluriseta	5	0	0
Microglossa pyrifolia	20	0	0
Tridax procumbeas	5	2	3
Pycnostachys umbrosa	30	15	20
Asparagus falcatus	10	10	10
Ormocarpum kirkii	3	2	2
Indigofera ambelacensis	15	10	12
Phyllanthus sepialis	5	2	3
Combretum collinum	4	2	3
Terminalia brownii	2	1	1
Ocimum grutissimim	10	5	8
Hibiscus micranthus	25	10	15
Kiu ranch			
Solanum incanum	20	10	15
Lantana camara	40	25	30
Melhania velutina	10	5	8
Ipomea hildebrandtii	15	10	15
Ulu ranch			
Solanum incanum	15	5	10
Lantana camara	30	15	20
Ngaamba ranch			
Solanum incanum	20	15	20
Lantana camara	40	30	35
Melhania velutina	5	3	5
Abuliton mauritianum	5	3	5
Ocimum kilimandscharicum	15	10	15

Shrubs species recorded in different land use types

Ranch	Konza		Ngaamba		Kiu		Ulu/Aimi	
	Land use type (% cover)							
Species	G	C	G	C	G	C	G	C
Solanum incanum	15	7	18		15		10	
Lantana camara	32		35		32		22	
Melhania velutina	5		3	1	8			
Abuliton mauritianum	5		3	1				
Ocimum kilimandscharicum	8		13					
Aspilia pluriseta	2							
Microglossa pyrifolia	10							
Tridax procumbeas	3							
Pycnostachys umbrosa	22							
Asparagus falcatus	10							
Ormocarpum kirkii	2							
Indigofera ambelacensis	12							
Phyllanthus sepialis	3							
Combretum collinum	3							
Terminalia brownii	1							
Ocimum grutissimim	5	3						
Hibiscus micranthus	17							
Ipomea hildebrandtii					13			

Key: G…Grazing; C…Cultivated

Appendix 3: Grasses species recorded in various ranches, their distribution across seasons and different land use types

Konza ranch

	Percentage cover in season		
Species	Wet 1	Dry	Wet 2
Cenchrus ciliaris	5	5	5
Cyperus rotundus	2	0	0
Eragrostis heteromera	5	5	5
Eragrostis superba	10	10	10
Perotis patens	5	5	5
Panicum coloratum	20	10	20
Cynodon ulemfuensis	10	0	0
Digitaria milanjiana	3	0	0
Cyperus rubicundus	1	0	0
Cyperus niveus	1	0	0
Pennisetum mezianum	5	5	5
Bothriochloa insculpta	5	5	5
Brachiaria leersiodes	5	5	5
Dactyloctenium aegyptium	5	5	5
Sedge			
Cyperus rotundus	2	0	0
Ngaamba ranch			
Cenchrus ciliaris	60	40	50
Eragrostis cilianensis	10	0	0
Sedge			
Cyperus rotundus	10	0	0
Kiu ranch			
Eriochloa meyerana	15	0	10
Cynodon dactylon	35	25	35
Eragrostis cilianensis	10	0	0
Chloris roxburghiana	15	10	20
Sporobolus pyramidalis	15	0	20
Harpachne schimperi	10	0	10
Ulu ranch			
Sedge			

Cyperus rotundus	10	0	0
Eragrostis superba	10	0	0
Sporobolus pyramidalis	20	20	20
Brancharia nigropedata	50	50	50

Grasses species recorded in different land use types

Ranch	Konza		Ngaamba		Kiu		Ulu/Aimi	
	Land use type (% cover)							
Species	G	C	G	C	G	C	G	C
Cenchrus ciliaris	5		50					
Cyperus rotundus		1		3				13
Eragrostis heteromera		5						
Eragrostis superba	10						3	
Perotis patens		5						
Panicum coloratum	17							
Cynodon ulemfuensis	3							
Digitaria milanjiana	1							
Cyperus rubicundus	0.3							
Cyperus niveus	0.3							
Pennisetum mezianum	5							
Bothriochloa insculpta	5							
Brachiaria leersiodes	5							
Dactyloctenium aegyptium	5							
Eragrostis cilianensis			3			7		
Sporobolus pyramidalis					17		20	
Brancharia nigropedata							50	
Eriochloa meyerana					10			
Cynodon dactylon					40			
Chloris roxburghiana					15			
Harpachne schimperi					10			

Key: G…Grazing; C…Cultivated

Appendix 4: Forbs species recorded in various ranches, their distribution across seasons and different land use types

Konza ranch

	Percentage cover per season		
species	Wet 1	Dry	Wet 2
Commelina benghalensis	2	2	2
Oxygonium sinuatum	1	1	1
Indigofera tanganyikensis	5	3	5
Ocimum obovatam	5	1	0
Ipomea obscura	5	1	0
Sonchus oleraceus	3	1	0
Mexican merigold	5	2	3
Bidens pilosa	2	1	2
Leucas grandis	6	0	0
Glycine wightii	2	1	0
Solanum renschii	5	0	0
Ageratum conyzoides	1	0	0
Monechma debile	1	0	0
Justicia striata	1	0	0
Phyllamitius spatensi	1	0	0
Crossandra subacaulis	1	1	1
Orthosiphon parvifolium	1	1	1
Trichodesma zeylanicum	10	10	10
Emilia coccinea	3	2	3
Launaea cornuta	10	10	10
Tagetes minuta	2	0	0
Indigofera spinosa	0	0	2
Leucas micranthus	1	0	0
Abutilon fruticosum	5	0	0
Achyranthus asperagus	1	0	0
Ngaamba ranch			
Endostemon tereticaulis	10	0	0
Commelina benghalensis	10	10	10
Oxygonium sinuatum	10	5	10
Portulaca oleracea	5	5	5
Asystasia schimperi	3	0	0

Euphorbia hirta	10	0	0
Commelina africana	5	0	0
Indigofera tanganyikensis	20	15	20
Ocimum obovatam	0	0	5
Ipomea obscura	0	0	5
Sonchus oleraceus	0	0	10
Mexican merigold	10	5	10
Bidens pilosa	8	4	10
Leucas grandis	0	0	5
Glycine wightii	0	0	5
Ageratum conyzoides	5	0	0
Trichodesma zeylanicum	5	0	0
Emilia coccinea	0	5	10
Launaea cornuta	5	0	0
Tagetes minuta	10	5	10
Indigofera spinosa	3	1	2
Leucas micranthus	4	2	3
Achyranthus asperagus	10	5	10
Kiu ranch			
Endostemon tereticaulis	20	0	0
Commelina benghalensis	10	5	8
Oxygonium sinuatum	5	1	2
Justicia exigua	6	0	0
Cleome monophylla	1	0	0
Portulaca oleracea	2	2	5
Asystasia schimperi	3	0	0
Indigofera tanganyikensis	10	10	20
Leucas grandis	0	0	5
Leucas pratensis	0	0	5
Ulu ranch			
Commelina benghalensis	5	3	5
Oxygonium sinuatum	10	5	10
Portulaca oleracea	5	5	5
Gynandropsis gynandra	5	0	0
Tribulus cistoides	8	0	0
Indigofera tanganyikensis	30	25	30
Sonchus oleraceus	10	0	5

Mexican merigold	5	0	3
Bidens pilosa	5	0	4
Emilia coccinea	10	0	0
Achyranthus asperagus	5	0	5

Forbs species cover in different land use types

Ranch	Konza		Ngaamba		Kiu		Ulu/Aimi	
	Land use type (% cover)							
Species	G	C	G	C	G	C	G	C
Commelina benghalensis	1	1	3	7	2	6		5
Oxygonium sinuatum		1	3	5		2	2	8
Indigofera tanganyikensis	4		18		13		28	
Ocimum obovatam	2	1		2				
Ipomea obscura	2	1		2				
Sonchus oleraceus		1		3				
Mexican merigold		3		8				3
Bidens pilosa		2		7				3
Leucas grandis	2	1		2		2		
Glycine wightii	1			2				
Solanum renschii	0.3							3
Ageratum conyzoides	1	1		2				
Monechma debile	0.3							
Justicia striata	0.3							
Phyllamitius spatensi	0.3							
Crossandra subacaulis	0.3							
Orthosiphon parvifolium	1							
Trichodesma zeylanicum	1							
Emilia coccinea		10						3
Launaea cornuta	2	1						
Tagetes minuta		10						
Indigofera spinosa		1						
Leucas micranthus	1							
Abutilon fruticosum	0.3							
Achyranthus asperagus	1	1						3
Leucas pratensis						2		
Endostemon tereticaulis				3	2	5		
Portulaca oleracea				5		3		5

Asystasia schimperi			1		1			
Euphorbia hirta			3					
Commelina africana			2					
Gynandropsis gynandra								2
Tribulus cistoides								3
Justicia exigua					1	2		
Cleome monophylla						0.3		

Appendix 5: Association between herbaceous plants and soil characteristics

Correlations

	Grasses (n=21)	Shrubs (n=18)	Forbs (n=35)
Soil pH	0.24, p = 0.267	-0.4, p = 0.029*	0.2, p = 0.359
Moisture	-0.53, p = 0.008*	0.06, p = 0.196	-0.17, p = 0.432
Organic carbon	-0.35, p = 0.096	0.61, p = 0.879	-0.02, p = 0.810
Total nitrogen	-0.25, p = 0.246	0.42, p = 0.629	-0.18, p = 0.414

*Correlation is significant at 0.05 levels

Appendix 6: Check list of plant species collected in the study sites

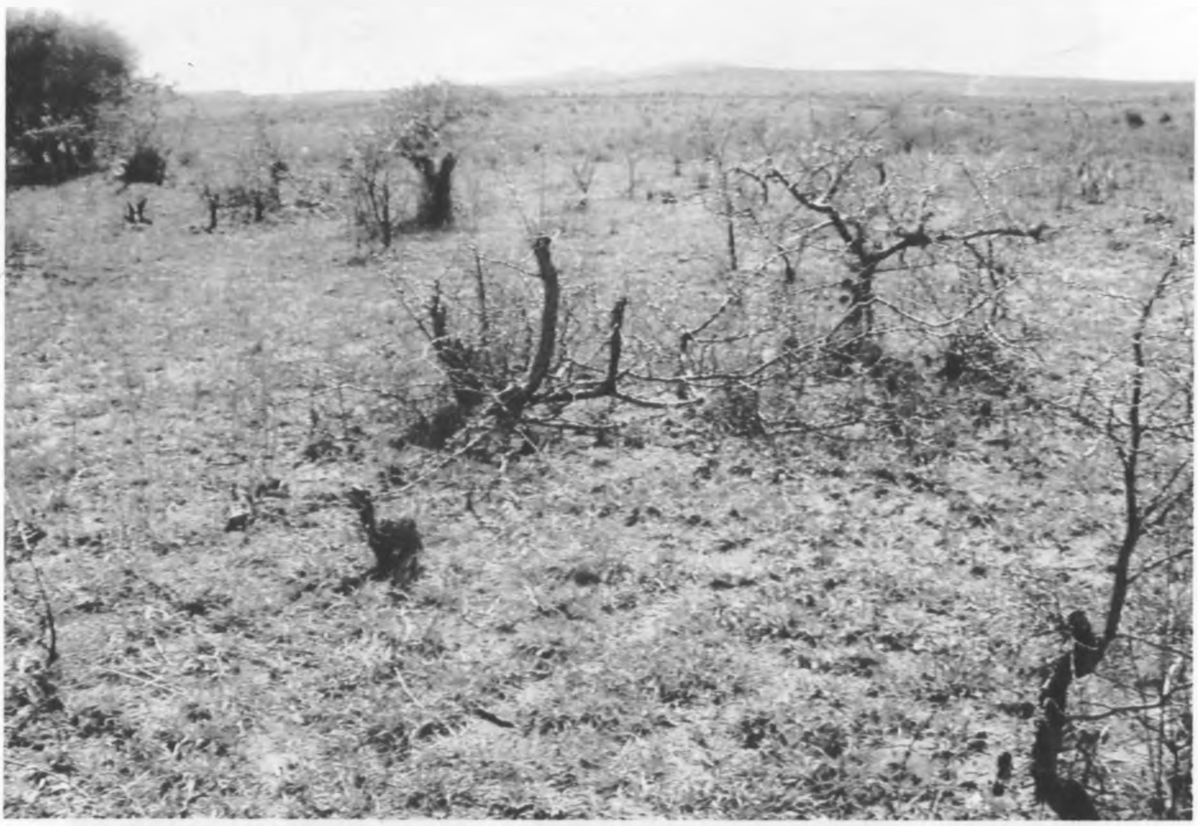
FAMILY	SPECIES	LIFE FORM
Labiatae	*Endostemon tereticaulis* (Poir.) Ashby	Herb
	Ocimum kilimandscharicum Gurke	Shrub
	Ocimum obovatam (E. Mey. ex Benit.) N. E Br.	Herb
	Leucas grandis Gurke	Herb
	Orthosiphon parvifolium Vatke	Herb
	Leucas micranthus Gurke	Herb
	Commelina benghalensis Wall.	Herb
	Commelina Africana L.	Herb
Gramineae	*Eriochloa meyerana* (Nees) Pilg.	Grass
	Cynodon dactylon (L.) Pers	Grass
	Chloris roxburghiana Schult	Grass
	Sporobolus pyramidalis P. Beauv.	Grass
	Eragrostis cilianensis (All.) Link ex Lutati	Grass
	Harpachne schimperi A. Rich.	Grass
	Cenchrus ciliaris L.	Grass
	Brancharia nigropedata (Ficalho and Hiern) Stapf	Grass
	Eragrostis heteromera Stapf	Grass
	Eragrostis superba Peyr.	Grass
	Perotis patens Gand.	Grass
	Panicum coloratum L.	Grass
	Cynodon ulemfuensis Vanderyst.	Grass
	Digitaria milanjiana (Rendle) Stapf	Grass
	Dactyloctenium aegyptium (L.) Willd.	Grass
	Brachiaria leersiodes (Hochst.) Stapf	Grass
	Bothriochloa insculpta (Hochst. ex A. Rich) A. Rich	Grass
	Pennisetum mezianum Leeke	Grass
Polygonaceae	*Oxygonum sinuatum* (Meisn.) Dammer	Herb

Acanthaceae	*Justicia exigua* S. Moore	Herb
	Asystasia schimperi T. Anderson *Monechma debile* (Forssk.) Nees *Justicia striata* (Klotzsch) *Crossandra subacaulis* C. B. Clarke	Herb Herb Herb Herb
Capparaceae	*Cleome monophylla* L. *Gynandropsis gynandra* (L.) Brig.	Herb Herb
Portulacaceae	*Portulaca oleracea* L.	Herb
Solanaceae	*Solanum incanum* L. *Solanum renschii* Vatke	Shrub Herb
Euphorbiaceae	*Euphorbia hirta* L.	Herb
Cyperaceae	*Cyperus rotundus* L. *Cyperus rubicundus* Vahl *Cyperus niveus* Retz	Grass Grass Grass
Zygophyllaceae	*Tribulus cistoides* L.	Herb
Leguminosae	*Indigofera tanganyikensis* Baker, F. *Glycine wightii* (Wight and Arn.) Verdc. *Indigofera spinosa* Forssk *Acacia kirkii* Oliv. *Acacia tortilis* Forssk.	Herb Herb Herb Tree Tree
Verbenaceae	*Lantana camara* L.	Shrub
Burseraceae	*Commiphora Africana* (A. Rich.) Engl	Tree
Compositae	*Bidens pilosa* L. *Tagetes minuta* L. *Sonchus oleraceus* L. *Aspilia pluriseta* Schweinf. ex Engl. *Ageratum conyzoides* L. *Launaea cornuta* (Hochst. ex Oliv. and Hiern) C. Jeffrey *Emilia coccinea* (Sims) Sweet	Herb Herb Herb Shrub Herb Herb Herb
Sterculiaceae	*Melhania velutina* Forssk	Shrub

Convolvulaceae	*Ipomoea obscura* (L.) Ker Gawl Var. Obscura	Herb
	Ipomoea hildebrandtii Vatke	Shrub
Malvaceae	*Abutilon mauritianum* (Jacq.) Sweet *Hibiscus micranthus* L. F	Shrub Shrub
Balanitaceae	*Balanites aegyptiana* (L.) Delile	Tree
Boraginaceae	*Trichodesma zeylanicum*(Burm. f) R. Br.	Herb
Anacardiaceae	*Lannea schwenfurthii* (Engl.) Engl	Tree

Appendix 7: Photos of some indicators of degradation in the study sites

Tree stumps and soil bareness in Ulu/Aimi ranch grazing areas

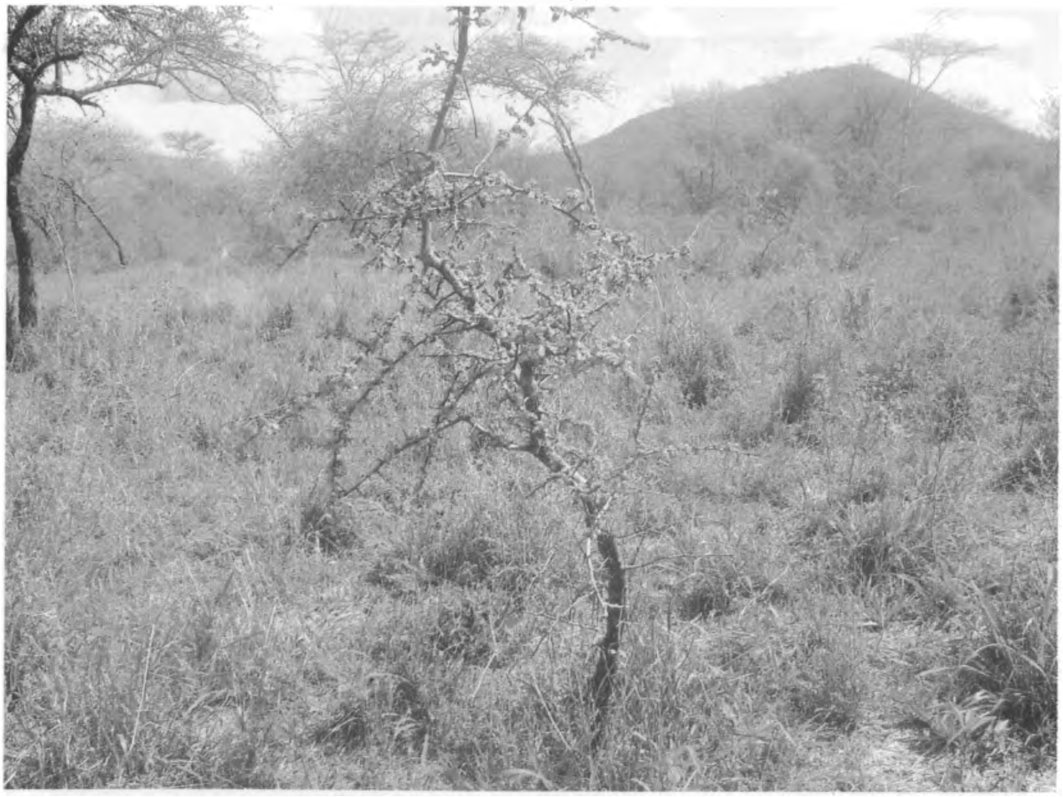


Perotis patens and *Eragrostis heteromera*

Indigofera tanganyikensis and *Melhania velutina*

Microglossa pyrifolia

Panicum coloratum



Solanum incanum

Hibiscus micranthus

Asparagus falcatus

Cyperus rotundus