IMPACT OF LAND-USE ON VEGETATION RESOURCES AND SOCIO-ECONOMIC ENVIRONMENT IN KAKUMA DIVISION, TURKANA DISTRICT, KENYA: A CASE STUDY OF A PASTORAL COMMUNITY.

BY

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DECLARATION

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

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DEDICATION

This work is dedicated to the Almighty God who has given me life and strength to be what I am today. My family has also given me support and a habitation of peace, to you I dedicate this work too.

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ABSTRACT

This study was conducted in the northern part of Kenya, Turkana district, in Kakuma division. Its aims were to study the impact of human settlement on vegetation and soil resources and the socio-economic environment.

Kakuma is a semi-arid area under nomadic pastoralism as the main activity. This area has a high population concentration than other areas. The presence of the refugee camp has attracted many people from within the turkana community and also the outside community. This has in turn had an effect on the vegetation and the social patterns of the local community.

Vegetation plays an important role in the sustenance of the Turkana people, either directly (food) or indirectly (forage for animals). For the study of vegetation, 4 transects, each 6 Km long, were laid from the settlement camp. Vegetation density, cover and diversity values were taken for trees, shrubs and herbs at the intervals of 1 Km. The 6th Km from the settlement camp acted as the control. There was a significant difference *($P>0.05$)* in vegetation cover, density and diversity along distance gradient. The mean tree crown cover was low near the settlement camp-6.24%, but high away from the settlement camp-57.69%, as many trees were cut down for charcoal burning, firewood and building poles. The density was high near the settlement camp as many trees were re-sprouts and young trees. The cover of this was low compared to mature trees. Shrub crown cover was low in the 1st and 4th Km, 0.87% and 3.54% respectively, compared with 6.84%, 9.82% and 7.8% for the 2nd, 3rd and 5th Km. Areas around the 1st and 4th Km had settlements. The need for fencing and building materials was the main cause of low shrub cover. The density of the shrub species generally increased as one moved away from the settlement camp. Shrub species most cut were *Acacia reficiens, Acacia mellifera* and *Abutilon fruticosum.* Herb species cover and density was high near the settlement camp 68% and 202.17 individuals/m^2 compared to 45.43% and 187 individuals/m^2 at the 6th Km., but this comprised mostly of species unpalatable to livestock like *Tribulus terrestris* and *Portulaca oleraceae.* Though herb cover was low away from the settlement camp, the proportion of palatable species was high. Species diversity was low for trees and shrubs near the settlement camp but high for herb species. Direct cutting into tree and shrub

species must have reduced the number of species available. The high number of herb species was a result of over-utilization of palatable species.

The region in the recent past has undergone various ecological and social changes due to various factors. The study revealed that droughts and livestock raids in the previous years have set in motion social and ecological changes. The loss of livestock through raids and droughts has encouraged the sedenterization of the Turkana. Many families opted to settle after losing their livestock and abandon their pastoral lifestyles. This has not only affected their cultural patterns but has had an effect on the rangeland condition. Lack of mobility had concentrated livestock in specific areas depleting the forage resources and creating conditions for soil erosion. The study revealed that the range condition was poor near the settlement camp.

The Turkana population near the settlement camp consisted mainly of the destitute families who had lost their livestock in raids and droughts. The refugee camp within the division has been their main source of income especially through trade. Trading activities included the sale of cereals, clothing materials and household goods to the Turkana. They occasionally exchanged the items with livestock. At the same time the Turkana sold building materials and wood-fuel to the refugees and people within the settlement camp. Apart from this they also sold livestock to the refugee camp. The most common sold livestock were goats and camels. Apart from trading activities they also came to Kakuma in search for employment mostly in the refugee camp. School enrolment was low as many school-going age children opted to look for a part time work within the refugee camp to earn some money.

Though there were already some changes in the pastoral lifestyle of the Turkana around the Kakuma area, the introduction of the refugee camp has hastened the process of change. The increase in population has set in motion various changes that have affected not only the vegetation but also the social structures within the Kakuma area. In regard to this there is a need for education on the impacts, both short term and long term, of the various activities on the vegetation, livestock resources and also the pastoral lifestyle. This is also necessary since the refuge camp may be relocated or closed down in future.

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CHAPTER 1

1.0 INTRODUCTION

In the recent past there has been a lot of pressure on the resources in the arid and semi-arid lands (ASALs). Neither humans nor livestock can survive in the arid areas without the other i.e. it is a symbiotic relationship. Land use in this pastoral society has traditionally been governed by a complex sophisticated set of rites and traditions, which provides access to vital although precarious resources. Common property resources, the use of land as well as other natural resources such as water, vegetation and saltlicks was regulated to prevent monopolization and degradation through overuse (Joeckes and Pointing, 1991). Various factors have necessitated a change in the exploitation of the resources in the ASALs in Kenya. Some of the factors that have caused a change in the mode of resource exploitation are rapid population growth, changing property rights, insecurity, climatic changes and environmental degradation. It is however noted that no single factor leads to environmental degradation in the drylands than rapid population growth (World Bank, 1989). This has in turn affected the vegetation density, cover, diversity, frequency and soil status (Jones, 1973; Swift *et al.*, 1996; Sinha, 1996; Lusigi, 1984; Jan Bojo, 1992).

The setting of refugee camps in ASALs has had a negative impact on the ecological integrity of the areas. Lazarus (1993) analyses the chain process of refugee influx: refugees cut down trees and bushes for fuel-wood and construction. He noted that for cooking every ton of wheat or beans, three tons of firewood is needed. The denudation of the landscape for cooking fuels in turn exacerbates the erosion of the environment. The less the vegetation, the less the rain trapped and infiltration into the soil; the less the trapped rain, the less the vegetation; the less the vegetation, the more the erosion; and so people must walk further for fetching firewood. The more the effort people have to put into searching for fuel-wood, the less they have to do about the havoc they wreak on the land on which they try to live (UNHCR, 1997; UNICEF/UNSO, 1992).

1.1 JUSTIFICATION FOR THE STUDY

In the arid Turkana ecosystem, different vegetation types play an important role in the management of livestock, in the provision of habitats for wildlife and in supply of energy, food, shelter materials and fibre requirements for the human population (Amuyunzu and Oba, 1991; Skarpe, 1991; Reid, 1995).

Trees have always played an important role in the pastoral economy and many species are valued and protected for their particular uses. In general terms, the more arid the climate, the more important the woody vegetation becomes, it is considered the most important stabilizing component in maintaining the long term productive capacity of the environment (Zumer-linder, 1983). Vegetation and land degradation in the arid zones assume different pathways; some are chiefly induced by climatic events while others are induced by human activities e.g. deforestation, cultivation and livestock grazing (Fernandez-rivera, 1995). A change in vegetation attributes is bound to affect or alter the traditional pastoral ecosystem since they depend on livestock resources that are maintained by vegetation. These changes might all have a long-term impact on the environment, especially on sustainable development.

Kakuma division of Turkana district has for a long time been reserved as a dry season grazing land (Herlocker *et al.*, 1991). Also due to frequent famines and droughts it was used as a relief food distribution center and administration center (Mohammed, 1992). Because of this the area attracted many people from the local population. But with the introduction of the refugee camp in 1992 the population within the division grew exceeding the capital of Turkana, Lodwar. This has a profound impact on the environment.

An understanding of the interactions between the human and livestock population and the environment will help us appreciate or broaden our strategies of planning for the range resources. There is need to build informed strategies to handle the damage on the environment once the refugees pressure is removed. Turkana as a range area is used for this case study.

1.2 OBJECTIVES

1.2.1 Broad objective

To assess the impact of land use on environmental quality using vegetation and soil resources and describe socio-economic patterns within Kakuma division, Turkana district.

1.2.2 Specific Objectives

a). Assess the impact of human settlement on the vegetation and soil attributes.

b). Describe the socio-economic patterns among the Turkana of Kakuma division.

1.2.3 Hypothesis

There is no change in soil and vegetation attributes with increasing distance from the settlement camp.

CHAPTER 2

2.0 LITERATURE REVIEW

2.1 LAND USE IN DRYLANDS IN AFRICA

2.1.1 Size and characteristics of drylands

Arid and semi-arid lands in tropical Africa constitute more than 50% of the land surface area (Skoupy, 1988) and support about 49% of the human population (Stiles, 1998). It has been estimated that 13 – 16 million Km^2 or nearly half of the continent South of the Sahara is desert or arid grassland and savanna where cultivation is a high-risk enterprise (Cossins, 1983). These are areas having climates that are marginal or totally unsuitable for rain-fed agriculture. Drylands vary in most of their physical and biological characteristics, amount of rainfall, length of the dry season, soil characteristics and density of trees, fauna and microorganisms. Spatial variability of rainfall is a key feature of the regional climate in Kenya's arid and semi arid lands. Rainfall is patchy particularly over short time scales. This variability in turn determines patterns of human occupation and land use (Young and Solbrig, 1990; Swift *et al.*, 1996).

In Kenya, the arid and semi-arid Lands comprises of about 80% of the total land area and carry over 25% of the total human population and slightly over half of the livestock population. The majority of people living in these areas are pastoralists although semi-pastoral and farming communities as well (Government of Kenya, 1978 – 83; Kiome and Ndiritu, 1995). Lusigi (1980) estimated that of the total 80% arid land in Kenya, 52% is very arid, 19% is arid and 17% semi-arid. Rainfall varies from less than 150mm-400mm or more at higher elevations (Lusigi, 1980; Swift et al, 1996; Pratt and Gwynne, 1977). The rainfall pattern is largely bi-modal, with peaks in April and November. In many cases the potential evepotranspiration rate (PE) is in excess of 2,500mm/year (Swift *et al.*, 1996). This implies that most of the precipitation is evaporated back to the atmosphere hence not utilized by the plants, especially deep-rooted plant species.

2.1.2 Traditional pastoral production systems

People living in drylands depend heavily on ecological resources, animals and vegetation, for their subsistence. In many areas, native plants and animals provide energy for cooking and heating, medicines, veterinary products, vital objects or substances, food, building materials and trade items (Lusigi, 1980; Stiles, 1998). The many years of interaction with their environment has made pastoralists develop strategies to enable them in this harsh environment. Their vast knowledge about their environment has enabled them develop an elaborate system of resource management for very many years. Knowledge of the soils, the seasons, vegetation attributes such as cover and species is important for their survival. Sometimes this knowledge of the environment transcends technical notions such as carrying capacity and allows them to link ecology with cosmology and religious values (Mohammed, 1992).

Cossins (1983) summarized pastoral production systems in East Africa as follows:-

1. Maintenance of more than one species of livestock. This ensures maximized yields by ensuring that all niches are full and all resources are used. Niche separation occurs not only because different species consume different plants but also because different species can utilize different types of terrain, consume forage at different heights in the plant community, and have different watering requirements which converts to different travelling distances from watering sources. Unpredictable environmental conditions may favor different species such that a diversity of livestock will ensure that some livestock species survive as environmental conditions change. Different animals provide a wide range of products at different times e.g. small stock have high reproductive rates and small body sizes which provide meat products easily while large stock provide milk and blood when required (Swift *et al.*, 1996; Lamprey, 1983).

2. Division of livestock holdings into spatially separate units to minimize the effects of localized droughts. This reduces or spreads the risk of livestock loss. Livestock species are often best suited to different vegetation, topography and water availability, and each species will forage under optimal conditions (Lamprey, 1980). If all are kept together, there is a danger that all will simultaneously fall victim to disease, disaster or raiding. During drought animals are split according to their economic function.

Toulmin (1993), observed that the pastoralists spread their livestock over a large area at a low stocking rate especially when grasses are flowering and setting seed, to avoid damage to grass. This reduces grazing pressure on forage near homesteads and improves foraging conditions for animals producing milk for the vulnerable members of the pastoral family.

The pastoralists seasonal movements are planned, usually involving movement from wet season to dry season range e.g. among the Turkana of Kenya, moving from the wet season range on the Turkana plains to a dry season range at the rift escarpment. Mobility results in complex patterns of aggregation and dispersal of pastoralists and their herds, and so affects spatial and temporal patterns of grazing intensity. Among the Ngisonyoka in Turkana, people and livestock are most strongly aggregated during wet season, when conditions provide adequate forage and drinking water for all livestock within a small area. People remain together during this period because environmental conditions permit aggregation (Swift *et al.*, 1996). At the onset of the dry season, when the forage resources start declining social groups begin to disperse. Mobility is a response to the urge or need to maintain the continuous health and production of livestock (Oloka-Onyango *et al.,* 1993; Katie, 1993; Zumer-linder, 1983; Skoupy, 1998; Toure, 1990). When mobility is motivated by concern to avoid diseases or other threats to humans, the aim is to minimize risk of death for both animals and humans.

3. Establishment and maintenance of a special system of sharing, borrowing, lending and giving resources to relations, kinsmen and friends within the clan or outside the clan and sometimes in different geographical areas.

4. Maintenance of large herds or as large as possible to maximize the chances of having some left when the drought is over. There are various reasons that necessitate the keeping of large numbers of animals. This includes the daily dietary requirements of milk and sometimes meat and blood, high bride price in the cases of marriage and the cultural valuation of wealth and societal status. The Karamajong adage that 'every man wants to find a wife, friends, and happiness: to become a man of importance and influence. Without cattle he cannot achieve any of these things', explains the above point (Widstrand, 1975). Livestock being the sole investment available to them, also makes them aim to maintain a level of production adequate for current needs and subsistence, while also creating a buffer

against the uncertainties and risks of their environment. Lamprey (1983) estimated that sometimes they keep more animals by 50% to carter for possibilities of drought, disease and cattle raiding.

5. During drought period or disaster, they minimize the reliant human population by sending away all able-bodied people not required in the system to work in adjacent agricultural areas. As nutritional stress deepens, those people who are not essential to herding often emigrate to neighboring areas and attempt to subsist there, returning to their homes when the threat of starvation ends. The tactic improves the probability of survival of both those who leave and those who remain. Temporary emigration is sometimes used by drought stricken pastoralists to find work and money to buy back livestock and other necessities (Swift *et al.*, 1996; Katie 1993).

Pastoralists subsist wholly or mainly upon livestock products i.e. milk, meat, blood and hide. Diets vary from one society to another depending on climatic conditions and plant production. The diets also vary seasonally, in dry seasons less milk is produced and more animals are killed or die, so that meat becomes more important in the diet. Lamprey (1983) estimated that a family of 8 people required a daily supply of 16 litres of milk. This was to be provided by an estimated 7 cows or 4 camels. Since the lactation period of cows is usually less than 6 months in semi-arid regions they are forced to keep twice as many i.e. 14-15, while the lactation period of camels is 18 months, but many times they herd more than this. For the small stock it was estimated that 50-60 animals is the minimum flock for the subsistence of the same size of the family. Grain whether cultivated or bought, is relatively important comprising roughly 30% of the Turkana diet (Heriocker *et al.*, 1994). Sorghum is planted in areas of fertile soils situated in areas of low lying flood plains where rain water collects easily. The gardens are surrounded by thorn fences. As the rains are highly unpredictable cultivation is always risky and highly susceptible to failure. As a result most Turkana do not rely too heavily on cultivation and are more likely to invest in livestock than grains.

Although pastoralism has evolved over many years and is, in many ways a successful adaptation to the dryland and ecologically fragile ecosystem, recent interventions and trends in the arid and semi-arid lands have worked against its continued survival. Due to changing economic, social and political factors and external factors outside their control, the pastoralists have been changing their lifestyles. There has been a shift in their diets, cultural practices, subsistence strategies and ecological management techniques. These factors include:-

2.1.3 Rapid increase in human population

People are the most important factor in the biotic complex affecting pastureland ecosystems, particularly in areas of communal land. They determine in large measure whether the component parts (soil, water, plants and animals) exist in optimum productivity or in a state of degradation (Strange, 1980; Darkoh, 1982; Bourn and William, 1994). The problem of accelerated human population growth in and into the arid areas is perhaps not unique to Kenya but it is certainly one of the key factors in the deterioration of the arid and semi-arid land resources in the northern part of Kenya. The increase in the human population has brought a corresponding increase in the numbers of domestic livestock.

The rising human population has increased demands on the woody vegetation. In addition to the usual wood requirements for building and for fuel, the pastoral people in N. Kenya use large quantities in constructing night enclosures *(boma)* to keep their animals at night and to avoid depredations by carnivores and also man predators. These *bomas* are built at both permanent and temporary camps. In the latter situation they may be occupied for a short time as a week before the livestock are moved to a new area and a new *boma* is constructed. In the semi-permanent settlements an accumulation of ticks and other parasites usually necessitates the periodical burning of the *boma* and movement to a new area that may be near as 100m apart. This practice appears to have the greatest impact upon the woodlands of N. Kenya and is one of the most serious causes of resource deterioration in the region (Lusigi, 1984; Lamprey, 1983). The emmigrants compete with the local population for land, water and energy resources. The problem is further exacerbated by migration of ecological refugees who spontaneously occupy the ASALs with their livestock and who are agro-pastoralists (Karaba, 1995). Apart from over exploitation of range resources, increase in population has reduced home ranges and tended to concentrate animals in certain areas leading to over-utilization of vegetation and degradation (Lusigi, 1984; Zaba, 1994).

Increased human interactions between the pastoralists and the non-pastoral communities has also expanded the pastoralists market for dairy products, brought greater diversification and improvement in their diet and health, involvement in the market economy, greater dependence on others for labor and essential household needs and changes in systems of marriage and traditional authority structures. Mohamed (1992) in a study done among the Fulani in northern Nigeria, observed that as in the case of the Turkana, they started charcoal making with the advent of urban dwellers but still ridicule those who earn their living from wood selling or charcoal making. The expansion of the cash economy into traditional pastoral lands has made the pastoralists produce surplus stock for sale to bring in revenue for the purchase of food and other necessities. Ormerod (1978) observed that one of the factors operating to increase aridity in west Africa is the economic demand for livestock which has stimulated the growth of herds and of arable farming which compete for land in the range areas. If poorer pastoralists have to sell their stock to get cash then they risk further impoverishment and ultimately become stockless migrants to towns (Coppock *et al.*, 1986; Joeckes and Pointing, 1991; Reckers, 1997).

2.1.4 Insecurity and rangeland use

Insecurity in pastoral areas can be viewed from two perspectives, insecurity from armed bandits or raiders and also insecurity from the natural environment e.g. diseases and drought. The politico-military dimension of the crisis is evident in the internal wars in Africa (NORAGRIC, 1990), in which the pastoralists are always the major victims. Competition from agriculture, herd dispossession, wars and population increase have contributed to mass displacement of the pastoralists. In many situations pastoralists as a system of production and a way of life, seems to be fighting a losing battle (Hendrickson *et al.,* 1998).

Hendrickson *et al.* (1998) in a study done among the Turkana on the causes of raiding, observed that raiding is an old age practice in this region. There were various reasons advanced for the practice; it was a way of relocating pastoral resources between poor and rich herders and was a common feature both between intra-tribal and inter-tribal relations; for young men, warfare was a rite of passage and it is an important inspiration for raiding; it is also viewed as a way in which a young man can earn prestige and gain independence from his father. Livestock being the currency used in social transactions, there is always tremendous pressure to accumulate more. Marriage for instance requires the payment of high bride prices, this constitutes a strong motivation for young men to raid.

This traditional mode of resource relocation is being replaced by predatory raiding which has involved raiding actors outside the pastoral system. This has undermined pastoral livelihoods and the socio-economic integrity of the pastoral system as a whole. The bandits include armed military or bandit groups in Kenya or surrounding states as well as economic 'entrepreneurs'. Their motives are commercial. In retaliation the local herders or pastoralists have been forced to arm themselves and also more often raid for livestock in the neighborhood. The result has been constraints in livestock mobility for fear of raiding and retaliation from the other groups. This concentration of animals has had an effect on the vegetation of the area. In some cases it has affected the production causing the system to suffer from famine and is said to increase when there is drought. Turton (1992), in a study done among the Mursi, Ethiopia, notes that famine of the early 1970's was greatly increased by an intensification of armed conflict which affected all the herding peoples of the lower Omo. Insecurity can also be viewed from a different perspective i.e. interms of wars and their effect on the ecology of the area. A study done in Eritrea showed that insecurity led to loss of vegetation and exposed the area to soil erosion (Giorgis, 1993). Livestock numbers were also affected, from 1977 to 1992 cattle reduced by 70%, Sheep and Goats by 62%, Oxen by 51% and Camels by 60%.

2.1.5 Drought and famine in the rangelands

Recent African history has demonstrated how drought and famine may lead to starvation and disaster. They have an effect of 'fuelling' conflict over resource availability and control of food. The quest for food security tends to cause political conflict to the extent that scarcity prevails and causes ecological degradation in areas where pressure on land does not really permit increased food production without structural changes in food production systems (Anders and Salih, 1989).

Effects of drought on pastoralists and their animals vary in different areas. The immediate effect is a fall in availability of fodder affecting animal nutrition where livestock numbers are already high and leading to decline in productivity i.e. milk, fertility and animal live weight (Anders and Salih, 1989). Eventually if drought is prolonged and fodder even scarcer, more animals die. With the persistence of drought herders move further afield, some with their animals to find dry-season grazing or distant water supplies, others to towns and settlements to find work or food for the family. Katie (1993) estimated that drought can claim up to 80% of the stock and can take decades to recover. Several years of drought changes climax communities to a species of shorter cycle. Baumer (1990) reports that a study done in Niger showed that *Aristida mutabilis* Trin. and Rupr. grass was replaced by *Boerhavia repens* and *Tribulus terrestris* L, herbaceous plants which are unpalatable species.

Choksi *et al.*, (1996) in a study done among the Rabaris of Gujarat observed that the loss of animals led to sedenterization. This latter brought greater exposure to the value systems of other social groups, who rarely value pastoralism. This exposure coupled with the influence of formal schooling, which followed an urbanized model, increased their stratification. In particular it has allowed the rise of a new class of community leaders, who gain their status because of their capacity to mediate between non-literate pastoralists and the outside world (Mohammed, 1992; Sinha, 1996).

2.1.6 Changing land tenure systems

Pastoral land in the drylands is mainly owned by a community i.e. communal land tenure system. All the individuals of the community traditionally have the right of access to the land and it's resources. They also have an obligation to sustainably manage the resources therein. Customary land rights have been undermined all over the semi-arid zones of Africa, grazing land available to herders is diminishing and there is increasing competition for access to scarce water and pasture resources (Place and Otsuka, 1998). A change in land tenure has disrupted seasonal grazing movements and has led to concentration of animals on smaller areas of rangeland. Conflicts and political crises also destabilize pastoral communities, uprooting them from places where they have traditional land rights and hampering livestock movements. In a study conducted in Rajasthan, Sinha (1996) observed that land reduction due to increase in population in the area had forced the Johya pastoralists to change from traditional pastoralists to owners of land i.e. sedenterization.

Widstrand (1975) argued that cattle are owned by individuals but the natural resources necessary for livestock operations such as grazing and water are owned communally. This means that the individual owner may not decrease the pressure on the grazing land by reducing the size of his own herd, doing this would only put him in an unfavorable economic position, as he would have no guarantee that other livestock owners having access to the same land would do the same. This situation, plus the uncertainty of long-term predictions of the availability of water and grazing leads to an opportunistic use of the land. The above discussed factors have led to the sedenterization of pastoralists. However Gillet (1979) observes the sedenterization was common even among the traditional pastoralists. Mostly among them that were of less economic status after livestock loss to drought and diseases. It was seen as a temporary way sought to rebuild herds and reintegration into the pastoral economy. Permanent settlements have evolved slowly in Turkana since the beginning of this century, with the exception of some sedentary, fishery compounds along the shores of Lake Turkana. Originally the villages began to grow as administration and military centers followed by famine camps, missionary stations and lately as particular clusters of development, educational and health activities (Zumer-Linder, 1983; Darkoh, 1990).

2.1.7 Effects of grazing pressure on vegetation cover and density

Population pressure through settlements and encroachment of cultivation into pastoral prime grazing lands in arid and semi-arid areas of Africa have resulted in the reduction of natural vegetation cover, in turn transforming land use systems (Diress *et al.*, 1999; Berry, 1979). Around water sources high livestock concentrations greatly reduces the plant cover especially grasses. The earth may be bare encouraging erosion by both wind and water but the potential of regeneration is high, because the soil enriched by animal dung often contains large quantity of seeds brought there by animals and which will germinate when given chance. Degradation can be therefore only on the surface thus there is no loss of regenerative ability (Baumer, 1990; Berry, 1979). The dissemination and germination of certain seeds, particularly those of *Acacia species* are greatly facilitated by ingestion by livestock which consume the pods and ingest the seeds. The dormancy is broken after passage through digestive tract of the grazing animals (Baumer, 1990; Reid and Ellis, 1995).

The trees rooting system allows trees to explore both the surface and deeper soil layers but the herbaceous vegetation tap only the topsoil layer (Knoop and Walker, 1985). Bourliere and Hadley (1983) observed that grasses may become eliminated in a sufficiently dense woody vegetation. Trees on the other hand can survive the densest grassland, as long as rainfall is sufficient to reach the subsoil and there is no problem of recruitment from seedlings. Many trees are safe from destruction by herbivores, because for there protective mechanisms. If heavy grazing destroyed grasses, more water becomes available for trees and shrubs leading to changes in the interactive patterns and to an increase in woody species. This is one of the main causes for the increase in woody species cover and density and a reduction of herbaceous cover and density (Coughenour *et al.*, 1990).

Skarpe (1990) in a experiment done in Botswana showed total grass cover was effectively unchanged in the control area and under moderate grazing, but in the heavily grazed area the proportion of bare ground and of herbs other than grasses increased. The basal cover of grasses did not change significantly with no or moderate grazing, but decreased with heavy grazing. Grass basal cover was 1.3%, 1.1% and 0.3 % respectively the opposite trend of that of shrubs. The result showed that shrubs invade when grasses have been killed. Increase of total shrub density and biomass with heavy grazing was from *Acacia mellifera* Vahl to *Grewia flava* L. This is because they are shallow rooted and have access to water easily when grass is removed, same as *Lycium spp* but *Boscia spp.* are deep rooted. Success of shallow rooted *Acacia spp.* compared to deep rooted species in encroaching overgrazed areas is their better access to nutrients and *Rhizobium* in the surface soil (Mayeux and Johnson, 1990). Cutting of trees and shrubs directly reduces cover and density. Although in some instances, it has given rise to a new set of young trees and shrubs which show a high density but less cover (Duncan and Jarman, 1993).

2.1.8 Effects of Grazing pressure on vegetation diversity

Species diversity, a characteristic unique to the community level of biological organization, is an expression of community structure. A community is said to have a high species diversity if many equally or nearly equally abundant species are present. On the other hand if a community is composed of a few species, or if only a few species are abundant then species diversity is low (Brower *et al.*, 1989). High species diversity indicates a highly complex community, for a greater variety of species allows for a longer array of species interactions. These population interactions involving energy transfers (food webs), predation, competition, and niche apportionment are theoretically more complex and varied in a community of a higher species diversity.

Grazing is an important factor in shaping the composition of vegetation (Young and Solbrig, 1990). Beside it influences various other attributes of a plant community such as , biomass, plant structure and chemical component of plant tissues (Silvertown, 1996). Competitive ability is reduced for preferentially grazed species and these are subsequently out-competed by less grazed species. When competition takes place between seedlings, quickly established ephemerals may out-compete slow germinating perennials. Succession may lead to an almost complete plant species turnover and to vegetation types dominated by unpalatable or poisonous di-cots, herbs or dwarf shrubs or annuals (Skarpe, 1991; Skarpe, 1992; Stiles, 1993). Walker (1993), noted that in Serengeti area in Tanzania, those grassland communities with the highest species diversities were the most constant interms of biomass and also showed both the greatest resistance to resilience after grazing. Maintaining high resilience and high species diversity was associated with considerable variation in the proportional species composition over time.

Although many plant species are not resilient to grazing, there are reports of plants responding to herbivory with increased growth compared with that of ungrazed plants (Belsky, 1986). However as grazing intensity increases, losses of biomass will reach levels that cannot be maintained by re-growth and productivity will decline (Silvertown, 1996). Waters-Bayer and Bayer (1992) noted that goats reduce bush encroachment by their browsing action making room for better grass growth for the cattle. Although Adams (1990) noted that in some areas in Turkana intensive grazing led to the loss of the herb layer and to bush encroachment. Some plants develop defensive mechanisms by producing inhibitive chemicals that make them unpalatable and sometimes physical defensive mechanisms, like spreading thorny crowns in young *Acacia tortilis* (Forsk)Hayne plants. Spreading branches impair herbivory access to the center of the plants (Coughenour *et al.*, 1990).

The highly variable rainfall in the semi-arid and arid areas results in a "constant disequilibrium" or a "permanent transition" of rangeland vegetation (Anne, 1995). In the arid environments, rain is often only enough to wet the soil surface, and water may also be intercepted by shallow roots before it sinks to deeper layers. Thus when the dorminance of grass species is broken, shrub species with shallow lateral roots may have an added advantage compared to species with a large part of there root systems restricted to deeper in the soil (Skarpe, 1990). Because of this the vegetation of the arid lands are physiognomically diverse and related to water availability (Coughenour *et al.*, 1990).

Herbaceous biomass dynamics are extreme, depending on the season, a landscape may appear quite barren or 'lush'. Peak greenness lasts for a relatively short period, one month, then leaves dry and senesce, with the ensuing extreme dryness and occasional strong winds, leaf tissues disintegrate. Within 4 -8 months the sites take a barren appearance again. Most of these herbaceous plants are palatable though they disappear quickly when rains cease, and again when the rains return they sprout quickly from the seed bank giving impression of quick recovery (Skarpe, 1991; Coughenour *et al.,* 1990). Cully and Cully (1991) in a study done in N.W New Mexico, found that annual plant populations were spatially and temporarily highly variable. During favorable years the annual plant species had patterns of dominance and diversity that was different from those of perennial species.

2.1.9 Effect of human settlement on soil nutrient content

Higher nutrient content is generally associated with a better developed woody layer. Trees may improve nutrient conditions in there immediate surroundings. If such fertile patches shift as trees die and others establish in other places they may form a patch dynamic system, and in a longer time perspective they will increase the overall nutrient level in the system (Waters-Bayer and Bayer, 1992).

Large herbivores are known to speed up the nutrient turn over rate in the drylands. Moderate degrees of herbivory also seem to concentrate nutrient flux at the soil-plant-herbivory interface reducing the leakage to deeper soil layers. Exclusion of large herbivores from grasslands may result in a rapid loss of nutrients from the soil surface. It may even lead to an increase in woody growth, as more nutrients leak to deeper soil layers, from where they may be restored to the soil surface by the woody vegetation (Skarpe, 1992; Waters-Bayer and Bayer, 1992). Heavy grazing by cattle substantially reduces the amount of nutrients in the herb and grass layer of savanna species (Ernst and Tolsma, 1991). However large percentage of nutrients taken up by plants in grazing ecosystems is cycled directly through animal excreta, resulting in an accelerated soil incorporation particularly nitrogen and phosphorus (McNaughton and Ruess, 1987).

Breman and deWit (1983) in a study done in the Sahel region of Africa, showed that low nitrogen and phosphorus levels is a limiting factor to plant growth than rainfall. Improved soil fertility leads to the use of more water by the vegetation, improved water use efficiency, and thus a higher production. Hence the limiting factor to vegetation growth is nitrogen and phosphorus rather than water (Dutta , 1998). Availability of water relative to that of nitrogen and phosphorus determines the quality of forage produced. Low water availability produces a small amount of biomass of good quality and higher water availability results in more biomass of increasingly inferior quality (Breman and deWit, 1983). Protein content is closely related to the Nitrogen content in the soil. Species preference by livestock tends to parallel protein content. Specific plant parts may also be selected e.g. dry season seeds and fruits have the highest protein content, followed by re-growth of perennials and then by leafy annuals. Stems of perennial grasses and cereals such as millet and sorghum have very low protein content.

For successful agricultural development, the importance of maintaining the organic matter contents of these soils at the highest practicable levels cannot be overemphasized. Organic matter acts as a source of nitrogen and also maintains soil structure, water holding capacity and resistance to erosion and in providing much of the cation exchange capacity (CEC). The amount of organic matter in the soil is a product of a number of diverse factors acting over a period of time on the relative rates of the return of organic residues to the soil and their subsequent breakdown in the soil (Jones, 1973). Fuel-wood harvesting, bush clearing and lopping trees excessively for feed causes a reduction in the size of the nutrient pool because of the removal of twigs and branches with high nutrient concentration (Agboola and Kintomo,1993; Ernst and Tolsma, 1991). Trees increase the supply of nutrients within the rooting zone of plants through input of Nitrogen by biological Nitrogen fixation, retrieval of nutrients from below the rooting zone of plants and reduction of nutrient losses from processes such as leaching and erosion (Buresh and Tian, 1998).

2.1.10 Effects of grazing pressure on soil bulk density

High stocking rates increases trampling on the barren soils tends to reduce the chances of successful establishment of seedlings, decrease water infiltration rates, increase sediment production, increase soil bulk density and soil erosion (Heitschmidt *et al.*, 1987; Abdel-Magid *et al.*, 1987). However this depends on various factors like the type of soil. Some soils are easily eroded when subjected to soil erosion agents. In some studies it has been observed that livestock trampling loosen the soil and improve water infiltration and also create a good micro-environment for plant growth. In other cases soil compaction impedes the movement of water and air through the soil by reducing the number of large pores. This affect root growth and infiltration, in turn affecting productivity of the land (Hillel, 1982).

CHAPTER 3

3.0 MATERIALS AND METHODS

3.1 Location of the study area

This study was conducted in Kakuma division of Turkana district. Turkana district of the of the Rift valley province is situated in the North-western corner of Kenya (Figure 1). Much of the eastern end of the district borders L. Turkana which stretches North-South for more than 200 Km with much of it being in Marsabit district (Government of Kenya, 1997). The district lies between long 34° 0' and 36° 40' E and between lat. 10° 30' and 5° 30' N and has an area of 77,000 Km^2, which is 42.4% of the rift valley province, and about 96% falls under eco-climatic zones IV and VI i.e. the arid and very arid respectively (Adegi Awuondo, 1990).

Kakuma division is located on the cooler and better-watered higher grounds that rise into Karamoja in Uganda between Lat. 3° 43'N and Long. 34° 52'S, on the Northern side of Turkana. It has an area of 10,946 Km5 i.e. about 14.2% of the districts total land area. It is located on a fairly flat land that extends to the neighbouring areas of Lopur, Kalobeiyei, Loreng and Lokichar (Adegi-Awuondo, 1990).

3.2 Topography and climate

The district consists of low-lying plains with isolated mountains and hill ranges. The altitude rises from 900 m at the foot of the escarpment marking the Uganda border to the West and falls to 369 to the shores of L. Turkana in the East. Altitude of the mountainous regions ranges from 1,500 m to 1,800 m in the east reaching the peak at Loima hills, which form an undulating stretch of 65 Km5. The district has several rivers with Turkwell and Kerio, both originating from the highlands to the south, as the major rivers and the rest being seasonal rivers. These are the main water sources within the district, apart from boreholes. The relief of the area can be categorized into 4 sections: uplands 21%, piedmont plains 41%, sedimentary plains 15% and 23% consists of riverine flood plains (Adegi Awuondo, 1990).

Arid and semi-arid environments are found within the district. The lowest rainfall was recorded in the central plains around Lodwar at an annual average of 120 mm and the heaviest around Lokichoggio with an annual average of 430 mm. Rainfall patterns and distribution are unreliable and erratic over the years. It is recorded that Lodwar has shown a wider range of rainfall from 19 mm – 380 mm over a long period of time. Long rains occur from April – August and the short rains from November – December (Government of Kenya *et al.*, 1997). Beneficial effects of rainfall depend on its distribution due to conditions of poor soil cover, high evaporation rates and rapid run-off. Numerous small falls distributed throughout the wet season have greater effect than 1 or 2 big storms followed by rapid drying, even though the total storm water may be higher. The daily temperatures range from 24°C to 38°C and the area experiences strong winds (Government of Kenya, 1997; Herlocker *et al.*, 1994).

The climate of the region plays an important role in determining range condition. During the dry seasons the range condition is poor or fair, since the productivity of the range areas depend on the availability of rain (Swift *et al.*, 1996). During the El-Nino rains in 1998 it was reported that the range condition was good compared with the years with low rainfall levels. However there was also a high incidence of animal diseases, due to this drastic change in weather (G.O.K, 1998).

3.3 Human population characteristics of the study area

The largest human population is concentrated in Kakuma refugee camp situated near Kakuma town. The camp was set up in July 1992, mainly with the purpose of providing refuge to the refugees of the southern Sudanese region. Due to armed conflict and wars in Democratic republic of Congo, Rwanda, Burundi, Ethiopia, Uganda, and Eritrea the present population consists of many nationalities and ethnic groups and is estimated at about 80,000 people. During the 1999 census, the population of Kakuma division was estimated to be 36,600 people ,thus giving a total of 116,600 people within the division. The camp presently being the largest population center in the district, exceeding the capital of Turkana, Lodwar, has a profound impact on the environment.

The main economic activity within Kakuma division is pastoralism but with the advent of the refugee camp there has been an introduction of other activities especially trade and employment opportunities within the refugee camp. The social and economic interaction with the refugees has made the local population adapt new cultural patterns.

3.4 Experimental design and data analysis

The study had a field phase and a laboratory phase. The field phase of the study involved the collection of data on vegetation attributes i.e. woody and herb density, cover (aerial and crown) and diversity, soil samples and socio-economic data. The laboratory phase of the study entailed analysis of soil samples and identification of plants that could not be identified in the field.

A completely randomized design (CRD) (Steel and Torrie 1980; Gomez and Gomez 1984) was used in the study. Four main line transects, each 6 Km long were laid from the settlement camp. From each main transect, six perpendicular line sub-transects measuring 100 m each were established at regular intervals of 1 Km. There were a total of 24 line sub-transects. The sixth line sub- transect acted as the control, on each main transect. On each sub-transect, three plots measuring 10 m x 10 m were marked out. The plots were 30 m apart and 5 m from the edge of the sub-transect line. The experimental units were the 100 m5 plots. On each sample plot data on trees, shrubs, herb density, cover and species composition was collected. With four transects and 6 sub-transects, the 6th one being the control, and three sample plots on every sub-transect, a total of 72 sampling units were used for analysis.

The main plot was the (10 x 10)m plot. This was used to collect data on trees. Within this plot there was a small plot, (4 x 4)m which was used to collect data on shrubs. A smaller plot of (1 x 1)m placed within the edge of this plot was used to collect data on herbs. Figure 3 shows the nested plot Quadrat technique. The four main transects were the replicates and the distance from the settlement camp was the treatment. Each treatment was replicated three times on each sampling site. Six sites were sampled corresponding to the 6 treatments and a total of 18 samples collected per main transect. This represents 30% of the sample population. An ANOVA was then conducted for species cover, density and diversity and also along distance gradient from the camp. Comparison between the distances was made with the assumption that plots equidistant to the camp, in all the four replicates, have similar vegetation characteristics and equal population pressure.

Figure 1: Map of Kenya showing the location of Turkana district, Kakuma division and the study area

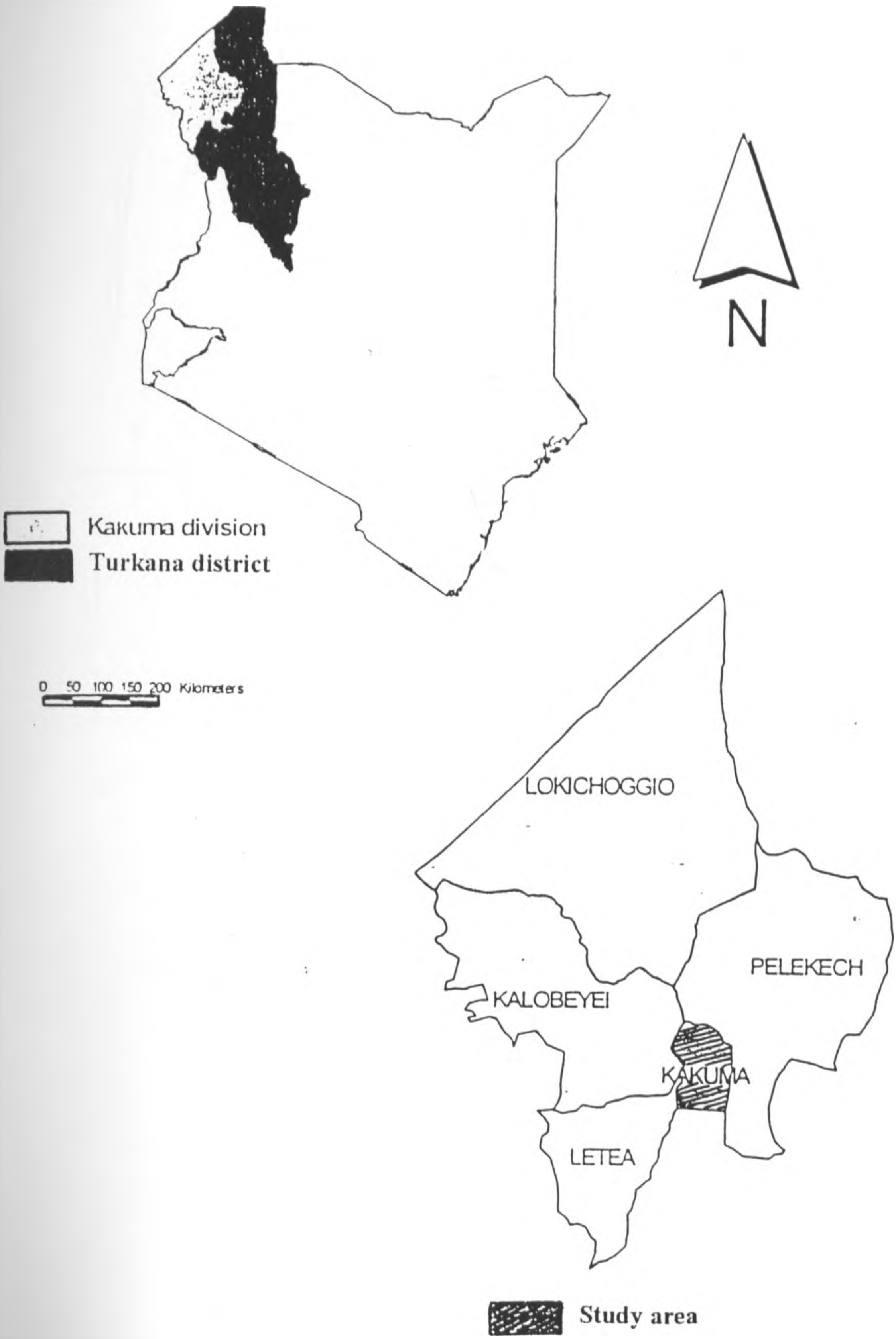


Figure 2: Transect layout in the study area.

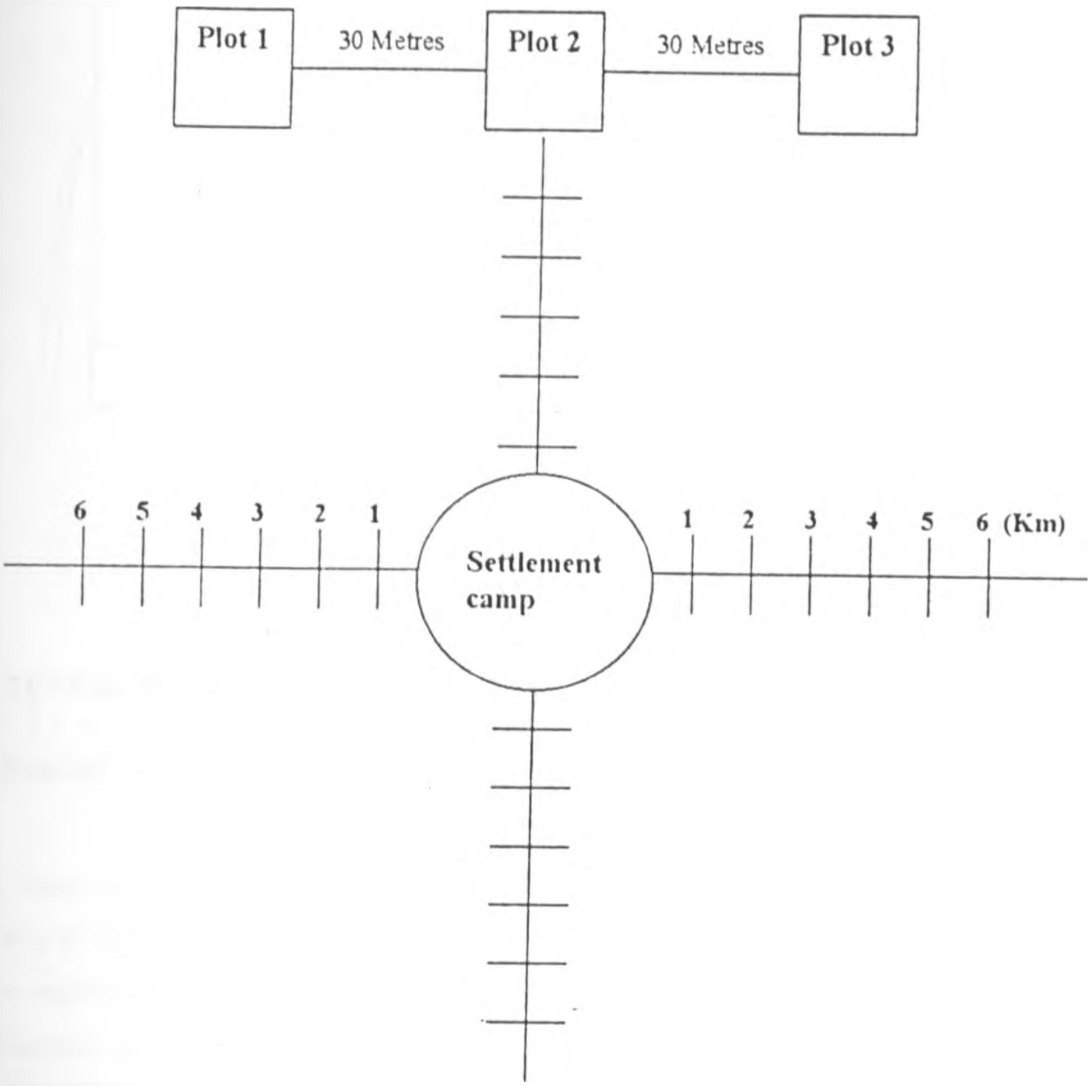
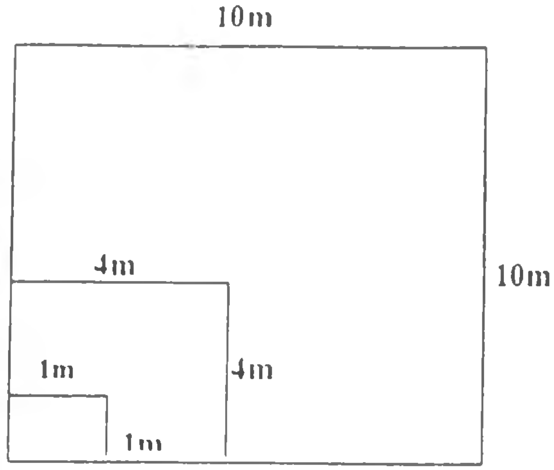


Figure 3: Sampling plot layout.



3.4.1 ECOLOGICAL DATA

3.4.1.1 Density measurement

All the trees within the 10m x 10m plot were counted and species recorded for the calculation of density and relative density. Shrub density data was collected from the 4 m x 4 m plot and the herbaceous vegetation data collected from the 1 m x 1 m plot. The number of individuals was recorded for each species, then species density and relative density calculated using the following formula (Cook and Stubbendiek, 1986):-

$$\text{Density (Individuals/unit area)} = \frac{\text{Total no. of individuals}}{\text{Total area}}$$

$$\text{Relative density \%} = \frac{\text{Total number of a particular species}}{\text{Total number of individuals}} \times 100\%$$

3.4.1.2 Plant species diversity

For diversity the Simpsons index was used. The index considers the number of species (ni) and also the total number of individuals (N).

$$Ds = 1 - \frac{\Sigma ni(ni - 1)}{N(N - 1)}$$

Where Ds = Diversity index

ni = number of species

N = total number of individuals

3.4.1.3 Vegetation cover

Vegetation cover studied was aerial cover for herbaceous vegetation and the crown cover for the trees and shrubs. The line intercept technique was used for herbaceous vegetation Canfield (1941). A line or tape was stretched tight at a height to contact vegetation aerial canopy in each of the 1m long plot. The length of each intercepted plant species part was measured from vertical projection for aerial cover. Each species intercepted was recorded. The length of line and total length intercepted by vegetation was used to estimate % aerial cover using the following formula:-

$$\textbf{\% Cover} = \frac{\Sigma d}{\textbf{Tape length}} \times 100\%$$

where Σd = total intercept distance.

For the trees and shrubs the crown diameter method was used Mûller and Ellenberg (1974). A measuring tape was placed from one side of the crown perimeter of the tree or the shrub crown to the other side making one diameter (D1). A second measuring tape perpendicular to the first was also placed on the crown of the tree or shrub to provide the second measurement (D2).

Crown cover was then calculated using the following formula:-

$$\% \text{ Crown cover} = \tfrac{1}{2}(D1 + D2)^2 \times 100$$

3.4.1.4 Soil sampling and analysis

Soil samples were collected from the 10-m x 10-m vegetation sampling plots. Three soil samples were collected from each sampling plot. Two soil samples were collected using the soil augur at 0-15 cm and 15-30 cm depths, a total of 48 samples were collected. These soil samples were analyzed for pH, texture, soil carbon, nitrogen and phosphorus. One soil sample was also collected per plot using a 5cm-diameter soil core ring and with known weight, and this was used for the analysis of bulk density. A total 24 samples were collected.

3.4.1.4.1 Bulk density

Blake and Hartje method was used in bulk density analysis. Soil samples were oven-dried to constant weight. Bulk density was calculated using the following formula :-

Pb = Ms/Vt

Where **Pb** = (bulk density) g/cc·

Ms = Weight of the oven dry soil sample (g)

Vt = Volume of soil at field condition (cm;)

3.4.1.4.2 Soil texture

Soil samples were passed through a 2-mm sieve and taken for soil texture analysis using Bouyoucos Hydrometer method. This gave the percentage of sand, silt and clay. Soil texture analysis involved the initial destruction of soil organic matter with Hydrogen peroxide, dispersion with Sodium hexametaphosphate and mechanical stirring, then analysis by the hydrometer. Soil textural classes were determined from the standard U.S Department of Agriculture textural triangle (Hinga *et al.*, 1980).

3.4.1.4.3 Soil nutrients

Analysis of the soil samples for nutrients were done in the laboratory. A total of 48 samples were used for the analysis of phosphorus, nitrogen and soil carbon. The samples constituted two sampling depths i.e. 0-15 cm (24 samples) and 15-30 cm (24 samples).

Soil carbon was analyzed using the Walkley and Black method, phosphorus was analyzed by the Olsen's Sodium bicarbonate extraction method and nitrogen by the Phenoldisulfonic acid method (Hinga *et al.*, 1980).

3.4.2 SOCIO-ECONOMIC DATA

3.4.2.1 Primary data collection

Socio-economic primary data was collected in and around the camp and away from the camp i.e. from the refugees and the local population. Open-ended and close-ended questionnaires were administered to the Turkana. A total of 40 households were sampled for the Turkana community. In each block 10 households were sampled, two on each line sub-transect (the nearest house to the main transect, one on each side of the transect). Forty-two questionnaires were administered to the refugees. There are seven major nationalities within the refugee camp i.e. the Sudanese, Somalis, Rwandese, Congolese, Burundis, Ugandans, Ethiopians and Eritreans. Among the Turkana data was collected on household sizes, literacy levels, economic activities, sources of woodfuel, environmental perceptions, livestock numbers, settlement patterns and social interactions.

Focussed group discussions were also done with the Turkana through an interpreter and direct communication through Kiswahili language. This was aimed at getting more information on issues that could not be expressed in the questionnaires. Discussions centered on the values attached to their environment and the various uses of vegetation. Data collected from the refugees was centered on their perceptions of environmental degradation, economic activities, educational background and energy use.

3.4.2.2 Secondary data collection

Additional data was collected from secondary sources that included previous research reports from the Kakuma area and in Turkana district, project reports from the area, newspaper articles, and Government of Kenya reports.

3.4.2.3 Method of data processing and analysis

Data was statistically analyzed using computer packages, SPSS and MsExcel. The results were later presented in frequency tables, as percentages, means and some data were descriptive, describing general trends and perceptions (Weissberg and Bowen, 1977).

CHAPTER FOUR

4.0 RESULTS

4.0.1 Tree cover along distance gradient

The 10 most common tree species used in the measurement of tree crown cover and density were *Acacia tortilis, Acacia elatior, Dobera glabra, Salvadora persica, Acacia mellifera, Acacia nubica, Balanites aegyptiaca, Boscia coriacea, Cordia sinensis* and *Prosopis chilensis*. The mean percentage tree crown cover values of the 10 common species within transects and along distance gradient are recorded in table 1.

Table 1: Mean % tree crown cover values of the 10 common species within transects and along distance gradient.

Block	Distance from the settlement camp (Km)					
	1	2	3	4	5	6
1	2.560	9.18	26.27	35.98	47.66	74.32
2	11.19	25.41	32.37	54.78	57.70	43.09
3	2.070	26.20	29.96	25.58	60.68	81.22
4	9.130	14.45	10.33	26.51	44.86	32.12
Mean	*6.24*^{a}	*18.81*^{b}	*24.73*^{bc}	*35.71*^{cd}	*52.72*^{d}	*57.69*^{d}
Standard deviation of mean	*±4.61*	*±8.37*	*±9.92*	*±13.55*	*±7.65*	*±23.79*

* Numbers with the same superscripts a, b, c, d are not significantly different *(P>0.05)*.

Analysis of variance (ANOVA) indicated a significant difference in percentage tree crown cover along distance gradient, as one moved away from the camp in all the four transects ($P<0.05$). Percentage tree crown cover showed an increase away from the settlement camp (Figure 4). T-tests for equality of means indicated significant differences in treatment effects on tree crown cover along distance gradient from the settlement camp ($P<0.05$).

The trees near the camp were cut mainly by the Turkana people for charcoal burning and for building poles and mainly stumps remained. Tree species were cut for the provision of wood-fuel and building materials. Some trees were coppicing especially *Acacia tortilis* and *Salvadora persica* when cut at a distance of some feet from the ground. This were also the most important sources of forage. Trees cut at the very base did not sprout or rather died. All the tree species have cultural and economic importance among the Turkana community.

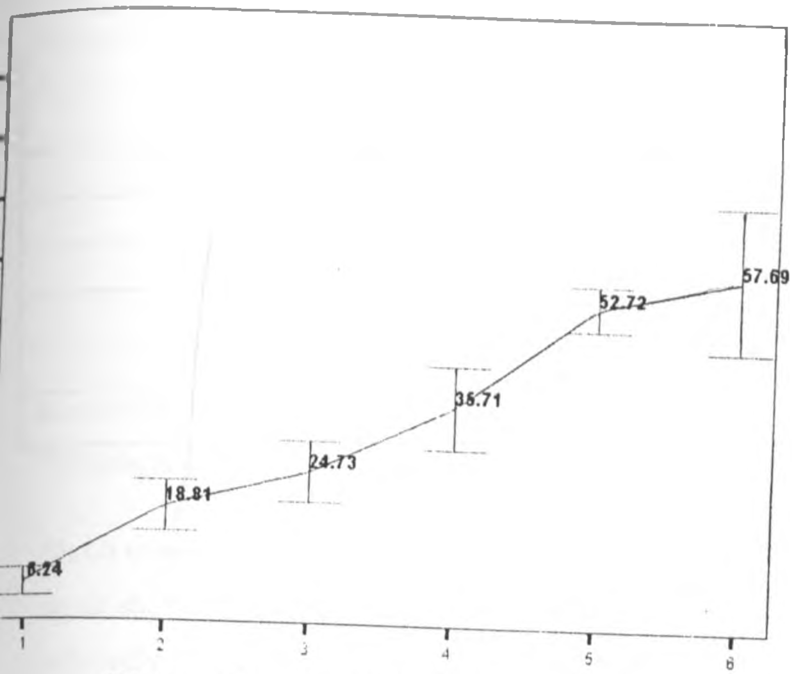


Figure 4: Mean % tree species crown cover along distance gradient

4.1.2 Shrub cover along distance gradient

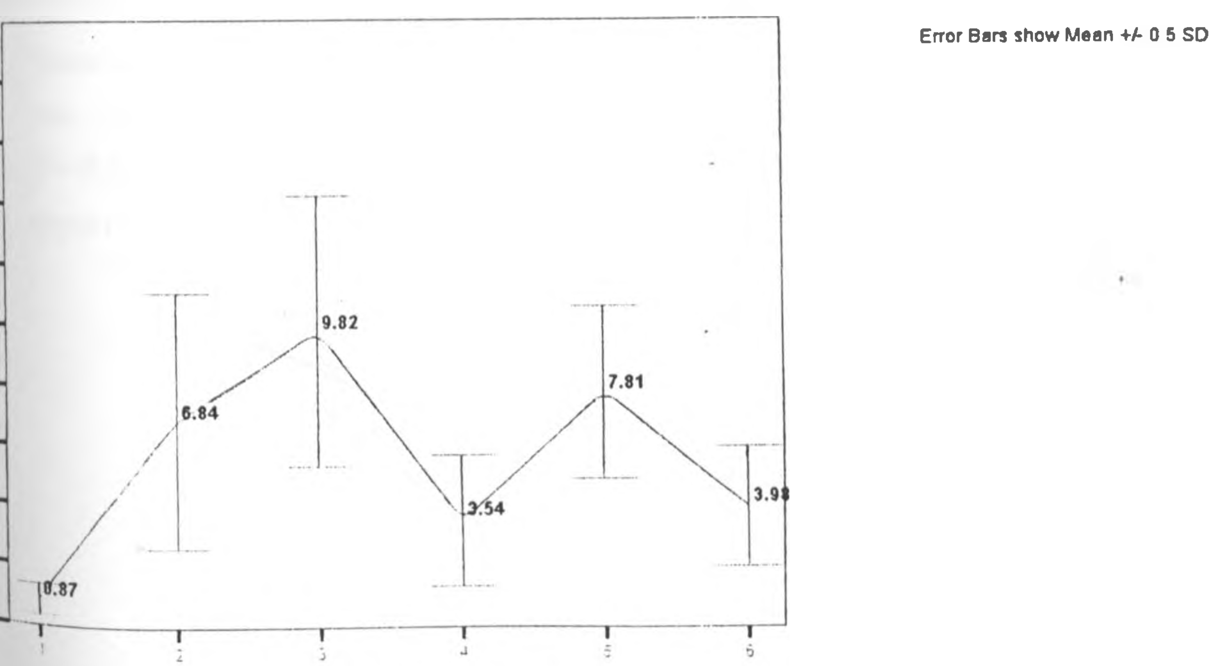
The 10 common shrub species used in the study for measurement of crown cover and density were *Acacia reficiens, Abutilon fruticosum, Cissus quadrangularis, Dichrostachys cinerea, Lyicum shawii, Euphorbia cuneata, Cadaba rotundifolia, Maerua spp., Commiphora spp.*and *Zizyphus mauritania.* There was a significant difference in shrub cover along distance gradient, as one moved away from the settlement camp, in all the four transects *(P<0.05)*. T-tests for treatment means showed significant differences in the treatments *(P<0.05)* (table 2).

Table 2: Mean % shrub crown cover of the 10 common species within transects and along distance gradient.

Block	Distance from the settlement camp (Km)					
	1	2	3	4	5	6
1	1.48	0	0.62	0.08	12.90	9.42
2	0	19.02	15.02	1.27	2.94	2.22
3	0	6.15	19.55	9.87	2.73	0
4	2.00	2.17	4.08	2.93	12.65	4.26
Mean	*0.87^{a}*	*6.84^{a}*	*9.82^{b}*	*3.54^{b}*	*7.80^{b}*	*3.97^{b}*
Standard deviation of mean	*±1.03*	*±8.51*	*±8.93*	*±4.38*	*±5.74*	*±4.03*

*Numbers with the same superscripts a, b are not significantly different *($P>0.05$)*.

Shrub cover increased between to the 3rd Km from the camp but reduced at the 4th Km and again showed increase at 5th Km (Figure 5). It was observed that at the 4th Km, there were a relatively high number of Turkana settlements, and the people had a profound impact on the shrub species. From the study, it was observed that the most cut shrub species were *Acacia reficiens* and *Cadaba rotundifolia*. These were mainly cut for the construction of livestock enclosures and houses. Shrub species like *Euphorbia cuneata* and *Cissus quadrangularis* were found in abundance but un-exploited.



Distance from the settlement camp (Km)

Figure 5: Mean % shrub species crown cover along distance gradient

4.1.3 Herbaceous and dwarf shrub cover along distance gradient

The 10 most common herbaceous species used in the measurement of cover and density were Duosperma eremophyllum, Heliotropium longiflorum, Indigofera spinosa, Sericocomopsis hildebrandtii, Tragus barteronianus, Tribulus terrestris, Portulaca oleraceae, Cenchrus ciliaris, Aristida mutabilis and Amaranthus hybridus. The mean percentage herb cover for 10 common species within transects and along distance gradient is recorded in table 3.

Table 3: Mean % herb cover for 10 common species within transects and along distance gradient.

Block	Distance from the settlement camp (Km)					
	1	2	3	4	5	6
1	71.00	63.20	66.40	56.70	49.70	40.00
2	93.40	81.20	74.00	61.00	47.40	36.80
3	62.60	52.80	44.90	32.40	28.40	47.80
4	45.00	41.60	40.40	16.90	27.90	57.10
Mean	*68.00*^{a}	*59.70*^{a}	*56.43*^{ab}	*41.75*^{bc}	*38.35*^{c}	*45.43*^{bc}
Standard deviation of mean	*±20.10*	*±16.83*	*±16.31*	*±20.81*	*±11.82*	*±8.99*

*Numbers with the same superscripts a,b,c are not significantly different *($P>0.05$).*

There was a significant difference in herbaceous cover along distance gradient, ($P<0.05$). T-tests for equality of means showed a significant difference between treatment means ($P<0.05$). Figure 6 shows that herb cover reduced as one moved away from the settlement camp (there was a high % herb cover near the settlement camp).

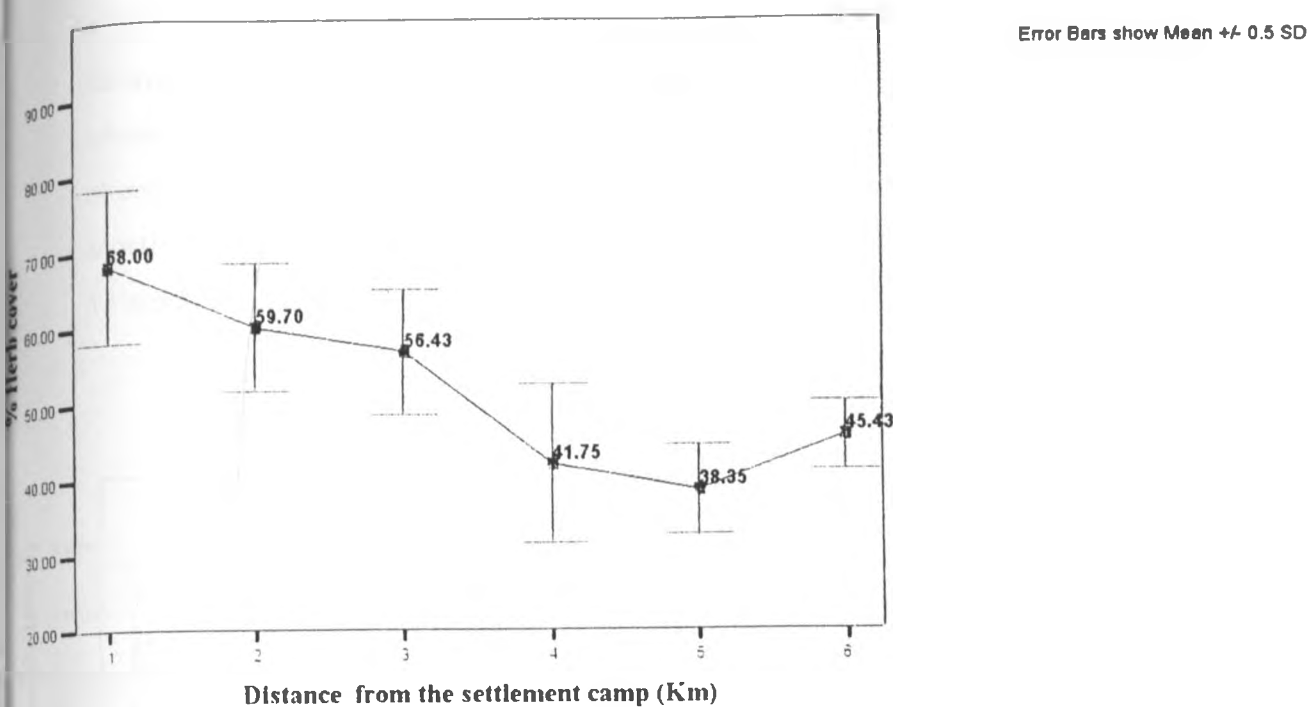


Figure 6: Mean % herb species cover along distance gradient

4.2.1 Tree density along distance gradient

Table 4. Mean tree density values within transects and along distance gradient for the 10 common species.

Block	Distance from the settlement camp (Km)					
	1	2	3	4	5	6
1	5.00	4.00	6.33	4.00	3.00	7.67
2	17.33	12.33	8.00	6.00	7.67	5.00
3	12.67	5.67	4.33	4.33	6.00	7.67
4	15.67	13.00	6.00	6.00	6.67	6.33
Mean	*12.67*[a]	*8.75*[ab]	*6.17*[b]	*5.08*[b]	*5.83*[b]	*6.67*[b]
Standard deviation of mean	*±5.46*	*±4.58*	*±1.50*	*±1.07*	*±2.01*	*±1.28*

*Numbers with the same superscripts a,b are not significantly different *(P>0.05)*.

Analysis of variance showed a significant difference (*P<0.05)*, in tree density along distance gradient. T-tests for equality of means showed a significant difference between treatment means along distance gradient *(P<0.05)*.

Figure 7 shows a reduction in tree density up to the 4th Km, then an increase from the fifth kilometer onwards. Though the density of trees around the settlement camp was high, it was observed that they were relatively young and tree re-sprouts. The presence of many tree stumps near the settlement camp was also an indication of tree cutting. Mature trees were mostly found far away from the settlement camp. Mean tree density values ranged from 5 to 13 along distance gradient.

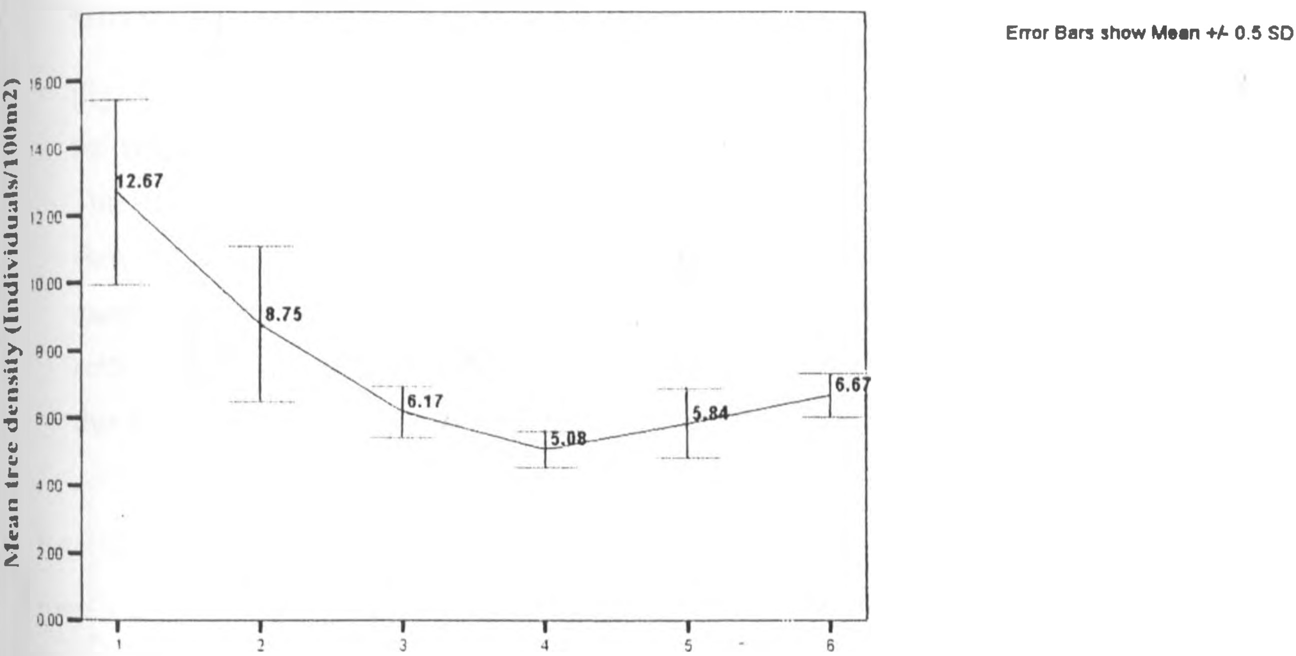


Figure 7: Mean tree species density along distance gradient

4.2.2 Shrub density along distance gradient

There was a significant difference in shrub density along distance gradient *($P<0.05$)*. T-tests for equality of treatment means showed a significant difference between the treatments ($P<0.05$).

Table 5: Mean shrub density for the ten common species within transects and along distance gradient.

Block	Distance from the settlement camp (Km)					
	1	2	3	4	5	6
1	5.67	0	2.00	3.67	3.67	11.00
2	0	7.00	13.00	7.00	5.00	18.00
3	0	9.00	19.00	17.33	26.00	0
4	4.00	12.00	12.00	3.00	32.33	20.67
Mean	*2.42*^{a}	*7.00*^{bc}	*11.50*^{c}	*7.75*^{c}	*16.75*^{cd}	*12.42*^{c}
Standard deviation of mean	*±2.87*	*±5.10*	*±7.05*	*±6.62*	*±14.58*	*±9.22*

*Numbers with the same superscripts a,b,c,d are not significantly different *(P>0.05)*.

Figure 8 shows an increase in shrub density along distance gradient as one moves away from the settlement camp. Low density was observed around the 4th Km along the transect line. This areas were had a relatively high number of Turkana settlements. They exploited the shrubs for fencing their *bomas* and making shelter. Unpalatable shrubs like *Cissus quadrangularis, Euphorbia cuneata* and *Cadaba rotundifolia* had a high density near the settlement camp. *Abutilon fruticosum* a palatable shrub species showed a low density and this was attributed to over-exploitation by the livestock as a source of forage.

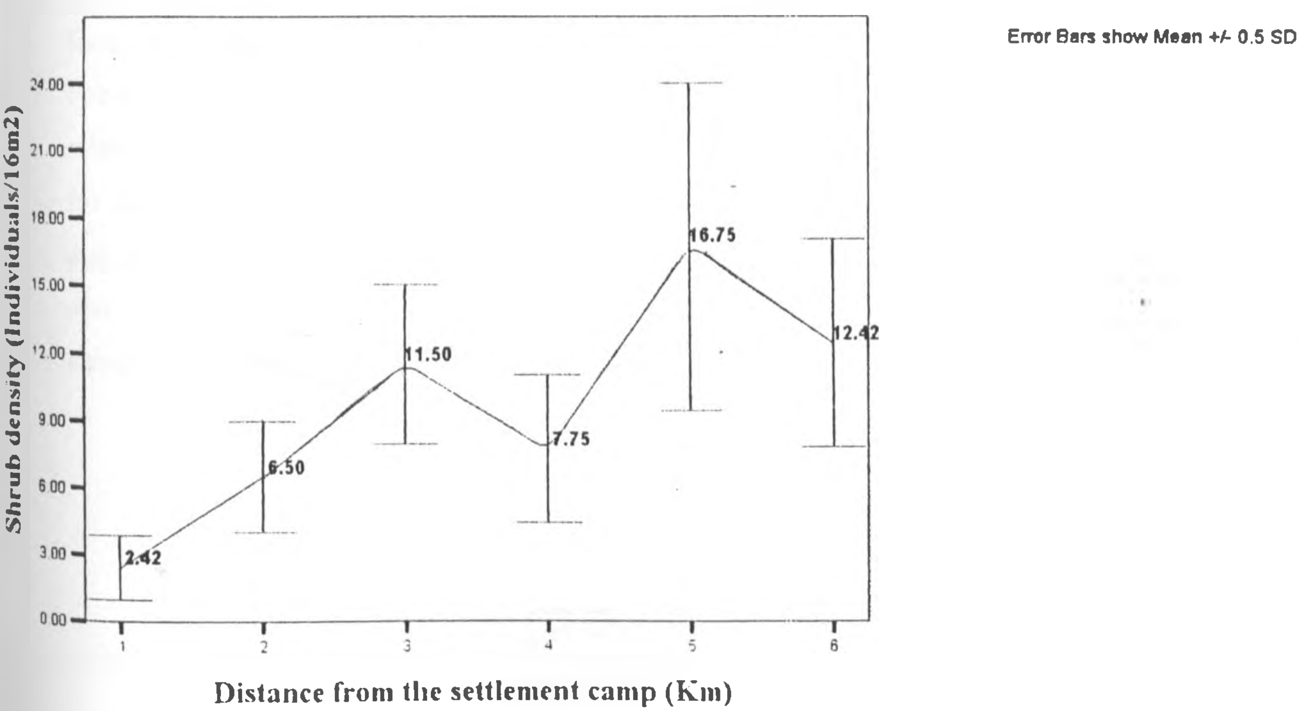


Figure 8: Mean shrub density along distance gradient

4.2.3 Herbaceous species density along distance gradient

Table 6: Mean Herb species density for the 10 common species within transects and along distance gradient.

Block	Distance from the settlement camp					
	1	2	3	4	5	6
1	377.00	62.00	124.00	96.00	62.00	68.00
2	98.00	78.00	40.00	108.00	44.00	37.00
3	286.67	120.00	106.00	40.00	165.00	570.00
4	47.00	116.00	214.00	214.00	312.00	73.00
Mean	*202.17^{ac}*	*94.00^{b}*	*121.00^{b}*	*114.50^{b}*	*121.00^{b}*	*187.00^{bc}*
Standard deviation of mean	*±155.6*	*±28.52*	*±71.75*	*±72.65*	*±81.26*	*±255.83*

*Numbers with the same superscripts a, b, c are not significantly different *(P>0.05)*.

Herbaceous plants density showed a significant difference along distance gradient, *(P<0.05)*. T-tests for treatment means showed a significant difference (*P<0.05)* Table 6. Herbaceous plants density showed significant reduction along distance gradient from the settlement camp (Figure 9). Some herbaceous plants which could not be found near the camp were found away from the camp at 4-5 Km. This were plant species used mostly for food and medicine e.g. *Corchorus spp* and *Amaranthus spp*. This may be due to overuse.

For the trees, shrubs and herb relative density, it was observed that the species with a high relative density near the settlement camp were of less use locally. They were not exploited for wood-fuel, building materials or for the provision of food. This species include *Cissus quadrangularis, Cadaba rotundifolia, Prosopis chilensis, Tribulus terrestris* and *Portulaca oleraceae.* Economically viable species had a high relative density away from the settlement camp. This is an indication of overexploitation of the resources near the settlements.

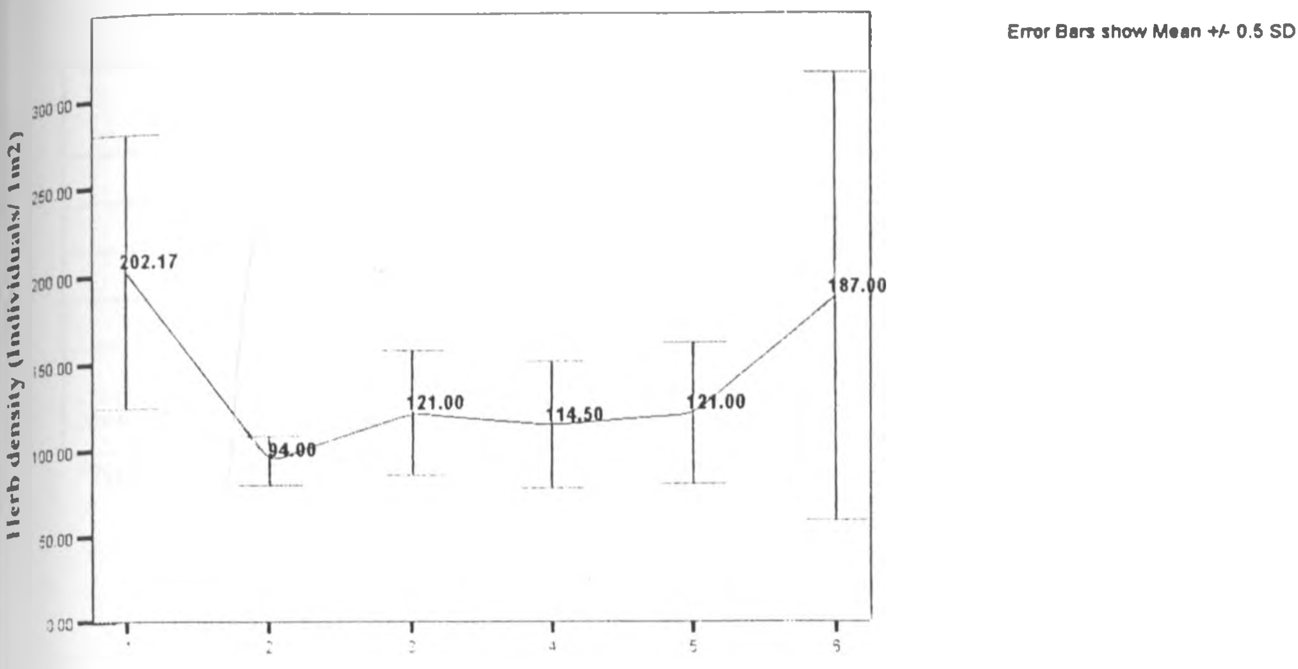


Figure 9: Mean herbaceous species density along distance gradient.

4.3 Species diversity

In general species composition (no. of spp.) around Kakuma is very low and natural regeneration very suppressed. Shrubs and dwarf shrubs are heavily browsed. Further away from the camp this changes. Species composition differs from site to site, indicating the relative importance of specific site conditions (soils, rainfall, availability of seeds) for the occurrence of plants. Some of the areas around the camp are naturally devoid of vegetation.

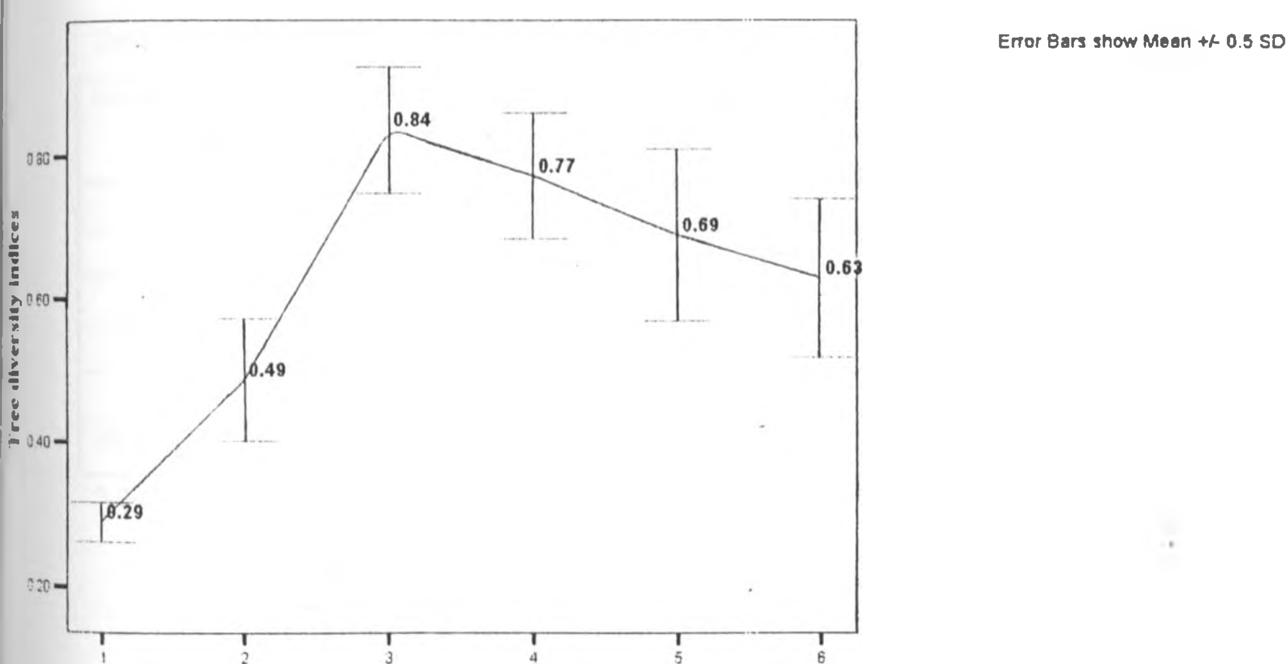
4.3.1 Tree species diversity

There was a significant difference in tree species diversity along distance gradient, *($P<0.05$)*. T-tests for treatment means showed a significant difference *($P<0.05$)*, Table 7. Tree density was generally low near the settlement camp but increased to the 6th Km. Tree species diversity increased to the 3rd Km and later showed decreases from the 4th Km onwards (Figure 10).

Table 7: Mean tree species diversity indices within transects and along distance gradient

Block	Distance from the settlement camp (Km)					
	1	2	3	4	5	6
1	0.30	0.48	0.59	1.00	0.90	0.84
2	0.23	0.60	0.86	0.81	0.83	0.51
3	0.27	0.25	0.89	0.61	0.36	0.79
4	0.36	0.62	1.00	0.67	0.67	0.38
Mean	*0.29^{a}*	*0.49^{bc}*	*0.83^{c}*	*0.77^{c}*	*0.69^{bc}*	*0.63^{bc}*
Standard deviation of mean	*±0.56*	*±0.17*	*±0.17*	*±0.17*	*±0.24*	*±0.22*

*Numbers with the same superscripts a, b, c are not significantly different *(P>0.05)*.



Distance from the settlement camp (Km)

Figure 10: Mean tree species diversity along distance gradient

4.3.2 Shrub species diversity

Analysis of variance (ANOVA) indicated a significant difference *(P<0.05)*, in shrub species diversity along distance gradient. T-tests, for treatment means showed significant difference in the treatment means *(P<0.05)* table 14. Shrub species diversity was low near the settlement camp and showed a reduction from the 5[th] Km onwards (Figure 12).

The demand for shrubs as building and fencing materials put a lot of pressure on the available shrub resources depleting them. The most cut shrub species were the *Cadaba rotundifolia, Acacia reficiens, Abutilon fruticosum* and *Commiphora spp.* This were depleted giving way to dominant species like *Cissus quadrangularis* and *Euphorbia cuneata*, that were not used as animal forage and building materials. This two species thrived well in the sand dunes and the bare lands.

Table 8. Mean shrub diversity indices within transects and along distance gradient.

Block	Distance from the settlement camp (Km)					
	1	2	3	4	5	6
1	0.55	0.00	1.00	0.86	0.33	0.25
2	0.00	0.33	0.48	0.81	0.58	0.82
3	0.00	0.41	0.42	0.39	0.42	0.00
4	0.25	0.54	0.35	0.93	0.37	0.59
Mean	*0.20^{a}*	*0.32^{a}*	*0.56^{ab}*	*0.75^{b}*	*0.43^{ab}*	*0.42^{ab}*
Standard deviation of mean	*±0.26*	*±0.23*	*±0.30*	*±0.24*	*±0.11*	*±0.36*

* Numbers with the same superscripts a, b are not significantly different *(P>0.05)*.

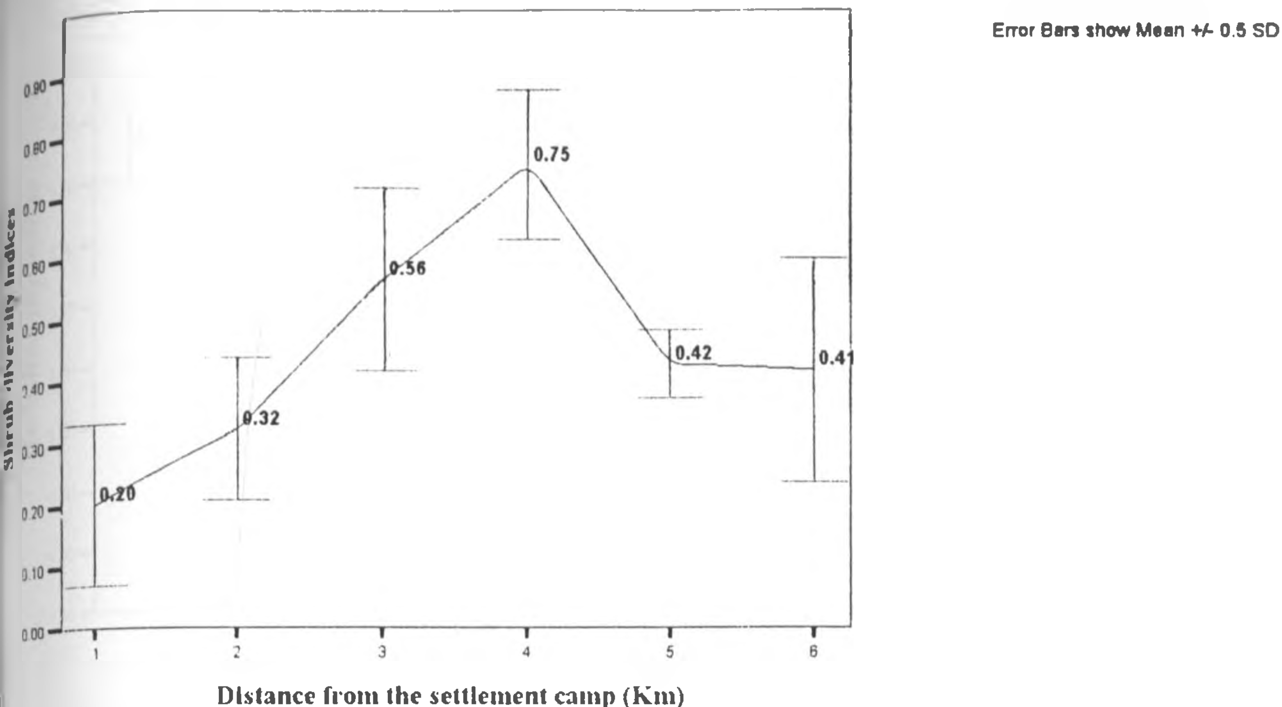


Figure 11: Mean shrub species diversity along distance gradient

4.3.3 Herb species diversity

There was a significant difference in treatments for herbaceous species diversity along distance gradient *(P<0.05)*. T-tests for the treatment means showed high significant differences *(P<0.05)*, Table 9. Herbaceous plants diversity was high near the settlement camp but low far away from the camp. The decline in diversity was from the 5th treatment onwards (Figure 12).

Table 9. Mean herb diversity indices within transects and along distance gradient.

Block	Distance from the settlement camp (Km)					
	1	2	3	4	5	6
1	0.75	0.78	0.82	0.80	0.74	0.53
2	0.85	0.57	0.83	0.84	0.88	0.88
3	0.60	0.80	0.68	0.75	0.52	0.40
4	0.83	0.65	0.62	0.69	0.50	0.60
Mean	*0.76^a*	*0.70^a*	*0.74^a*	*0.77^a*	*0.66^a*	*0.60^{ab}*
Standard deviation of mean	*±0.11*	*±0.11*	*±0.10*	*±0.06*	*±0.18*	*±0.20*

* Numbers with the same superscripts a, b are not significantly different *(P>0.05)*.

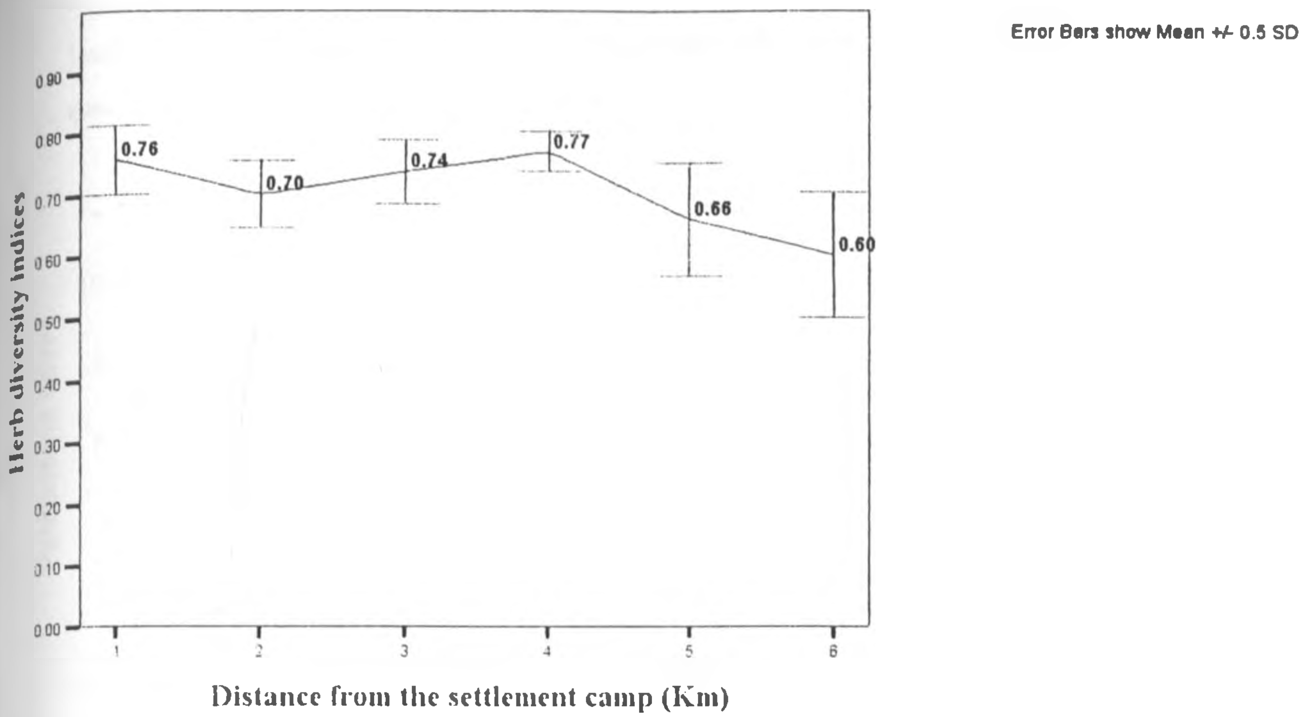


Figure 12: Mean herb species diversity along distance gradient

4.4 Range Condition

All the respondents observed that there were changes in forage availability to all animals. The changes were seen in-terms of a reduction in the amount of forage available, both in the dry season and the wet season.

The following reasons were given as indicators of changes in forage availability: -

1. Perennial grasses are fast disappearing and they are being replaced by unpalatable plant species. Perennial grasses like *Aristida spp.* and *Cenchrus ciliaris* are disappearing and unpalatable species like *Tribulus terrestris* and *Portulaca oleraceae* are emerging with the highest ground cover.

2. Emergence of new grasses in the area. These are grasses that were introduced by a joint pilot project between University of Nairobi and GTZ (German Technical Co-operation). As the livestock feed on the grasses they help in propagation of the seeds and ultimately the area covered by the grasses, though this is still on a small scale and can only be found around the project site.

3. The land is becoming bare and there is soil erosion, both by wind and water. Much part of the land that was once forested and covered with vegetation is now bare. Much of the bare

land is covered with unpalatable plant species like *Cadaba rotundifolia* and *Cissus quadrangularis.*

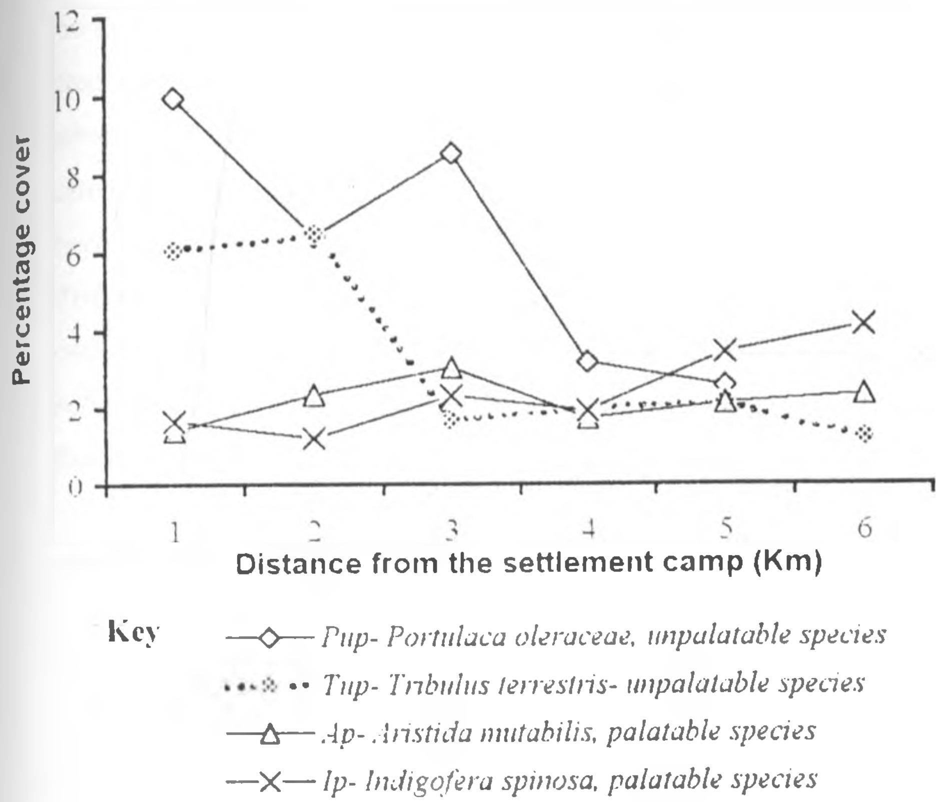


Figure 13: Comparison of palatable and unpalatable plants species along distance gradient.

4.4.1 Causes of the observed changes.

Two main causes were given for the observed changes in forage availability. These were climatic changes and variations and population increase. Some respondents noted climatic change as a reason for the observed change in forage availability. Most of the rainfall was being experienced over a few days of the rainy season and not in all areas. In many instances the rains disappear before plant maturity or seed formation and maturity causing seed impairment and a loss of regenerative potential of the vegetation.

4.4.2 Vegetation Regeneration

Around the camp and Kakuma the regeneration potential of trees and other plants seems to be largely suppressed by the high grazing pressure. Herbaceous regeneration under mature tree cover was observed to be poor as compared to areas with less tree cover. It was observed that different plant species were growing well under different site conditions. The removal of mature trees could have the effect of opening up the canopy allowing for herbaceous regeneration to occur. *Portulaca oleraceae*, *Heliotropium longiflorum* and *Tribulus terrestris* were growing well in open flat land and in depressions where water collects. *Acacia tortilis* was growing well in depressions where water collects but *Acacia reficiens* grew well in stony grounds. *Cadaba rotundifolia* and *Cissus quadrangularis* were found mostly in areas prone to wind erosion. They acted as wind breaks.

4.5 Plant varieties and their uses

Different plant species had different uses. Contradicting information was obtained from the Turkana on the usefulness of *Prosopis chilensis* as source of fodder. Some say it is useful because it provides valuable pods, others complain about a degree of poisoning from the same pods if fed in excess during the dry season. It is reported that it does not produce much litter as other indigenous species. It was also cut and used for fencing. *Salvadora persica* was used as a fodder and toothbrush; *Acacia reficiens* for fencing homesteads and millet farms; *Acacia tortilis* for wood-fuel, building material, fodder, debarked for rope making and furniture; *Cadaba rotundifolia* for wall making, shed construction, fencing around homesteads and windbreaks.

4.6 Soils

Soils textural classes within the study area were sandy-loam and sandy-clay-loam. The pH values ranged from 6.3 – 8.9, largely alkaline in nature. There was no significant difference in treatment means along the distance gradient *($P>0.05$)*. Bulk density was high and ranged from 1.21/g/cc to 1.62/g/cc.

4.6.1 Organic Carbon

There was no significant effect of treatments along distance gradient from the settlement camp, *($P>0.05$)*. Mean values ranged from 0.53% to 0.98%. There was a high organic carbon content in the soils near the settlement camp and a reduction to the 3rd Km then an upward trend again.

Table 10: Mean % organic carbon values along distance gradient and soil depth

Distance (Km)	Mean % Value	0-15cm	15-30cm
1	0.98	0.92[a]	1.05[a]
2	0.48	0.49[a]	0.47[a]
3	0.53	0.38[a]	0.67[a]
4	0.78	1.06[ab]	0.50[a]
5	0.84	0.95[a]	0.74[a]
6	0.84	0.83[a]	0.84[a]

*Numbers with the same superscripts (in rows) are not significantly different *(P>0.05)*.

4.6.2 Soil total nitrogen

There was a significant treatment effect along distance gradient, *(P<0.05)*. T-tests for the treatment means showed significant differences along distance gradient *(P<0.05)* (Table 11). Mean values ranged from 101.29 μg/g soil to 177.10 μg/g soil. There was a high concentration of nitrogen near the settlement camp and a reduction to the 3rd Km and later an upward trend.

Table 11: Mean total nitrogen values (μg/g soil) along distance gradient and soil depth

Distance (Km)	Mean Value (μg/g soil)	0-15cm	15-30cm
1	177.10	187.6[a]	166.6[a]
2	101.29	108.2[a]	94.38[a]
3	112.65	89.10[a]	136.2[a]
4	119.2	137.6[a]	100.8[a]
5	174.3	200.2[a]	148.4[a]
6	174.7	179.2[a]	170.2[a]

* Numbers with the same superscripts (in rows) are not significantly different *(P>0.05)*.

4.6.3 Soil phosphorus

There was no significant effect of treatment along distance gradient *(P>0.05)*. T-tests for treatment means showed no significant differences along distance gradient *(P>0.05)* Table 12. Mean values ranged between 113.49 ppm to 195.94 ppm. There was a high phosphorus concentration near the settlement camp than the distances far away.

Table 12: Mean phosphorus content (ppm) along distance gradient and soil depth.

Distance (Km)	Mean Value (ppm)	0-15cm	15-30cm
1	195.94	192.3[a]	199.6[a]
2	147.92	141.7[a]	154.2[a]
3	139.48	154.8[a]	124.2[a]
4	160.90	168.4[a]	153.4[a]
5	119.38	91.3[a]	147.5[a]
6	113.49	84.5[a]	142.5[a]

* Numbers with the same superscripts (in rows), are not significantly different *(P>0.05)*.

4.7.1 Livestock ownership

A total of 40 households were sampled among the Turkana. From the sampled population, 97.5% of the respondents kept livestock and the remaining 2.5% initially had livestock but lost them to either raiding or drought and are now poor, some of them begging for food. The livestock kept were cattle, camels, goats and sheep. The distribution of livestock was as follows: -

Table 13: Livestock numbers and distribution among households in the study area

Livestock numbers	Number of households	% Distribution
1 – 20	14	35.0
21 – 40	11	27.5
41 – 60	5	12.5
61 - 80	7	17.5
81 – 100	3	7.5
Above 100	-	-

More than 60 % of the respondents had a herd size of not more than 40.

4.7.2 Livestock slaughters

Livestock slaughters in Kakuma showed an upward trend since 1990, especially for goats (Figure 11). Sheep and cattle slaughter numbers showed a declining trend, between 1992 and 1995 and an upward trend from 1996. The main consumers of the meat were the Kakuma refugee camp and the local population. Apart from these, the local population also slaughtered donkeys, though this was not recorded. The figures of livestock slaughters were suspected to be higher than this since many animals were consumed in the interior parts of Kakuma. The price for goats and sheep was low compared to other livestock species and could be purchased or bartered for with food rations from the refugee camp. The prices of the livestock depended on the available stock on sale on a single day. The average price of sheep and goat was between Ksh. 500 and Ksh. 800, cattle between Ksh. 4,000 and Ksh. 7,000 and camels between Ksh. 7,000 and Ksh. 9,000. The prices near the camp were said to be higher than the other areas. In some cases the animals were bartered for maize, beans and cooking oil from the refugee camp. Livestock was put to various uses within the study area. The reasons according to their importance include: - sale for cash, direct source of food, barter for food, male for female animals and gourds for keeping milk, cultural activities like weddings, loaning to friends, fines in traditional court cases and gifts. From the survey satisfaction of basic human needs came first and the rest followed.

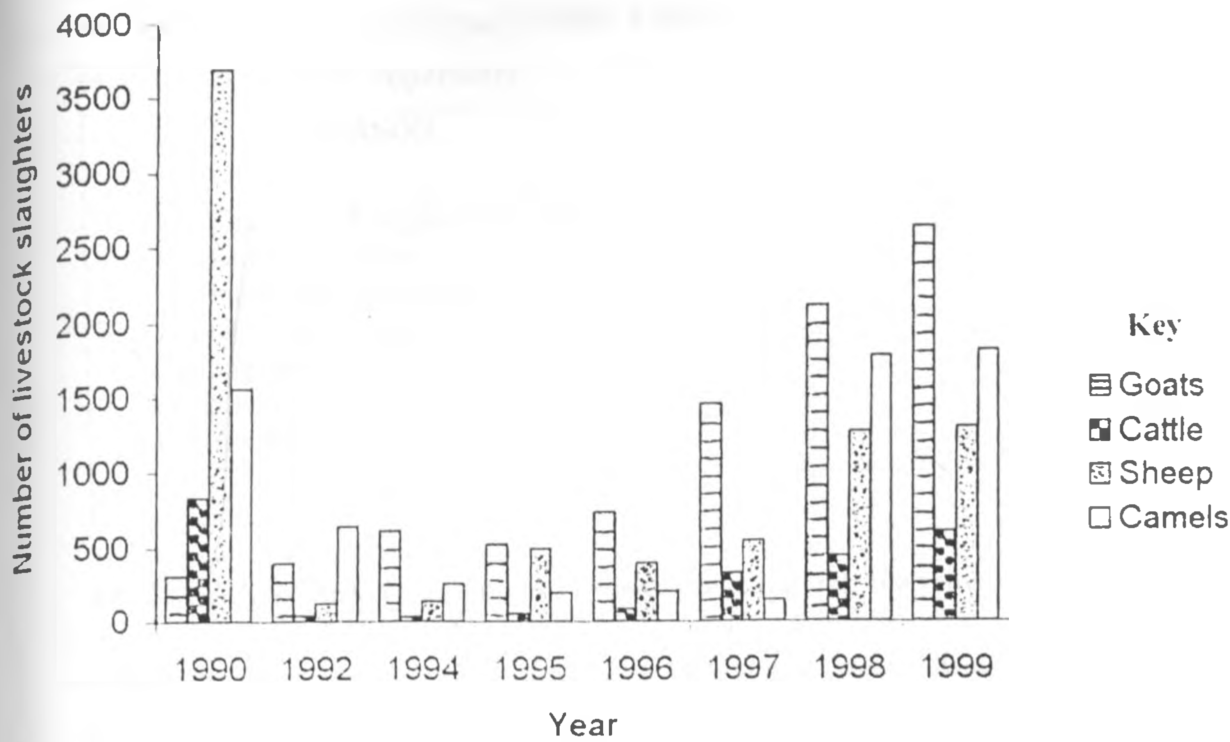


Figure 14: Number of livestock slaughters in Kakuma (1990-1998) (Source: G.O.K. 1999).

4.7.3 Reasons for keeping livestock around the settlement camp throughout the year

From the interviewed population, 65% of the respondents kept their livestock around the camp throughout the year and 35% half of the year. Reasons advanced for keeping the animals around Kakuma refugee camp throughout the year are presented in table 20.

Table 14: Reasons for keeping animals around settlement the camp throughout the year in order of their importance

REASON	NUMBER OF HOSEHOLDS	PERCENTAGE
1. Small stock herd i.e goats and sheep	14	35.0
2. Availability of forage	11	27.5
3. Availability of cheap food and water	7	17.5
4. Market for woodfuel, livestock, building materials and casual labor	5	12.5
5. Raids and insecurity from bandits and cattle rustlers	3	7.5

4.7.4 Reasons for keeping animals around the camp half the year.

During the wet season there is a lot of forage and browse for their livestock around Kakuma refugee camp but during the dry season they move to forested mountainous and hilly regions of Letea, Kalobeiyei, Lopur, Loreng and near the Uganda mountains and sometimes into Uganda and Ethiopia. The respondents with the largest number of livestock are the ones who migrate in search of forage, especially large stock like cattle and camels. Around Kakuma refugee camp, the tree and shrub cover has been depleted and people with large herds opt to move away in search of forage. This serves as a source of forage especially for the browsers. Some families have part of their large stock in the hilly regions and only settle in Kakuma during the wet season with the small stock and during the dry season they migrate back to rejoin their families in the mountainous areas. The families in the mountainous areas remain with the large stock.

4.7.5 Settlement Patterns

The usual migration patterns responding to climatic changes have changed and many Turkanas in Kakuma have opted to settle around the refugee camp area. The survey revealed that 50% of the respondents (households) were original in the area i.e this is their ancestral land. The remaining 50% came from the surrounding regions i.e Letea, Kalobeiyei, Lopur, Pelekech and Loreng areas, which are between 8km to more than 25 Km away from Kakuma. Various reasons are responsible for their migration and settlement in Kakuma. The reasons according to their importance are droughts, raids and insecurity especially the 1980-

82 period, hunger i.e. the general lack of food, availability of forage and water around Kakuma and a small stock of animals especially goats and sheep.

4.7.6 Household Sizes

Table 15: Percentage household size distributions

Number of individuals	Number of households	% No. of households
1 – 3	5	12.82
4 – 6	23	58.97
7 – 9	11	28.21
10 and above	-	-

According to the study, 87.18% of the households had a family size of less than 7 members. Of all the families interviewed there was not a family that had children attending school, although all the households had children of the school going age.

4.7.7 Economic activities

There were various economic activities recorded from the respondents during the survey. The economic activities according to there importance were:-

Table 16: Economic Activities within the study area.

ECONOMIC ACTIVITY	NO. OF RESPONDENTS	%
1. Selling wood-fuel	33	82.5
2. Selling water	14	35
3. Seasonal farming of sorghum	6	15
4. Cutting and selling building poles and fencing material	1	2.5
5. Collecting and selling stones for construction	1	2.5

Selling wood-fuel was the main economic activity because of the demand. Due to water scarcity, water was also on high demand not only by the Turkana, but also by the population in Kakuma town. The water was fetched from the Kakuma refugee camp boreholes or from hand dug wells along the Tarach riverbed. In the dry seasons the water is sought for from distant places. The above economic activities had market either from the refugee camp or the Kakuma town. From the survey 95% of the respondents said they got market for what they sold and 77.5% said they got profit, though they could not ascertain the profit in monetary terms. The profit was expended in the purchase of food, clothing and ornaments, drugs for livestock, human health and in the purchase of more livestock.

4.7.8 Wood-fuel Collection

The survey indicated that 100% of the respondents use firewood as a source of energy. An alternative source of energy was animal feacal matter though this accounted for only one respondent. The Turkana, according to the survey did not use charcoal. In the cases of scarcity fuelwood was bought from the market place with those that had money but sometimes they had to walk long distances to fetch it.

Around Kakuma town live wood was used. It was observed that tree species like *Acacia elatior, Acacia tortilis* and *Salvadora persica* were cut for charcoal and the cutting of shrubs like *Acacia reficiens* was done by women and converted into charcoal in earth mounds. The women mainly did selling wood-fuel. Dead wood was available in abundance beyond 25 Km. zone in Kakuma division, though some of the areas were inaccessible due to lack of road maintenance. Accessibility may prove to be a more important limitation to the firewood availability than the actual amount of dead wood. Most of the dead wood in this region was transported by trucks, after the local population collected it to specific collection sites and sell it. Further away towards the Ugandan border insecurity is the strongest limiting factor to the exploitation of wood-fuel resources in this region.

4.7.9 Perceptions on environmental degradation

The survey indicated that 97.5% of the respondents acknowledge that there was environmental degradation. Population increase in the area was the major cause of environmental degradation. They made a demand on vegetation, livestock, water resources and even space in this fragile environment. Changing lifestyles due to the influence of the population, majority of who are non-pastoral, was seen to affect the sense of communal responsibility of taking care of resources. The turkana people generally conserve the shrub and tree resources as a source of fodder for their animals, but the demand for woodfuel around Kakuma has given them an incentive to cut and sell. The respondents indicated that around the settlement camp, because of population increase, control on the use of vegetation and water resources was difficult. Drought was also indicated as a factor in degradation that led to the loss of livestock and vegetation exposing the land to wind erosion.

There are measures that had been previously put in place to address the degradation of the environment. These were joint efforts by the government, the local people and the NGOs. The *EKWAR* system, a system in which families were apportioned areas where they had 'legal' right of use, was one of the strategies for control of resource exploitation in which the elders set rules on the utilization of the home range. This is more effective near the riverine areas or the riverine vegetation and the water resources. The government through the forest department office employed some people to enforce conservation laws, though the effectiveness of this depended on the mobility of the persons involved.

The government and donor funded Turkana rehabilitation project had a re-afforestation programme around Kakuma. The trees planted were mainly *Prosopis chilensis*, an exotic tree species from Israel. Their survival rate was low because of their high water demands, but they thrived well along the river channels and streams. The trees are good for pods only when they are dry, green pods cause diarrhoea in the animals. The trees also provide shade, hedge and also building and fencing materials. The locals have also, for a long time as a conservation strategy, utilized only dry stems for wood but this has diminished with the increased demand for fuel-wood, hence they cut into live vegetation. In the refugee camp this tree species is doing well because of constant watering by the refugees. An observation on most of the trees is that there is a dieback in the active growing zone of the trees, mostly during the dry season.

4.8.0 Positive and negative impacts of the refugee camp

Since the introduction of the refugee camp there are a number of positive and negative impacts that have been observed in Turkana. The camp has provided a number of employment opportunities, training, schooling opportunities and medical services which otherwise could not have been readily available. Regarding economic issues, there are more marketing opportunities for the turkana livestock. Partly it has a negative environmental impact, of which the most significant is the cutting / burning of large mature trees, to obtain the raw material to burn charcoal (around Kakuma). The camp thus offers a market for the charcoal and woodfuel. Majorities of the people that burn charcoal around the camp are the poor women who are not able to cope well with the pastoral system, others are the families who have their traditional homes there and have lost too many animals to be able to provide for themselves. Grazing is dependent on movement to areas which are sometimes across the borders or otherwise insecure areas, movement to those areas depend on the male family members, thus destitute women have less opportunities to movement within the system. The insecurity in the adjacent area around the camp is thus probably emphasizing/ maintaining the existing structures. The cutting of live trees for charcoal burning is seen as an opportunity to solve the subsistence problems. But this is in the short term, it is no proper solution to the problem of poverty, because it only reduces the possibility for future sustainable subsistence.

5.0 DISCUSSIONS AND CONCLUSIONS

Grazing and rangeland management in Turkana is principally based on the availability of forage species of trees or shrubs. These are the source of fodder for the animals and may have some additional functions like medicine, as source of building materials, and fruit production. Animals are central to the survival of the Turkana. It is for this reason that traditionally the Turkana tend to be conservative in their use of tree and shrub species. Trees are to be protected because they form the basis of survival for the livestock of the Turkana. Available annual and perennial grasses are used opportunistically, due to high spatial and temporal variability in their occupancy, caused by climatic fluctuations.

The 1990 drought led to the death of animals, especially cattle, sheep and camels, reducing the viable herd for take-off and reproduction. The number of goats slaughtered increased despite the drought because of various factors. Their feeding habits make them less vulnerable to drought, since they can browse most plant species. In most cases the number of goats per household are always more than any other livestock species. Due to their high reproductive rates and their body sizes they are preferred for meat, hence they are sold and slaughtered more than any other species. The large stock is excellent for milk and blood (Coughenour *et al.,* 1990). From 1992 the number of goats slaughtered increased tremendously because of the market created by the presence of the refugee camp. The small stock was easy to sell and also barter than the big stock like camels and cattle, because of the low prices they attracted. As the refugee camp expanded over the years, the market also expanded.

Livestock seasonal migration has changed and many opt to stay near the settlement camp the whole year, though some stay near the camp half the year. Several reasons were given for this. Of the reasons given, a small stock herd was the main one, 35% of the respondents, while insecurity ranked the least. The small stock indicates goats and sheep. They did not neccesitate their movement in search of forage. Choksi *et al.* (1996) in a study done among the Rabaris of Gujarat observed that the loss of animals led to sedenterisation. The loss of animals can be through various channels such as raids, diseases and death by drought (Katie, 1993). This concurs with the observation in the field that many of the respondents near the settlement camp and who settled throughout the year were destitute. The market created for wood-fuel, livestock and building materials also led to the settlement of the Turkana.

Mohammed (1992) in a study done among the Fulani of N. Nigeria observed that charcoal making started with the advent of urban centers. This implies that the increase in the population will demand an increase in the supply of fuel-wood.

The demand for livestock by the refugee camp and the Kakuma town acted as an incentive for sedenterization. The demand for livestock products has drawn traders from the interior that come to sell their livestock in the Kakuma town market. The keeping of a large number of livestock around Kakuma for sale has had an effect on the rangeland. There has been range deterioration because the number of animals surpasses the available forage. Ormerod (1978) observed that one of the factors operating to increase aridity in West Africa is the high demand for livestock, which has stimulated the growth of herds. The same phenomenon was observed in Kakuma region, where livestock was mainly kept for sale. The keeping of livestock near the settlement camp for half a year was a risk spreading strategy, in which the pastoralists spread the effects of drought and disease outbreak and also take advantage of the wet season pastures in other areas. Kakuma area has been a dry season grazing reserve for a long time, but due to the increasing population of livestock and reduction of land available for pasture, some families opted to keep their animals near the settlement camp for a short period. Lusigi (1984) observed that increase in human population has tended to reduce the home ranges and concentrate animals in certain areas. This concentration of animals in certain areas has lead to overgrazing and overstocking (Darkoh, 1990; Fernandez-rivera, 1995; Gillet, 1979; Hendrickson *et al.*, 1998). Depletion of forage resources is what motivated them to move in search of pastures for their livestock elsewhere.

Settlement around Kakuma was also due to various factors one of which was insecurity. Insecurity in the area was seen from two perspectives i.e. raiding by the outside people i.e. the Toposa from Uganda, the Oromo from Ethiopia, Sudanese and from Kenya, mostly the Pokot. Apart from the 1981 to 1982 insecurity problem in the area, there has been a continual threat to the security in the region. Internal sources of insecurity included thefts from within turkana community, especially from South Turkana. Due to insecurity and the confinement of the population around Kakuma, there has arisen another sort of insecurity within the community. Personal interviews revealed that the Turkanas around Kakuma were not allowed access to the other grazing areas or blocks far away. There has been a clash over control of resources in the surrounding areas and to some extent confined them even more. This had hindered mobility and led to deterioration of range resources and destitution in some families. The high demand for livestock, due to the presence of the refugee camp, has also led to the increase in livestock thefts within the community.

Though raiding is an age old practice aimed at reallocation of resources, Hendrickson *et al.* (1998) in a study done among the Turkana, observed that in recent times it has been a dangerous practice due to the influence of the outside non-pastoral community and their access to arms, all because of economic reasons. Turton (1992) reported that increase in famine and destitution led to further armed conflict. From the field surveys some of the respondents admitted that due to poverty and the need for daily subsistence they raided for livestock. This was done to the communities far away from Kakuma area. In some instances there were clashes over resources and resource management in areas far away from Kakuma, among the Turkana community.

A reduction in livestock numbers coupled with lack of alternative lifestyles has led to famine i.e. general lack of food even in years of good rainfall. This was mostly observed in the families that had small stock relative to family sizes without any other source of subsistence. Famine was also accentuated by the fact that livestock migration was hindered, and access to the other dry season grazing pastures, affecting the production and reproduction of livestock. A small number of animals in relation to family numbers did not necessitate migration because the livestock was the basis of food supply to the family. In this case, the families opted to look for alternative sources of food like selling of charcoal, firewood and building and fencing materials to the refugee camp and Kakuma town apart from seeking for casual employment. This affected reproduction rates and production of milk, meat and blood among the livestock. Hunger also affected their health and the ability to move long distances with their livestock in search of forage. The government intervention measures included the supply of relief food and Kakuma was used as the relief food supply center, attracting settlement.

The start of the refugee camp in 1992 acted as an incentive to further their settlement. The camp was and has been a source of food, employment and trade. Herd recovery was slow and efforts to boost herd recovery were less considered due to the presence of potential food sources. Though traditionally settlements in times of drought were temporary to boost herd recovery, loss of a large percentage of animals and many years of herd recovery forced them to settle. It was observed that 65% of the respondents settled since the 1990 drought in which most of their livestock died. Katie (1993) in a study done in Baringo reported that drought can claim up to 80% of the stock and long years many years of recovery can force the pastoralists to settle.

Family sizes were sizeable compared with the available food sources or livestock numbers. Lamprey (1983) estimated that for a family of 8 persons needs a small stock of 50 – 60 animals is the minimum and for large stock it's 7 cows or 4 camels for the supply of milk. However the condition of the animals matter a lot. Due to limitations of forage near the settlement camp, the respondents said that the production of livestock was not sufficient to meet their daily needs. Because of limited food supply they have engaged in other economic activities to supplement livestock production. This was seen as a pastoral production strategy reported by Cossins (1983). The income was used on the purchase of basic needs and ornaments.

The Turkana placed a high premium on their cultural values and claim that formal education is inferior to pastoral skills. Because of this they were reluctant to take their children to school because it interrupted the informal learning of pastoral skills. This agrees with the observation made in personal interviews within the community in which the old people complained that the young people might lose touch with their cultures if they go to school. Mwaniki (1981) and Khogali (1981) made the same reports. However interactions with the outside community and the effects cannot be avoided. The economic incentives and opportunity to make money may be other reasons why they didn't send their children to school. The children and the youth were engaged in trade in the refugee camp and also the Kakuma town.

This study revealed that there is degradation of the environment. Increase in population was one single most important factor of degradation. People within the study area exploited the vegetation for animal browse and forage, fencing and material for constructing *bomas*, water resources and wood-fuel. The populations from outside the district exploited the water resources, wood-fuel and building materials. It was seen that the demand of these resources outweighs the availability in the study area. Lusigi (1984) and Lamprey (1983) observed similar trend. The availability of a ready market from within and outside the district, for charcoal, firewood, building materials, livestock and labor increased the pressure on vegetation resources. Ormerod (1978) made the same reports in a study done in West Africa. He observed that the economic demand for livestock forced the pastoralists to increase their herds without a consideration of the ecological carrying capacity, to what he termed the 'economic carrying capacity'. Availability of a ready market for livestock, led to the justification for increase.

The value of trees was seen to be more than that of the shrubs because they provided for building materials and wood-fuel. Because of this trees were cut without choice of species, this was evident by the number of tree stumps around the camp. The need for shrubs for fencing and building house walls was the greatest pressure on this resource. *Acacia reficiens* (Vatke)Brehan was used for fencing around the bomas and the houses in the refugee camp and the surroundings because of its spines since they can keep off intruders. *Cadaba rotundifolia* Forsk and *Abutilon fruticosum* L.Del were mainly used for the construction of house-walls and shade. The harvested shrubs were sold in bundles or exchanged for food. The Turkana use the two shrubs to cover the houses against sun and rain and also for making shade. All the tree species were cut but the most cut tree species was *Acacia tortilis* (Forsk)Hayne. This was also lopped for the provision of fodder for the animals, though this was not a common practice among the Turkana, because of scarcity of fodder near the settlement camp. Other tree species that were cut were *Boscia coriacea* Pax, *Salvadora persica* L, *Acacia elatior* Brenan, *Dichrostachys cinerea* (L)Wight, *Cordia sinensis* Forsk and *Dobera glabra* Forsk(R.Br).

Shrub cover was much reduced near the settlement camp by the local population and also by the refugees. There was a reduction in shrub cover around the 4th kilometer from the camp. This area also had a comparable high number of Turkana settlements. The demand for shrubs for the construction of bomas and fencing was used to explain the phenomenon. The settlement camp did not have a significant impact on the shrub species as much as the Turkanas. The settlement camp and the Turkana settlements around the 4th kilometer had similar effects. Tree cover, away from the settlement camp, was not affected so much and this may point to their conservative nature of tree species. This agrees with Lusigi (1980) in a study done in Marsabit. He observed that the building of bomas and fencing were the major practices that have depleted the vegetation resources, especially shrubs, in the pastoral areas.

Herbaceous cover was high near the camp, though we had a high number of livestock in this area. Most of the grasses were annual grasses, with few perennial grasses. Though cover was high, it was observed that most of the herbaceous vegetation were unpalatable species like *Tribulus terrestris* L and *Portulaca oleraceae* N.E.Br. A study done in Baringo showed the same trends (Little, 1996). An increase in tree cover gave a corresponding reduction in herbaceous cover. Knoop and Walker (1985) reported that herbaceous vegetation can be depleted under dense woody vegetation. The opening up of woody vegetation therefore favored the growth of herbaceous vegetation. Grasses were over-utilized in the study area, especially near the settlement camp. This observation agrees with Skarpe (1990) in an experiment done in Botswana. The experiment indicated that in heavily grazed areas the proportion of bare ground and herbs was high than grasses. Livestock, mainly goats graze areas around Kakuma and deposit the seeds near the settlement camp. During the dry seasons the area looks bare, but in the rainy season the area is green. As the rains disappear they senescence and die. This temporal and spatial variability in annual vegetation was also observed by Cully and Cully (1991) in a study done in New Mexico.

Though tree cover near the camp was low, tree density was high. The explanation is that there was high tree recruitment and tree re-sprouts from cut trees near the camp. The young trees did not give so much cover. The cutting of big trees may have created a microenvironment for the growth of younger trees due to the exclusion of competition for resources for growth. It was also noted that since the need of the refugees and the settlements around was mostly building materials and wood-fuel, young trees were excluded by virtue of how much they can produce. In some cases they were much browsed, leaving the stems and a few branches. Further away from the settlement camp there were big trees with much developed crown cover. Shrub density was also observed as a function of settlement. The larger the Turkana settlement, the more the effect they have on the shrub resources. The shrubs were utilized for fencing, house making and also as a source of forage. Apart from cutting into the resources, their livestock also over-browsed the shrubs affecting even regeneration. Herbaceous plants density reduced as one moved away from the settlement camp. This may imply the possibility that the livestock forage and browse in other areas and deposit seeds near the settlements.

Tree diversity was low near the camp and increased away from the camp. This may be attributed to the effect of vegetation resource exploitation. Some tree species were hardly found near the camp and there were few tree species near the camp than far away. Browsing pressure and cutting had reduced the number of species. Tree species like *Boscia coriacea* Pax, *Salvadora persica* L. *Cordia sinensis* Forsk and *Dobera glabra* (Forsk)R.Br were hardly found near the settlement camp. Shrub species diversity was low near the camp and increased away from the camp. Though there was a high utilization of shrub vegetation, especially for construction of livestock enclosures, building materials and fuel-wood, there was a high number of individual species like *Caralluma spp, Cissus quadrangularis* L, *Cadaba rotundifolia* Forsk and *Euphorbia cuneata* Vahl, which are all unpalatable, dominating the area. They were invaders growing on the nearly barren land and sand dunes. Further away from the settlement camp due to the limited pressure on land, species diversity was high. Herbaceous species diversity was high near the camp up to the 4^{th} Km, then showed decrease. A greater part of the species was the unpalatable species. These were not so much affected by livestock feeding habits. The same observations were made by Adam (1990). It was also observed that species like *Amaranthus hybridus* L and *Corchorus spp, were* not found near the settlement camp. This two are palatable species for livestock and they are also used as vegetables. Duncan and Jarman (1993) reported that close and persistent cropping of plants by grazing animals is a natural phenomena and in many ecosystems it maintains or increases diversity, by creating germination sites through trampling and defeacation. The latter might be the cause of increased diversity of herbaceous plants, as the livestock feed in other areas they deposited the seeds around the settlement camp.

Water seemed to be the most limiting factor to vegetation regeneration. A forestry programme by International Rescue Center and the Government of Kenya in the refugee camp seems to be a pointer to this. The project has planted the following multipurpose tree species; *Carica papaya, Tamarindus indica, Dobera glabra, Psidium guajava, Salvadora persica, Mangifera indica, Cassia simea, Terminalia mentalis, Moringa oleifera, Parkinsonia aceuletum* and *Luceana lucocephala.* These are grown mostly in the refugee camp and watered on a daily basis. It was seen that the indigenous species i.e *Salvadora persica* L, *Zizyphus mauritania* Lam and *Dobera glabra* (Forsk)R.Br have a high survival rate than the 'imported' species as long as they are watered.

According to the forest guards around Kakuma, the people also collected the seedpods and stored them for later use as fodder for the animals, this is so especially for *Acacia tortilis* (Forsk)Hayne trees. This would also contribute to the lesser availability of seeds for regeneration. Apart from the collection of seed pods for use as forage the high number of goats around the camp had a negative effect on tree regeneration because of there browsing effects. But at the same time there was observed high vegetation regeneration in old livestock enclosures. Limited indigenous information is available on how to promote and protect the natural regeneration of the indigenous species, this is especially difficult because of the mobile nature of the pastoralists. Traditional protective measures to 'rest' or 'protect' certain areas from use are increasingly under pressure due to insecurity, more settlements and larger population sizes. Still the only realistic viable farming system in the area is the nomadic pastoral system and insight in the traditional protective measures would be of important value, this could be enhanced and adopted.

The range condition in Kakuma can be rated as poor. Especially around the town and the camp where the under-storey vegetation has been heavily browsed. At the time of the fieldwork mostly goats were found near the town and the camp, they foraged on the litter and seeds of the *Acacia tortilis* (Forsk)Hayne. Camels could frequently be seen in the A*cacia reficiens* (Vatke)Brehan bushes further away from the camp. Cattle and sheep were hardly found. The animals were watered in Tarach seasonal river mainly from hand dug wells in the dry season. Forage availability, which was mostly herbaceous, favored the small stock i.e goats and sheep and a few camels. Sorghum straws from millet farms supplemented as a source of forage during the dry season, though not so much of it is available. Herlocker *et al.* (1991) recommended 45 days for cattle grazing around Kakuma, 90 days for sheep and goats and less than 135 for camels. The keeping of livestock around Kakuma throughout the year implies that the range resources are over-utilized.

The woody vegetation improves away from the settlement camp. Unpalatable species dominate in some areas. Palatable forage species like *Acacia tortilis* (Forsk)Hayne, *Indigofera spinosa* Forsk, *Salvadora persica* L, *Duosperma eremophylum* (Millne-Redh)Napper, *Balanites aegyptiaca* L.Del, *Indigofera cliffordiana* Gillet, *Aristida mutabilis* Trin. and Rupr and *Grewia spp* were rare near the settlement camp. There was a high cover of unpalatable species near the settlement camp e.g *Cadaba rotundifolia* Forsk, *Cissus quadrangularis* L, *Sanseveria spp* and *Euphorbia cuneata* Vahl. This grew mostly in wind eroded areas and on small mounds of sand dunes. In some areas, the ground was bare and eroded by wind and water. The area of bare ground near the settlement camp was high compared with far away areas. This was mainly because trees and shrubs had been overexploited.

Most of the trees that were cut were also the main sources of forage. There are many tree stumps in the area as an evidence of tree cutting and some were burned down, as a way of felling them and burned for charcoal. The trees that were most cut for charcoal are *Acacia tortilis* (Forsk)Hayne and *Acacia elatior* Brenan with the reason that they produce good quality charcoal and building poles. Cutting the vegetation resources especially *Acacia tortilis* (Forsk)Hayne, denies the pastoralists the pods which are an important dry season forage. The bare soils have then been subjected to wind erosion, as seen from the formation of sand dunes and water erosion, evidenced by the gulleys in parts of the area. Strong winds also tend to blow away the seeds and it's assumed that there are a lot of seeds buried in the sand dunes. The problem is exacerbated by the effect of communal land-use tenure system. The Turkana and the outside population have equal access to the vegetation resources. This has made them lax in protecting their environment. Sinha (1996) in a study done in Rajasthan, observed that population pressure made the pastoralists to change their mode of land ownership from communal to individual ownership. Communal land ownership was seen as the root of irresponsible use of land. Hardin (1968) observed that livestock was individually owned but the resources were owned communally. Because of this there was a tendency for the people not to take good care of the resources, since the cost of degradation will be shared by all.

Dwarf shrubs and trees are important dry season grazing resources. Dwarf shrubs and shrubs were preffered by camels and formed the staple food of the goats in the dry season and often supplemented by the *Acacia tortilis* (Forsk)Hayne pods and sometimes *Prosopis chilensis* (Schartz)DC pods. Few trees and shrubs are truly evergreen in nature e.g. *Salvadora persica*

L, *Acacia elatior* Brenan and *Acacia tortilis* (Forsk)Hayne are semi-deciduous, the latter provide for constant litter fall in the dry season which also contributes significantly to the dry season grazing resources. This was also observed by Coughnour *et al.* (1990) in a study done in Southern Turkana. Most of the bushes were deciduous in character, thus they did not provide for significant grazing resources in the dry season. Dwarf shrubs like *Abutilon fruticosum* (Lam) Sweet, although ultimately deciduous tend to maintain some green leaves fairly long into the dry season and are thus very valuable grazing resource.

The soils in the area were clay-sandy-loam and sandy-loam, as also reported by Weeda (1987). The soils bulk density ranged from 1.21g/cc to 1.62g/cc. Donahue and Miller (1977) recommended that for good plant growth, bulk density should be below 1.4g/cc for clayey soils and 1.6g/cc for sandy soils. This shows that the soils in the study area are not too heavy for plant growth. There may be other limiting factors to plant growth other than the soil bulk density. Soil nutrient content i.e. organic carbon, nitrogen and phosphorus was high near the settlement camp and showed decline to the 3rd Km and increased again. It was observed that around the 4th Km from the main settlement camp there was a high concentration of Turkana settlements. The high soil nutrient content near the settlement camp can be attributed to the recycling of nutrients by the high livestock population within the settlements. The livestock graze in other areas and deposit the nutrients through defecation, maintaining a pool of nutrients near the soil surface, which are readily available to the plants. McNaughton and Ruess (1987) and Detling (1988) recorded the same observations. They observed that grazed pastures tend to have higher soil organic nitrogen and organic Carbon and sustain higher soil microbial populations in comparison to ungrazed grasslands. The pH values ranged from 6.3 – 8.9, indicating that the soils were alkaline. Weeda (1987) in a study done in Kakuma division, in areas 40Km away from the main study area got pH values ranging from 7.8-9.1 which was within the range observed in the study area. The study however realized low phosphorus and % organic carbon values, ranging from 12-21(ppm) and 0.4-0.6% respectively. These figures compared with the results from the study area around the settlement camp show a wide variation. This may be attributed to differences in vegetation cover, livestock density and nature of the soils.

The ASAL soils are generally low in organic matter due to the low density of plant life and fast microbial activities. Jones (1973) in a study done in West Africa showed a correlation between soil organic matter and rate of return of organic residues in the soil, which depends on the type of vegetation. The high density and cover of vegetation, mostly because of the herbs around the settlement camp, may be the reason for the high values of nutrients compared with areas away from the settlement camp. The reason may be that there was a lot of litter fall and decomposition releasing nutrients again into the soil. But due to the low organic matter content in semi-arid soils, they are generally poor in nitrogen content (Bremner, 1951). This later affects root development and uptake of other nutrients e.g. Phosphorus. The high Phosphorus content in the soils within the study area seem to have favored the growth of nitrogen fixing tree species like *Acacia spp.* and *Prosopis spp.* Similar findings were made by Villalobos (1999). Snyman and Ooshuizen (1999) in a study done in Bloemfontein, S.Africa showed that within a period of four years, the organic carbon and total nitrogen content of the top 5cm of soil tended to decline on account of rangeland condition. As the range deteriorated there was a loss or decline in nutrient pool. The poor range condition within the study area can also be attributed to the low levels of nutrients especially nitrogen and organic carbon. Overgrazing exposes the ground to erosion and surface runoff. Because of the poor soil texture, which together with the low vegetal cover at the beginning of the rainy seasons and the high intensity rainfall, there is a high susceptibility to land degradation (G.O.K, 1992).

From the study, several conclusions can be made:-

1. Insecurity in the region has affected livestock production and the social welfare of the community. The traditional pastoral values are changing as many are forced to settle down and change their mode of subsistence. Alternative lifestyles like selling of wood-fuel and water, which adversely affected the resource base, and searching for paid labor are short-term solutions. In the case of the closure of the refugee camp, a bigger part of the local population will remain with few options for survival.

2. The increase in refugee population and expansion of settlements has attracted destitute families around Kakuma. This has made the majority of the population to comprise of people who rely on food aid and begging for a living. This can be seen as the effect of poverty, which has enhanced the break-up of the traditional subsistence structures. Many of the families are not able to adapt to the former traditional pastoral ways.

3. Communal land tenure, though for a long time has been a good mode of resource management, has shown negative impacts. Immediate economic returns sought after by individuals has undermined the collective role of pastoral resource management. The result may be a breakdown in the ecosystem, as many people try to maximize the use of the resources to their own benefit.

4. Pastoralists have a pronounced effect on shrub species than the tree species. Mainly shrubs are used for the construction of *bomas* and fencing, but trees are good sources of dry season forage. Overexploitation comes in due to the economic demand not their normal day to day demand.

5. The cutting of trees and shrubs may increase the cover of herbaceous vegetation. High grazing pressure, if confined in the same area for long time, may later favor the growth of unpalatable species hence having an overall effect on vegetation community structure and species composition. The combined effects of livestock on soils and vegetation, later denudes the land affecting the range condition.

6. Changes in vegetation structure and composition affected vegetation use by livestock. This has later affected pastoral production strategies, since they have to shift from keeping large stock to small stock i.e from cattle to goats and in some instances from goats to few camels. A change in vegetation has limited or reduced the areas available to livestock species for grazing and browsing.

7. From the observations made in the on-going re-afforestation and afforestation programs by International Rescue Committee and Government of Kenya, there is a possibility of the establishment of tree planting programs. Water seems to be one of the most limiting factors in vegetation growth. Exploitation of this resource for tree planting may be of value.

8. Though no concrete data was collected on sorghum farming, the observations made in the field indicate that it promises much but is limited by the amount of rainfall available. The cultivated plots grew well and produced a good crop for most farmers. But this practice is limited on flat lands prone to sheet erosion and mostly near water resources.

5.1 Recommendations

1. To measure the primary production figures of the vegetation around Kakuma would be of interest in the future, so that one can well monitor the process of degradation. It could be tried to relieve certain areas from animal presence for an agreed period (agreement has to be with the local Turkana elders) in order to observe if the degradation would reverse naturally or if active conservation measures are to be taken. If the seed bank has been depleted or it is not enough to induce natural regeneration then reseeding could assist i.e. planting of tree species in plantations.

2. Seeding and re-seeding of grasses and important shrubs could be tried. This will be aimed at increasing the forage production in the area around Kakuma.

3. Destitute families who opt to return to their pastoral way of life should be supported either by the Government of Kenya or donor aided agencies to restock their livestock.

4. The issue of insecurity should be addressed by the government and with the help of the local Turkana community.

5. The government should place restrictions on the use of woody resources, especially charcoal burning, to avoid over-exploitation. This can be done through the forestry department.

6. The local population should be sensitized on the long-term impacts of the overexploitation of the vegetation resources on their environment, especially if the government will relocate the refugee camp or close it down.

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ANNEXES

Annex 1: ANOVA table, tree species % crown cover along distance gradient

Source of variation	DF	Sum of Squares	Mean square	F	Sig. of F
Distance	5	23893.612	4778.722	26.500	.000**
Error	48	8655.885	180.331		
Total	71	41528.601	584.910		

Annex 2: ANOVA table, shrub species % crown cover along distance gradient

Source of variation	DF	Sum of Squares	Mean square	F	Sig. of F
Distance	5	640.010	128.002	9.010	.000**
Error	48	681.945	14.207		
Total	71	3317.011	46.718		

Annex 3: ANOVA table, herb species % cover along distance gradient

Source of variation	DF	Sum of Squares	Mean square	F	Sig. of F
Distance	5	8022.790	1604.558	16.057	.000**
Error	48	4796.600	99.929		
Total	71	27290.655	384.375		

Annex 4: ANOVA table, tree species mean density along distance gradient

Source of variation	DF	Sum of Squares	Mean square	F	Sig. of F
Distance	5	472.111	94.422	3.806	.006*
Error	48	1190.667	24.806		
Total	71	2201.944	31.013		

Annex 5: ANOVA table, shrub species mean density along distance gradient

Source of variation	DF	Sum of Squares	Mean square	F	Sig. of F
Distance	5	1493.278	298.656	12.253	.000**
Error	48	1170.000	24.375		
Total	71	6492.611	91.445		

Annex 6: ANOVA table, herb species mean density along distance gradient

Source of variation	DF	Sum of Squares	Mean square	F	Sig. of F
Distance	5	114743.111	22948.622	5.931	.000**
Error	48	185736.667	3869.514		
Total	71	1268007.778	17859.264		

Annex 7: ANOVA table, tree species mean diversity indices along distance gradient

Source of variation	DF	Sum of Squares	Mean square	F	Sig. of F
Distance	5	2.046	0.481	18.369	.001**
Error	48	1.258	.026		
Total	71	5.458	.077		

Annex 8: ANOVA table, shrub species mean diversity indices along distance gradient

Source of variation	DF	Sum of Squares	Mean square	F	Sig. of F
Distance	5	2.187	0.437	25.432	.000**
Error	48	0.826	0.017		
Total	71	6.716	0.095		

Annex 9: ANOVA table, herb species mean diversity indices along distance gradient

Source of variation	DF	Sum of Squares	Mean square	F	Sig. of F
Distance	5	0.246	0.049	4.718	.001*
Error	48	0.501	0.010		
Total	71	1.775	0.025		

Annex 10: ANOVA table, soil pH values along distance gradient

Source of variation	DF	Sum of Squares	Mean square	F	Sig. of F
Distance	5	5.812	.726	1.447	.228 ns
Error	24	12.050	.502		
Total	47	28.839	.614		

Annex 11: ANOVA table, soil phosphorus values along distance gradient

Source of variation	DF	Sum of Squares	Mean square	F	Sig. of F
Distance	5	36219.473	7243.895	2.074	.104 ns
Error	24	83823.873	3492.661		
Total	47	792501.341	16861.731		

Annex 12: ANOVA table, soil nitrogen values along distance gradient

Source of variation	DF	Sum of Squares	Mean square	F	Sig. of F
Distance	5	50995.363	10199.073	2.655	.048*
Error	24	92190.067	3841.253		
Total	47	324691.556	6908.381		

Annex 13: ANOVA table, % soil organic carbon along distance gradient

Source of variation	DF	Sum of Squares	Mean square	F	Sig. of F
Distance	5	1.522	.310	2.122	.097 ns
Error	24	3.510	.146		
Total	47	8.335	.177		

<u>Key to ANOVA Tables</u>

* - significant

** - highly significant

ns- non-significant

Appendix 1: Percentage relative densities of the 10 commonest trees, shrubs and herbs used in the study.

PLANT SPECIES	DISTANCE FROM THE SETTLEMENT CAMP (Km)					
	1	*2*	*3*	*4*	*5*	*6*
Acacia tortilis (Forsk)Hayne	16	23	26	8	14	5
Acacia elatior Brenan	8	11	8	6	15	3
Dobera glabra Forsk(R.Br)	8	11	4	16	19	14
Salvadora persica L	8	6	19	6	3	15
Acacia mellifera Vahl	8	9	8	7	6	12
Acacia nubica Benth	-	11	12	16	1	12
Balanites aegyptiaca Sprague	8	-	-	5	14	15
Boscia coricea Pax	13	6	5	3	17	15
Cordia sinensis Forsk	8	8	13	6	3	5
Prosopis chilensis (Swartz)DC	24	15	-	6	-	5
Acacia reficiens (Vatke)Brehan	-	13	9	11	27	24
Abutilon fruticosum L.Del	-	-	2	10	9	9
Cissus quadrangularis L	59	11	5	-	6	6
Dichrostachys cinerea (L)Wight	-	-	1	40	12	14
Lycium shawii	-	13	3	-	13	14
Euphorbia cuneata Vahl	-	14	11	-	2	-
Cadaba rotundifolia Forsk	41	14	26	1	1	14
Maerua crassifolia Forsk	-	6	1	27	-	2
Commiphora africana (A.Rich.)Engl.	-	29	26	-	1	7
Zizyphus mauritania Lam	-	-	16	10	24	10
Dousperma eremophyllum Napper	7	5	6	11	11	3
Heliotropium longiflorum Vatke	6	13	9	8	8	4
Indigofera spinosa Forsk	4	6	8	17	17	17
Sericocomopsis hildebrandtii Schinz	8	7	7	3	7	4
Tragus barteronianus Schultz	6	7	7	10	15	15
Tribulus terrestris L	23	14	22	9	9	7
Portulaca oleraceae N.E.Br	26	20	15	10	7	5
Cenchrus ciliaris L	4	4	9	11	10	21
Aristida mutabilis Trin. and Rupr	6	10	11	12	8	18
Amaranthus hybridus L	8	13	6	9	7	5

Appendix 2: Wet and dry season forage species.

FORAGE SPECIES	SHEEP		CATTLE		GOATS		CAMELS	
	Wet	Dry	Wet	Dry	Wet	Dry	Wet	Dry
Acacia mellifera Vahl					x	x	x	x
Acacia elatior Brenan		x						
Acacia tortilis (Forsk) Hayne					x	x	x	x
Amaranthus hybridus L			x		x			
Aristida mutabilis Trin. and Rupr.	x	x	x	x	x	x		x
Duosperma eremophyllum (Millne-Redh)Napper							x	
Eragrostis superba Peyrs	x	x	x	x	x	x	x	x
Justicia exigua S.Moore			x		x			
Psidia arabica (Jaub)Spach.						x		x
Salvadora persica L							x	x
Zizyphus mauritania Lam.					x	x		x
Tribulus terrestris L	x		x		x			
Prosopis chilensis (Schwartz)DC						x		
Cenchrus ciliaris Linn	x	x	x	x	x	x	x	x
Indigofera cliffordiana Gillet	x		x		x		x	
Indigofera spinosa Forsk	x		x		x		x	
Heliotropium longiflorum Vatke							x	
Aerva spp (Burm.f)Schultes	x		x		x			
Maerua crassifolia Forsk								x
Phyllanthus maderaspatensis L	x				x			
Cordia sinensis Forsk					x		x	
Dobera glabra Forsk (R.Br)					x	x	x	x
Calotropis procera (Ait.)Ait.f.						x		
Grewia tenax (Forsk)Fiori					x		x	
Acacia reficiens (Vatke) Brenan							x	
Balanites aegyptiaca L.Del					x	x	x	x
Acacia horrida (L.)Willd.					x		x	x
Acacia nubica Benth					x	x	x	x
Chloris roxburghiana Schulz	x	x	x	x	x	x		
Sericocomopsis hildebrandtii Schinz					x	x	x	x
Barleria acanthoides Vahl				x		x	x	x
Commelina bengalensis L	x	x	x	x	x	x	x	x
Geigeria acaulis Oliv. And Hiern		x				x		

Appendix 3: Plant species found within the study area, their genera and uses.

SPECIES	FAMILY	USES					
		F	Wf	Bm	Dm	Fd	Am
Abutilon fruticosum (Lam)Sweet	Malv	X		X	X		
Acacia reficiens (Vatke)Brehan	Mimo	X		X			
Acacia tortilis (Forsk)Hayne	Mimo	X	X	X			X
Acacia nubica Benth	Mimo	X	X	X	x		X
Acacia elatior Brenan	Mimo	X	X	X			X
Acacia mellifera Vahl	Mimo	X		X			
Aerva jananica (Burm.f.)Schultes	Amar	X					
Aloe spp Engl.	Lilia				x		X
Amaranthus hybridus L	Amar	X				X	
Aristida mutabilis Trin. and Rupr.	Gram	X					
Asparagus flagellaris (Kunth)Bak.	Aspa						
Barleria acanthoides Vahl	Acan	X					
Balanites aegyptiaca L.Del	Balan	X	X	X		X	X
Blepharis ciliaris (L.)B.L.Burth	Acan	X			X		
Boscia coriacea Pax	Borag	X	X			X	X
Cadaba glandusa Forsk	Cappa		X	X			X
Cadaba rotundifolia Forsk	Cappa		X	X			X
Calotropis procera	Ascle		X		X		
Cenchrus ciliaris Linn	Gram	X					
Chloris roxburghiana	Gram	X					
Chrysopogon plumulosus Hochst	Chry	X					
Commelina bengalensis L	Comm	X			X		
Commiphora africana (A.Rich.)Engl.	Burce	X	X				X
Cordia sinensis Forsk	Borag	X	X				X
Cissus quadrangularis L	Vita					X	X
Croton dichogamus	Eupho		X				
Dactyloctenium aegyptiaca L.(Willd)	Gram	X					
Dobera glabra (Forsk)R.Br	Salva	X				X	X
Dichrostachys cinerea (L)Wight	Mimo	X	X				X
Duosperma eremophyllum (Millne-Redh)Napper	Acan	X					
Eragrostis superba Peyrs	Gram	X					
Eurphobia cuneata Vahl	Euph				X		
Geigeria acaulis Oliv. and Hiern	Compo						
Grewia tenax (Forsk)Fiori	Tili	X				X	
Heliotropium longiflorum Vatke	Borag						
Indigofera cliffordiana Gillet	Papilli	X					
Indigofera spinosa Forsk	Papili	X					
Jatropha spicata Pax	Eupho						
Justicia exigua	Acan	x					
Lippia javanica (Burm.f.)Spreng.	Verba						
Lycium shawii	Solan						
Maerua crassifolia Forsk	Cappa	x	X		X		X
Phyllanthus maderaspatensis	Eupho	x	X			X	
Pupalia lapacea (L.)A.Juss	Amar	x					
Psidia arabica (Jaub)Spach	Compo						
Prosopis chilensis (Schwartz)DC	Papilli	x	X		X		X
Salvadora persica L	Salv	X	X		X	X	X
Sanseveria species Thunb	Aspa						X
Sericocomopsis hildebrandtii Schinz	Amar	X					
Tragus barteronianus Schult.	Gram	X					
Zizyphus mauritania Lam	Rhamn	X	X			X	

Key to appendix 3

Malva- Malvaceae
Compo- Compositae
Cappa- Capparicidiae
Salva- Salvadoraceae
Eupho- Euphorbiceae
Borag- Boraginaceae
Solan- Solanaceae
Rhamn- Rhamnaceae
Papili- Papilinioceae
Tili- Tiliceae
Mimo- Mimoceae
Comm- Commelinaceae
Balan- Balaniticeae
Burce- Burceraceae
Amar- Amaranthaceae
Lilia- Liliaceae
Gram- Graminae
Verba- Verbanaceae
Ascle- Asclepiadaceae
Vita- Vitaceae
Acan- Acanthaceae
Aspa- Asparagaceae

F- fodder
Wf- wood fuel
Bm- building materials
Dm- domestic (medicine, toothbrush, walking sticks e.t.c.)
Fd- food
Am- amenities (shade, beauty, live-fencing)