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FORAGE DIVERSITY AND IMPACT OF GRAZING MANAGEMENT SYSTEM ON RANGELAND ECOSYSTEMS IN MBEERE DISTRICT, KENYA

By
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DEDICATION

To my lovely mother Cecilia W. Kamau and my dear daughter Cecilia Wanjiku

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ABSTRACT

Plant species composition, biomass, frequency and density of Mbeere rangeland has been described to compare open and enclosed sites. A total of 245 plant species were identified. Clipping and preference unit technique were used to estimate herbaceous and trees and shrub biomass respectively. Density and canopy cover were done through counting and visual estimation for three growth forms while forage preference was through direct observation. Soil samples were analysed for soil moisture, pH, total nitrogen, organic matter, exchangeable cations, percent carbon, available phosphorus, bulk density, soil colour and textural class (sand, clay and silt content). The species sampled were classified into twenty community types (ten each for herbaceous and all vascular plant species) using Syntax. The effect of grazing and management system in this rangeland was studied both on the vegetation and on the soil properties. Grazing reduces above ground biomass in communal lands mainly through overgrazing and elimination of palatable species. Forage productivity on the other hand largely depends on availability of rainfall and disturbance. In the dry season the biomass accumulated was relatively low but substantially increased during the wet season. Grazing management systems used in this particular rangeland have a direct impact on forage diversity. T-test results shows that total species richness and herbaceous richness in the open site were significantly different ($p<0.05$) from the enclosed site. Species diversity and evenness were higher in open than in enclosed sites. Biomass and shrub cover were also significantly higher ($p<0.05$) in enclosed site than in the open site. Comparisons of life forms dominance using ANOVA shows that phanerophytes and therophytes were significantly different ($p<0.05$) from the rest of life forms. The biomass of all plant life forms occurring in the dry season in the open site was significantly different from the others at ($p<0.05$). The life form spectrum of chamaephytes and therophytes differed from the normal life form of Raunkiaer. An investigation of the soil characteristic in grazed and ungrazed sites showed dramatic differences in some soil parameters. There were significant differences ($p<0.05$) in pH, organic matter, percent carbon, total nitrogen, moisture, bulk density and percent clay between the enclosed plots and open plots. Goats and cattle were observed to have complementary feeding habit thereby reducing forage competition.

1. INTRODUCTION

Pastoralism is a grazing strategy in arid and semi-arid rangelands where other land uses such as agriculture are not economically feasible (Herlocker, 1999) but they may include areas that have in the past or may in the future be used for cultivation. Rangeland in broader term include extensive grazing and woody areas which provide browse or/ grazing, as well as land used by wildlife from which livestock are excluded by diseases, bush encroachment or lack of water. Mostly rangelands are characterized by climatic extremes, low and erratic rainfall, prolonged periods of drought, limited water resource, severe cold or high temperatures resulting in high season to season variability (Friedel *et al.,* 2000; Noor *et al.,* 1999). Major causes of change are grazing of domestic livestock or wildlife, fire, cultivation for cropping and harvesting of resources like firewood, foods and building materials (Friedel *et al.,* 2000).

Rangelands comprise about 50% of the worlds land area and include natural grasslands, shrublands, savannas, deserts provide the majority of range ecosystems, with tundra, alpine communities, coastal marshes and wet meadows making up the remainder (Walker, 1993; Herlocker, 1999). In most African countries, rangeland livestock production is a form of extensive grazing system practiced by migratory pastoralists (nomads) of the arid regions (Osem *et al.,* 2002; Lamprey, 1979). The management systems vary from nomadic pastoralism through mixed subsistence farming (relying mainly on livestock) to commercial ranching. Considering the increasing demand for foodstuffs due to the growing human population, increasing livestock productivity gains importance particularly under harsh environmental conditions in arid and semi arid areas (Noor *et al.,* 1999). Whatever the objectives regarding livestock, the immediate objective for the rangeland itself is the supply of edible, palatable fodder of sufficiently high nutrient quality (Walker, 1993).

Grazing animals may exert beneficial or mutual influences on the vegetation for their own good, and their role in diversifying niche in temperate countries is well known (Edroma, 1981; MEC, 1999). On the contrary, large concentrations of livestock often have harmful effects on the plants because of selectivity and overgrazing. The grazing habits of some animals encourage certain grasses and eliminate others (Oba *et al.,* 2000d; Herlocker, 1999). The overgrazed plants become unable to produce healthy roots and ultimately deteriorate and may die earlier than usual. Other plants which are in any way more resistant to the various direct and indirect influences of the grazing animals become dominant (Herlocker, 1999; Edroma, 1981). These species are referred to as the increasers (Dyksterhuis, 1949).

Quantifying the impacts of livestock grazing on natural communities (forage) has become a major issue in the management of rangelands, especially where grazing is very widespread and it's impacts may be in conflict with conserving biodiversity (Landsberg *et al.,* 2002; Fleischner, 1994). There is no doubt that heavy grazing by livestock can change plant community composition. According to studies done by Zerihun (1985) in grazed sites the most important species like *Andropogon abyssinicus* and *Hyparrhenia spp.* were either reduced or eliminated and replaced by *Pennisetum schimperi, Eragrostis tenuifolia* and

Sporobolus africanus. *Pennisetum schimperi*, which is a characteristic species in grazed vegetation, is one of those species which the most favoured by grazing (Zerihun, 1985).
It is important in the maintenance of arid rangeland resources to know how the grazing animals make use of the forage produced and their preferences for different plant communities (Low *et al.*, 1981). Such information can assist in management and distribution of the grazing animals so that optimal use can be made of all range communities, productive and unproductive, stable and 0unstable, fragile and durable with minimal land degradation. Animal production is closely related to the nutritional value of the forage grazed. The quality of rangeland for livestock production is a result of the species present, the amount of forage available and the chemical and physical characteristic of each species (Vazquez-de-Aldana *et al.,* 2000). In Kenyan rangelands, herbage is generally adequate in quality and quantity during and immediately following rains (Ekaya, 1991). However, herbaceous vegetation matures rapidly in the dry season and is greatly reduced in both quality and quantity.

In areas of less intense grazing, grazers are able to exercise preference between different species available. Studies have shown that mixed stocking with two or more species of different feeding habits make more effective, and often more profitable, use of vegetation (Mwilawa *et al.,* 1996). Unlike stall-fed animals that receive their rations in proportions and amounts dictated by the herdsman, range animals have a wide choice while feeding, depending on the diversity of the plant community. The later depends on the diversity of the plant community (Ekaya, 1991). Different kinds of animals have different forage preferences and so will utilize the same plants to different extents when given the choice.

Literature review

1.1. Rangeland resources

Rangeland resources are influenced by a variety of site characteristics. About 80% of Kenya's land is classified as rangelands, which is characterized by scanty and unreliable rainfall (Herlocker, 1999; MEC, 1999). Rangeland resources are enormous but the ecosystems are fragile requiring appropriate management strategies to ensure sustainable productivity. Animal production through pastoralism and wildlife management is the main form of rangeland use with few agropastoralism.

Rangelands carry over 25% of Kenya's human population, support more than a half of the total livestock population and a large number of various species of wildlife (MEC, 1999; Brown, 1994). These wildlife species and the human population have co-existed without adverse effects on the range resources for a long time. However, recent management practices have led to environmental degradation of the arid and semi-arid land areas mainly through increased wildlife and livestock numbers beyond the carrying capacity (MEC, 1999; Bekure *et al.*, 1991). This overstocking and overgrazing not only encourage soil erosion, but also a selective increase in unpalatable and poisonous plant species (Herlocker, 1999).

Rangelands play an important role in the national economy of the country, with a large number of the population depending on these native forage producing lands for their livelihood (Nemati, 1986). Rangeland vegetation has multiple uses. These include forage for livestock (especially herbage for grazers) which is usually seen as the principle product of rangelands. Rangelands also provide a variety of other important products, services and values. These include forage for wildlife and livestock, habitat, biodiversity, products such as charcoal, gums and resin, honey and traditional plant uses (medicine, etc), water production and aesthetic values (Friedel *et al.,* 2000; Herlocker, 1999; Heady and Child, 1994). Expansion of dryland farming has increased the grazing pressure on the remaining areas and has reduced the area of good rangeland. The absence of satisfactory range management practices or legal control of stock movement has destroyed or reduced productivity of these rangelands (Oba *et al.*, 2000d).

1.2. Primary productivity in arid lands

All biological activities of plants, animals and human beings are dependent on the energy of gross primary productivity (Bonham, 1989). Primary production is the energy fixed by plants, and is perhaps the most fundamental characteristic of an ecosystem. Primary productivity in rangeland is highly variable. It depends on variations in climate (rainfall distribution, length of growing season, etc), soil, grazing intensity, and human pressure on the rangeland (Heady and Child, 1994). In the last century, technology and culture have changed and alongside them, the pattern of exploitation of arid and semi-arid areas by humans. Population densities have increased greatly resulting in over-utilization of some areas, particularly around water points. The natural vegetation has been cleared for fuel and farming which has a positive feedback to intensified the rate of desertification (Ludwig, 1987).

Measurements of primary production are necessary for proper understanding of ecosystem dynamics (Bonham, 1989). In rangelands, therefore, biomass production supplies biological material for use not only as food and animal fodder, but also as fuels, building materials and chemicals (Hall and Coombs, 1983). Vegetation composition, based on dry weight, is one of the best indicators of species importance within a plant community (Bonham, 1989). This is because the weight of live plant materials includes the inter-and intracellular water and any external moisture from vapour condensation, precipitation etc. Therefore the weight of freshly harvested plant materials is highly variable and hence biomass is expressed in terms of oven or air dry weight.

The productivity of a pastoral livestock system depends largely on the animal management, availability of water as well as the distribution, productivity and quality of forage (Bekure *et al.*, 1991). The amount and distribution of rainfall received in east African rangelands varies widely between seasons and years. This results in large fluctuations in forage productivity and hence in livestock productivity.

Most rangelands used for agricultural purposes are stocked with animals for at least part of the time and in many cases all round the year. While agriculture allows the harvest of more biomass per unit area, it does not generally increase the average productivity in terms of total energy or carbon fixation. Much of the grazing takes place in the growing season and that makes forage exceptional as an agricultural commodity. It is harvested whilst it grows and the harvestable product is at the same time the photosynthetic material that produces it (Mannetje, 2000). Hence diminishing overall productivity and the accompanying land degradation. Additionally, ever-increasing areas are used for the construction of buildings, roads, etc and thus their primary productivity is reduced.

1.3. Role of browse in rangelands

Browse refers to that part of an animal's diet derived from the leaves (dead or alive), twigs and fruits of shrubs and trees. Fortunately, the tropical Arid and Semi-Arid Lands (ASALs) occupied by pastoral communities are endowed with both lifeforms (Doyo and Farah, 1998). Since cropping is impossible or unreliable in these areas humans depend on ruminants for subsistence. Similarly the survival of the livestock in ASALs largely depends on the availability of the browse as the grass and forbs die off at the onset of dry season. Woody species besides provide materials for manufacturing household implements, building material for construction, firewood, medicines, shade and food but are also source of forage to livestock (Lamprey *et al.,* 1980).

Trees and shrubs survive harsh climatic conditions and are particularly important for goats and camels (Le Houerou, 1980). In some systems browse constitutes the bulk of available forage, while in others it may be the only available forage during certain times of the year (Oba, 1995; Bonham, 1989). Due to the highly irregular rainfall of drylands and virtual disappearance of nutritious grasses during the dry seasons, trees and shrubs are an essential part of the pastoral environment (Bergstrom, 1992; Le Houerou, 1980).

Goats and camels are adaptable in their feeding habits and can utilize a wide range of plants and plant parts. Apart from the foliage, goats feed on flowering plants twigs and pods of

Acacia. When no other food is available, they feed on barks, roots and most other organic matter (Mwilawa *et al.*, 1996). Browsers rely on their hind legs and sometimes even climb onto low trees in search of browse. Hence, browse is important to small ruminants such as goats whose efficient utilization represents an important feeding strategy (Mwilawa *et al.*, 1996).

Seventy to eighty percent of all woody rangeland plants and most herbaceous species are palatable to either browsing or grazing livestock (Herlocker, 1999; Mwilawa *et al.*, 1996). Browse has a relatively high crude protein and mineral content, and is less subject to seasonal variation in its nutrient content. For example, Herlocker (1999) reports that *Albizzia amara* leaves have a crude protein content of up to 26% and are rich in other minerals. *Boscia angustifolia* leaves and young twigs have up to 33% crude protein. Other important tree and shrub fodder species include *Acacia senegal, A. polyacantha, A.nilotica, A.bussei, Cordia monoica, Delonix elata, Diospyros mespiliformis, Grewia spp., Balanites aegyptica, Maerua angolensis, Ziziphus mauritania*. Browse is also essential in that it is available at the end of the rainy season as fodder bank at a time when the animal's needs for high nutrients content.

Browse being available does not necessarily mean that it will be eaten as browsers too have preferences. Browsers select among plant species as markedly as grazers do. A preferred forage species is defined as one which is proportionally more frequent in the diet and accepted by the animal (Smit *et al.*, 1996). Studies on browse and browsing impact on woody plants in African drylands show that browse can be a significant part of the total feed for large herbivores (Mwilawa *et al.,* 1996; Bergstrom, 1992). Utilization of browse is little studied and patterns are therefore difficult to elicit. Interactions between browsers and woody plants are dynamic, since responses of woody plants to browsing result in changes in feeding behaviours of the browsing animal, both in savannas and in arid ecosystems.

The drylands of Africa have an important component of ligneous species, many of which are browsed and or lopped as dry season feed. The browse trees and shrubs here have higher crude protein and mineral content and sometimes higher dry matter digestibility, than associated grasses particularly during the dry season (Rocheleau *et al.,* 1988). So, despite a history of grazing, shrubs and trees because of their persistence, play an important role in ecosystem stability and ordinarily provide an important energy link between the livestock on one hand and humans on the other (Oba, 1995). Woody species also play a fundamental role in the ecological dynamics of the rangeland ecosystems as they affect biomass (dry matter yields) or, in some cases, alter nitrogen economy of the habitat and the feeding value of the understorey herbage (Mannetje, 2000). Removal of these woody species may lead to permanent loss of productivity for the fragile arid ecosystem (Lusigi *et al.,* 1986).

1.4. Herbivory and plant diversity

Grazing according to Lamprey (1979) is among the important agents, which influence distribution of some vegetation types. In most rangelands ecosystems, grazing, browsing and other factors such as fire and climate contribute to vegetation change. The grasses of eastern Serengeti for example are maintained in very short condition (<10cm) by intensive grazing by numerous ungulates (Lamprey, 1979). The semi-arid rangelands of Kenya are rich in biodiversity of forage grasses and woody species, which are important resources for use by indigenous people for livestock production (Bekure *et al.*, 1991).

Grazing animals influence species composition, changes in biomass and distribution of biodiversity (Oba *et al.*, 2001; Zerihun & Saleem, 2000). However, the influence depends on the extent of grazing. A number of studies on impact of grazing on vegetation show that grazing increases species diversity (Oba *et al.*, 2001; Lamprey, 1979). Discussions on the effect of grazing livestock on plant species diversity have not led to consensus (Osem *et al.*, 2002; Oba *et al.*, 2000d; Zervas, 1998). Some authors suggest that ungulate grazing increases plant species diversity while others report the opposite.

Disturbances influence plant species richness and diversity (Cumming, 1982). The effect of grazing by large herbivores on the diversity of plant communities has been investigated in different terrestrial ecosystems (Oba *et al.*, 2001; Milchunas and Lauenroth, 1993). Grazing increased, reduced or lacked consistent effect on plant diversity (Zervas, 1998; Welch and Scott, 1995). These contrasting patterns of response have frequently been attributed to differences in grazing intensity, with greatest diversity expected at intermediate level of grazing (Grime, 1973). Usually diversity is low in environments with very low availability of resources (i.e. where few species can survive) and increases with increasing resource availability (Osem *et al.*, 2002).

The impact of grazing on diversity differs along gradients of primary productivity (Milchunuas *et al*,1998) but there is no general consensus about the process involved in this interaction (Osem *et al.,* 2002). Grazing intensity affects the quantity and quality of organic and mineralized materials that are delivered to the litter and soil as vegetative residues, urine, and manure (Mannetje, 2000). Grazing also affects the quality of herbage in the sward and this ultimately impacts degradation rate of litter, soil organic matter, and soil nutrient minerazation rates. Huston (1979) predicted that grazing could change diversity in opposite ways in resource-poor versus resource-rich ecosystems.

Changes in plant species composition are central to range management for sustainable production and off-reserve conservation. Plant species can be characterized as "increasers" or "decreasers" corresponding to their shifts in relative abundance in response to grazing (Dyksterhuis, 1949). According to Crawley (1997) grazing-sensitive or highly preferred species decline in abundance (decreaser) while grazing-tolerant or unpalatable species became more abundant (increaser). On the other hand, there are noxius weed, which are not palatable/preferred by animals (invaders) which encroach the whole system. Generally the decreasers are the high quality pasture plants and the increasers are the less valuable (lower digestibility and nutrient content).

Grazing intensity is also important and according to Harper (1977), at low intensities; diversity might be low because of competitive exclusion by the dominant plant. Plant diversity peaks at intermediate grazing intensities when the dominant is suppressed but other species are not substantially affected. Diversity may be low at the highest grazing intensities if there is only a small pool of grazing tolerant (or avoided) species (Crawley, 1997). Diversity may be reduced either by competitive displacement (and eventually exclusion) or by a high frequency of population reduction, which does not allow some competitors to recover between disturbances (Milchunuas *et al.*, 1988; Huston, 1979).

Differences in plant diversity inside and outside of enclosures were observed for several community types in the Serengeti (Belsky, 1986b). Diversity declined in all enclosure while equitability dropped sharply, although species richness was not significantly different. McNaughton (1986) attributed this to replacement by tall species in ungrazed areas formerly dominated by short species when the area was being grazed. Pattern diversity, rather than point diversity was found to be the major contributor of stand diversity (Milchunas *et al.*, 1988).

The negative effect of herbivory on plant growth and fitness approaches a paradigm in ecology (Belsky, 1986b; Harper, 1977). Removal of leaves, stems, sap, inflorescence, or roots reduces photosynthetic surfaces and by extension, nutrient and carbohydrates supplies, seed production, or surfaces for absorption of water and nutrients. Because plants are integrated organisms, reduction in area or biomass of one organ often leads to reduction in others. Since plant size influences the ability of the individual to capture solar energy, nutrients and water, reduction in size usually reduces the plant's competitive success. Hence herbivory is usually assumed to be harmful to the grazed individual (Belsky, 1986a).

It is difficult to generalize about the impact of herbivory on plant diversity because so few detailed long-term studies have been carried out with inconsistent results (Crawley, 1997). Several studies have shown increased plant species richness under herbivory (Oba *et al.*, 2001), a few have shown reduced species richness (Milton, 1940), and several have shown no effect of herbivory on species richness at all (Crawley, 1997).

Studies by Shackleton (2000) protected areas considered for preservation of biodiversity as their primary goal were characterized by significantly fewer plant species than the adjacent highly utilized communal lands at both the plot and point scale. Literature search showed that this kind of research has not been conducted in the Kenyan rangelands partly due to absence of permanent sites protected from grazing and also due to increasing human pressure on the rangelands initially protected for conservation. Most of the researches concentrated on the seasonal exclosures of rangelands (e.g. Osem *et al.,* 2002; Oba *et al.,* 2001; Oba, 1995; Ekaya, 1991), which may portray different patterns of forage diversity from that of permanent enclosure. Investigation for species diversity in permanent enclosures is necessary in order to know whether the biodiversity is being conserved or if it is been lost with the age of enclosures. The study was carried out using a range management system where permanent grazing exclosures and open areas display visually different spatial patterns of plant-species richness and biomass production.

1.5. Grazing management systems

Humans have interfered with natural processes of ecosystems. In developing countries increase in human population leads to corresponding increase in livestock numbers. This may naturally lead to depletion of natural resources, particularly in Arid and Semi-Arid Lands (ASALs) including natural vegetation. In response, pastoralism evolved as one of the earliest professions in which people traditionally moved their livestock from place to place in search of forage and water. This migratory life style helped vegetation to periodically recover from heavy utilization by domesticated animals (Bonham, 1989). Livestock mobility also relieves areas of concentration and allows herds to exploit grazing resources that are unevenly distributed in time and space (Oba, 2000d).

Grazing exclusion and planned water establishment are recent modifications to management interventions in ASALs. Unfortunately they alter traditional land-use patterns and have severe environmental consequence as they result in food scarcity for livestock and induce desertification (Bekure *et al.,* 1991). Grazing systems are linked to better performance of forage plants and the climate (Oba, 1995). The principal goal of range managers (pastoralists or ranchers) is to balance forage cover and composition against herbivore demand. Range managers usually either recommend or impose controlled grazing, expecting that this will enhance rehabilitation of the degraded range. The implication is that, decisions on controlled grazing are based on poor understanding of the ecology and of responses of plants to removal of herbivores (Oba, 1995). Controlled grazing, if over extended, reduces pasture productivity and quality because of accumulated dead phytomass or increased plant maturity.

The exclusion of domestic livestock from grazed rangeland often initiates secondary succession. If left undisturbed this succession may culminate in a plant community with a relatively stable composition (Brand and Goetz, 1986). Range managers have often used exclosures, cemeteries, church yards and other areas inaccessible to livestock to determine the potential for improvement on grazed rangeland. According to Zerihun (1985) floristic richness and the efficiency of the vegetation as an energy trapping system tends to decrease as aboveground biomass becomes concentrated in a few species. The opposite apparently occurs in the grazed sites. Hence, a greater aboveground herbaceous production and a greater grass height characterize ungrazed vegetation.

Some plant species in arid environments actually require regular grazing. According to Oba (1995) *Indigofera spinosa* is highly persistent in Turkana arid ecosystem because of its adaptation to herbivory. In the absence of grazing, the shrub accumulates dead necromass, while under continuous grazing it maintains production of green phytomass (Oba,1995) offering available forage during the dry seasons. Hence, if the over all goal of the pastoralists in the world is to optimize the current year's crop, extended deferral beyond 1-2 growth seasons offers no superior advantage over continuous grazing.

Long-term strategies of grazing management are closely linked to the longer-term variations in forage supply. Therefore livestock management is essentially grazing management, water development and marketing (Bekure *et al.,* 1991). Enclosures are primarily intended for preservation of forage, but they may also be important in conservation. Hatton and Smart (1984) described the effects of a 24 year exclusion of wild herbivores from a Ugandan savanna. Under natural conditions, elephants prevented the persistence of woody populations through their feeding and clearing activities. Once elephants were excluded, an increase in *Acacia* occurred and these extracted nutrients from the soil profile and deposited litter on the soil surface. Compared to unprotected sites, top soil of protected sites showed up to a five-fold increase in exchangeable cations, a 50%

increase in nitrogen and up to a 30% increase in organic matter (Coppock, 1993; Hatton and Smart, 1984).

A different perspective of the climate-plant-herbivory interaction model predicts that the removal of grazers (e.g. both domestic and wild ungulates) will neither improve range production nor range condition in the longer term i.e. greater than 5 years (Oba, 1995). Rather, an extended lack of grazing may result in the accumulation of "old" vegetation, a decline in live plant cover, the loss of species diversity, and reduced plant production (Oba *et al.*, 2000d). Rangeland plants that are grazed continuously may have lower residual biomass and ground cover, but they may have greater production and better survival than ungrazed plants (Oba *et al.*, 2000d). Consequently, grazing rather than being destructive is necessary for proper management of arid zone pastures.

1.6. Plant communities and life forms

Plant association can be grouped into assemblages using classification or cluster analysis (Whittaker, 1975). One of the common method used since the start of ecology is the rearrangement of data tables of species by sites followed by the definition of community types, each characterized by its characteristic species combination (Greig-Smith, 1983).

Classification can be hierachical or non-hierachical (Greig-Smith, 1983; Whittaker, 1975). Herachical systems aim to subdivide the population successively by the most efficient steps. Non-hierachical systems aim to produce the most efficient grouping regardless of the route by which they are derived. A hierarchy may be built up fusing individuals progressively into groups of increasing size until the entire population is fused into a single group (agglomerative) (Greig-Smith, 1983). The final result from any clustering technique depends on both the initial choice of the similarity measure used and the criterion for defining group similarity (Gauch and Whittaker, 1981).

Life forms represents attempts to classify individuals on the basis of vegetative morphology (Grieg-Smith, 1983). Life form grouping in relation to vegetation description may be comprehensive, assigning every species to its appropriate class (Kershaw, 1973). The best known description and classification of life forms and the use of life forms to construct a biological spectrum are due to Raunkiaer (1934). He emphasized that the growth of higher plants depends on the initiation of tissues at apices (meristems). He classified plants according to their life forms defined by the way in which these meristems were held and protected. This criterion appeared to reflect adaptation to climate. Since the perennating tissue makes possible the plant's survival during an unfavorable season, the location of this tissue is an essential feature of the plant's adaptation to climate. The relative frequency of different life forms is then used to construct spectra from the flora of different regions.

Raunkiaer recognized five principal life forms as described below. Phanerophytes are woody plants that have their buds well above the ground surface, fully exposed to the atmosphere. Chamaephytes are various plants with their buds above the ground surface, but below 25 cm. The surviving buds or shoot apices are borne on shoots very close to the ground. Chamaephytes include dwarf-shrubs and semi shrubs, small succulents and rosette-shrubs, and in some uses of life forms mosses and lichens. Hemicryptophytes have their surviving bud or shoot apices situated at the soil surface. Leaf litter or dead plant remains may give the buds of these plants some protection. Cryptophytes have their surviving buds or shoots apices buried in the ground (such as bulbs, corms, tubers, or rhizomes) (or under water).

Therophytes are short-lived annual plants that complete their life cycle from seed to seed during the favorable season of the year. The use of life forms is floristic in the sense of species composition of the community-in this case numbers of species in different life forms. When the numbers of species in life forms in a community, or a geographic area are converted to percent these percent form a life form spectrum. Raunkiaer's normal life form spectrum of the world vegetation is represented as follows; 46%, 9%, 26%, 6% and 13% for phanerophytes, chamaephytes, hemicrytophytes, crytophytes and therophytes respectively.

1.7. Forage preferences by goats and cattle

The preference of forage plants by livestock is also an important consideration in evaluating suitability of the range grazing (Lusigi *et al.,* 1986). It may in some cases be used in the determination of range condition. A range that is used by various livestock species can best be managed if the forage preference of each species is known and mainly, this is the underlying basis for understanding possible competitive interactions amongst them (Owen-smith and Novelie, 1982). This allows for the allocation of the available biomass to those livestock species known to prefer them during any particular season. Large areas of natural vegetation generally offer a greater variety of species and conditions from which animals select food that is favorable or at least pleasing to them (Hyder, 1970). The composition of diets selected by wild and domestic ungulates has long been of interest to range and wildlife ecologists (Ekaya, 1991).

Feed selection is a complex phenomenon involving plant and animal attributes (Illius, 1985; Devendra and Burns, 1970). What is acceptable to one goat does not automatically qualify it to be acceptable to another. Similarly, the relative positioning of the plant above ground level per plant species may also determine the plants which would receive more bites (Otieno *et al.,* 1984). Goats select their diet mainly from tall shrubs at a stratum laying between 0.5 m and 2 m (Schwartz and Said, 1980). The browse selected from this stratum were found to be inadequate in dietary energy during lush periods associated with rainfall due to the balkiness of the forage caused by high water content (Semenye *et al.,* 1989). According to studies done by Ekaya (1991) in south eastern Kenya, forage preferences showed that *Grewia spp* were high ranking in the diets of goats, sheep as well as cattle although cattle preferred grasses. Goat and sheep diets were dominated by *Balanites aegyptica, Chloris roxburgiana* and *Digitaria macroblephera* (Ekaya, 1991).

Energy and mineral requirements, and the avoidance of secondary compounds and toxins, have been shown to influence forage selection (Haschick and Kerley, 1997). Forage preferences can also be influenced by plant structural characteristics, such as spinescence, twiggy growth forms or leaf fibrousness (Owen-smith & Novellie, 1982). Dietary selection may also be influenced by an animal sensitivity to taste of various compound and early foraging learning experiences Cassini (1984) and constraints imposed by morphological, physiological and behavioural characteristics of the foraging animal (Skarpe, 1990).

Feed selection also depends on the heterogeneity of the pastures. At higher levels of availability, not only were selection and feed intake stimulated, but the amount of feed refused also increased (Bosman *et al.,* 1995). Holechek *et al.,* (1982) found that grasses, forbs and shrubs averaged 61%, 16% and 23% of the diets but differed with advancement of the growing season. Forbs were used heavily in the early part of grazing season before maturation. Browse comprised as much as 47% of the diet when green grass was unavailable. They concluded that cattle were opportunistic grazers and did not limit their selection to grass species only.

The browse selection may primarily reflect the animals ability to ingest the preferred species and to a lesser extent the tendency to avoid un-preferred species (Illius, 1985). Animal attributes such as herd size, breed, herd composition (age, sex, type), physiological status, appetite, special senses and social factors all interact with the chemical and physical attributes of plants. These attributes include stage of growth, botanical composition of the forage, nutrients status of the soil, climate, and management of the forage to affect selection of diet (Illius, 1985; Tribe *et al.,* 1963). As plants mature, crude protein (CP) and the more easily digestible carbohydrates decrease while crude fibre (CF), lignin and cellulose increase (Van Soest, 1982).

2. OBJECTIVES

2.1. Overall objectives

Sustainable utilization and management of rangeland resources for maximum livestock production in arid zones by agro-pastoralists farmers. Measurements of botanical composition in the rangeland ecosystem as a measure of available forage to the livestock and assessment of species diversity of Mbeere rangeland in enclosed and open site during dry and wet seasons.

2.2. Specific objectives

1. To study the effect of grazing on forage production and diversity in enclosed and open sites.
2. To investigate forage preferences of domestic livestock (cattle and goats) both in dry and wet seasons.
3. To study the effect of grazing on soil properties.

2.3. Research hypotheses

Grazing intensity affects rangeland vegetation but increases floristic diversity depending on the grazing pressure exerted. On the other hand, lack of grazing leds to accumulation of high biomass, bush encroachment leading to a loss in biodiversity. Forage diversity and availability influenced by the growing season (wet and dry) determine the forage preferences and acceptance by the livestock.

3 THE STUDY AREA

3.1. Location and description

Mbeere district is one of the 12 districts of eastern province in Kenya. Borders with Embu district to the NW, Tharaka/Nithi to the north, Mwingi district to the east, Machakos district to the south and SE and Kirinyaga district to the west (MEC, 1999). The district lies in latitude 0°20' and 0°50' south and longitude 37°16'and 37° 56' east and has a total area of 2097km^2 (GOK, 1986).

The study was carried out at University of Nairobi's Machang'a field station farm in Mbeere district covering an estimated area of 500 ha. The station is located in Mavuria location, Gachoka division of Mbeere district in eastern province of Kenya; about 160 km northeast of Nairobi (Fig.1). The farm is divided into two sections; in one section there is no grazing at all (i.e. permanent enclosed site) for conservation of rangeland biodiversity. The site has been protected from grazing for a period of 12 years and covers approximately 200 ha (farm manager, per.comm). The other section is the open site which is under permanent grazing where livestock graze year round without any restriction and measures approximately 300 hectares. This study site falls in ecological zone IV Pratt and Gwyne (1977) in eastern province of Kenya at an elevation of 1200 m above sea level. A barbed wire fence runs along the boundary except for the southwestern and southern side that borders banks of river Thiba and Kamburu dam respectively.

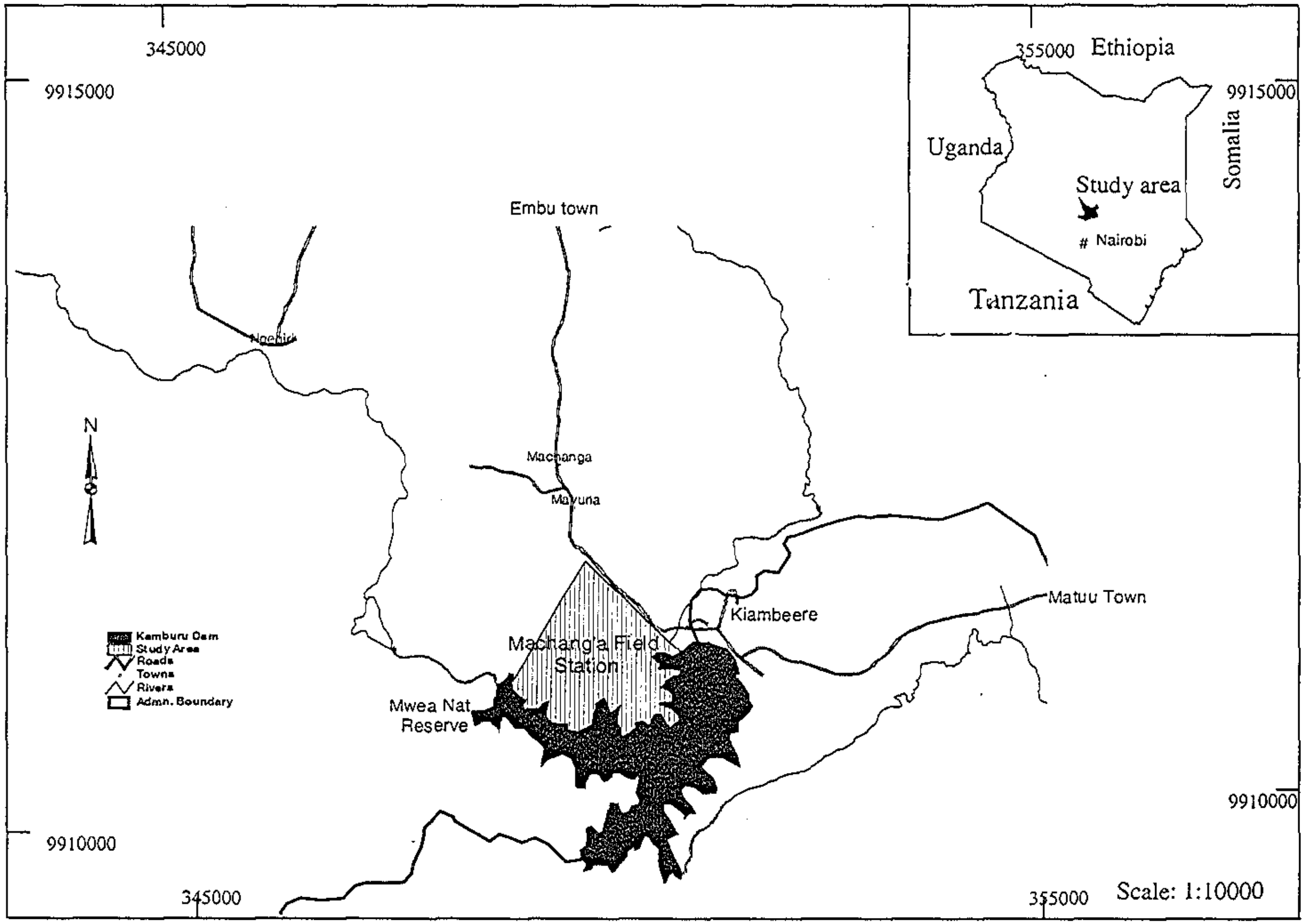
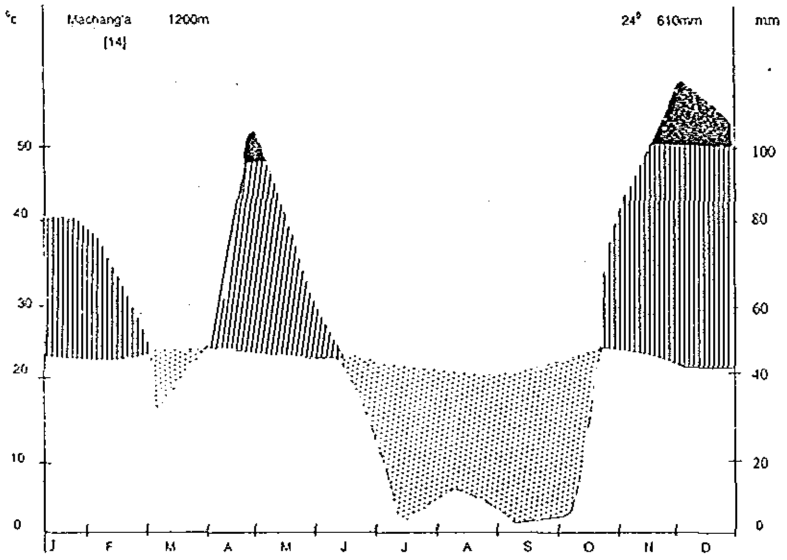


Figure 1. Map of the Machang'a field station

3.2. Climate

The area is semi-arid receiving an annual rainfall of 610-892mm (Mete dept, Embu; GOK, 2001). The general pattern of rainfall in this area is bimodal (GOK, 2001; GOK, 1986; Fig. 2.). The long rains come between end of March and May and again from October to December (Fig.2). April and November experience the heaviest rainfalls. The dry spell is normally in January and February, and June through September (GOK, 2001; GOK, 1986). The rainfall is however not very reliable and most parts receive less than 550mm of the rainfall per year, giving the area a marginal status. There are slight climatic variations in some parts of the district, especially the southeastern region due to proximity to the Kiambeere, Masinga, Kamburu, Gitaru and Kindaruma hydropower electric dams in this area (GOK, 2001).

The mean monthly temperature ranges from 20°C to 28°C, and the mean annual temperature is about 24°C (GOK, 2001). August is usually the coldest month with average monthly minimum temperature of 15°C. March is the warmest month with average monthly maximum temperature rising to 32°C (GOK, 2001).



Source: Embu meteorological station (1989-2002)

Figure 2. Climadiagram of study site

3.3. Topography

The district slopes in a SE direction rising gradually from about 515 m above sea level at the river Tana basin in the east to over 1200 m above sea level (GOK, 1986). The slope is however broken by existence of a few hills such as Kiambere, Kiang'ombe and Kianjiru, which rise above this general height. The Mwea plains cover the southern part of the district and then gradually rise northwards culminating in hills and valleys to the northern and eastern parts of the district. Five permanent rivers serve the district that includes Tana, Ena, Rupingazi, Thuci and Thiba all of which flow on a general southeasterly direction (GOK, 2001; Riley and Brokensha, 1988).

3.4. Soils

The district altitude and climate, coupled with the differences of the underlying geology, have given rise to varying soil types, which in turn influence land use patterns (GOK, 2001; Riley and Brokensha, 1988). The soils are generally sandy, loamy, blackish grey or reddish brown whose fertility ranges from low to moderate and fertilizers are needed for optimum crop production. The northern side of the district is covered by clay soils of different types. Various types of stones, useful precious stones and crystalline rocks cover most of the landscape in the areas. Most rivers and hill landscapes in these areas are too rocky and stony (GOK, 1986; GOK 2001). Cultivation in this region, however, takes place mostly on the better-watered areas along the riverbeds.

3.5. Land use

Except for a small area, the district is largely a low potential dry zone, hence crop production is a difficult venture (GOK, 2001). However, food crops such as maize, beans, sorghum and millet are grown mainly for subsistence (Riley & Brokensha, 1988). The main cash crops grown include cotton, tobacco and to a lesser extent sunflower.

Livestock production is the most significant economic activity undertaken by the Mbeere community (GOK, 2001; Riley & Brokensha, 1988). This is because of the dry rolling plains, most of which have thorn shrub, fertile soils are rare and water has been a perpetual problem in most parts (GOK, 1986). The main livestock reared include cattle, sheep, goats and poultry. The district is suitable mainly for beef cattle as the exotic dairy cattle can hardly survive in the marginal areas. Farmers in the district prefer keeping the low milk yielding breeds as these require less fodder and are easily adaptable to the harsh climatic conditions prevailing in the district (GOK, 2001). Rearing of beef cattle is a common undertaking throughout district. Sheep and goats are reared mainly for meat, with a higher concentration of goats (GOK, 2001). Eighty one percent of total area is suitable for livestock activities.

3.6. Vegetation

The natural vegetation cover ranges from moist, broad leaf, wooded savanna, *Combretum-Acacia* (with *Cordia, Faurea, Bauhinia* and *Terminalia*) to a dry thornbush scrub of *Acacia-Commiphora* (with *Boscia, Delonix* and *Maerua* and xerophytic *Terminalia* species) covering most of the area (Brokensha & Riley, 1986). The lower dry zones to the plains contain much shrub vegetation of short thorny trees growing in predominantly grassy areas (Riley & Brokensha, 1988; GOK, 1986). Some areas of the lower zones either have tough and dry grass, at times with isolated shrubby trees or tufts of grass with nothing growing except sandy plains or huge expanse of rocky ground. River valleys and hill slopes are covered with thick bushes at places where natural vegetation is relatively undisturbed by human activity.

4. MATERIALS AND METHODS

4.1. Sampling

Reconnaissance survey was carried out between 27th –31st August 2002 to identify suitable sampling sites. Two contrasting and adjacent sampling sites were identified at Machang'a field station. Stratified random sampling design was used to collect data. After identifying the sampling sites, four transects were laid down in the enclosed site with a total of 40 quadrats. In the enclosed site transects were laid running from the shores of the Kamburu hydropower station dam into the thick shrubland. Five transects were laid down in the open site total of 50 quadrats were sampled. Each quadrat was 10m x 10m with an interval of 50m since vegetation was homogenous.

The quadrats were marked with wooden pegs at each corner for future reference. In every quadrat four sub-quadrats each measuring 0.5m x 0.5m were established at each corner using a welded square frame for herbaceous biomass measurement (Whalley and Hardy, 2000; Mannetje, 2000; Brand and Goetz, 1986). The total standing aboveground biomass (g/m²) was estimated by clipping for the herbaceous layer and use of reference unit techniques for shrubs and trees (Bonham, 1989). To avoid repeated clipping of the same plots in the next season's sampling, the sub-plots were sequentially moved clockwise by one metre according to Ekaya (1991) within the 10m x10m quadrats.

In estimating biomass, litter was excluded for two main reasons according to Oba *et al.* (2001). (i) Litter in arid environment is highly dynamic and hence the true production is difficult to capture *in situ*; (ii) in both enclosed and open sites the previous years' litter is seldom accumulated due to grazing and rapid litter turn over. The density was estimated by counting of individuals in each plot following Mueller-Dombois and Ellenberg (1974). Percentage cover was estimated visually in every quadrat for the three plant growth forms (herbs, shrubs and trees). The presence and absence of species in the enclosure and open plots provided a measure of frequency for occurrence (%) and the response of plants to grazing (Oba *et al.*, 2001). The nomenclature of the species recorded here follows that of Beentje, 2000; Edwards *et al.*, 1995; Gillet, 1991; Hedberg & Edwards, 1989; Bridson & Verdcourt, 1988; Clayton *et al.*, 1974;

4.2. Vegetation data

4.2.1. Herbaceous biomass production

Changes in biomass are usually determined by harvesting plant material at time intervals suited to the growth pattern of the species under investigation, usually about one month (Roberts *et al.*, 1993). In this study plant material were first harvested during the dry season (October 2002) and this was repeated in the wet season (January 2003). Herbaceous vegetation in each sub-quadrat of (0.5m x 0.5m) was clipped at ground level using a secateur according to Mannetje (2000); Bonham (1989) and Zerihun (1985). It was then mixed together, sorted according to species or species group e.g. *poaceae*, packed in labelled brown bags, weighed and recorded. The fresh herbage was air dried and then oven-dried at 80°C for 48hrs and finally re-weighed (Whalley and Hardy 2000; Roberts *et al.*, 1993; Brand and Goetz, 1986).

4.2.2. Trees and shrubs biomass

Biomass yield of trees and shrubs was estimated using the reference unit technique Bonham (1989); Kirmse and Norton (1985) in the entire quadrat measuring 10m x 10m. A small unit of plant such as a shoot of a given dimension was designated as a reference unit (Bonham, 1989). The size of the reference unit was estimated to be 10-20% of the foliage weight of the average plant according to Kirmse and Norton (1985). Few reference units (5-7) were clipped and average green weight determined (Bonham, 1989). The number of counted/estimated reference units was multiplied by the average weight of clipped reference units to estimate biomass production according to Bonham (1989); Kirmse and Norton (1985). The whole reference unit was oven dried at 80°C for 48hrs and weighed. The total dry biomass of each species was estimated by multiplying the number of the units counted/estimated for a particular plant by the weight of the dry foliage in the reference unit (Kirmse and Norton, 1985). Finally the ratio of dry to fresh weight was calculated to get the actual biomass.

4.2.3. Trees and shrubs density

Counting and recording of shrubs and trees was done in each and every plot measuring 10m x 10m (Bonham, 1989; Mueller-Dombois and Ellenberg, 1974). All the plants that were rooted in the plot were counted but those that had their vegetation materials in the plot but rooted somewhere else were ignored. The average number of individuals per species in the open and enclosed sites was calculated and results converted into density per hectares according to Mueller-Dombois and Ellenberg (1974).

4.2.4. Canopy cover

Canopy cover is the projection of the plant canopies on to the soil surface, and usually expressed as a percentage (Whalley and Hardy, 2000). The canopy cover was estimated visually for the three plant growth forms i.e. herbaceous, shrubs and tree layers in each quadrat before clipping was done and expressed as percentages. Finally the mean cover scores for each plant growth were determined both for enclosed and open sites.

4.2.5. Forage preferences by cattle and goats

Quantitative information from the direct observation of the animals has been obtained from the 'bite count' and ' feeding minutes' (Bjugstad *et al.*, 1970). The latter was adopted for this study because the aim of the study was to assess forage preferences by timing the animals as they feed. Five goats and five cattle were randomly selected from the herd and marked for identification. In each alternative day, one of the selected goat/cattle was observed for four hours as the herd grazed. Grazing observation was done between 0800 and 1100hrs with one hour break. The time spent actively feeding either on the herbaceous or shrub layers by the selected animal was recorded and the feeding minutes/seconds summed up to get the results of the whole day. These goats and cattle were taken to new grazing sites every other day and the observation took two months with one month in each season.

4.3. Soil analyses methods

Soil samples were collected randomly at the plots where the vegetation had been clipped for biomass estimation. Twenty soil samples were collected from enclosed site and thirty samples from the open site. Soil samples weighing 2-3 kgs were collected from a depth of 0-10cm using a soil auger. The soil samples were labeled and sealed in polythene bags and taken to Jomo Kenyatta University, Horticulture laboratory for physical and chemical analysis. The samples were first air-dried before any analysis was done. A fraction of the soil from each sample was rolled and passed through a 2mm sieve except for the bulk density. The following physical and chemical properties were analyzed for each soil sample.

1. Particle size analysis was determined using the pipette method. Sodium hydroxide solution (NaOH) was used as a dispersing agent (Juo, 1978).
2. Bulk density was determined by inserting a 5 cm diameter metal tube (ring) of a known weight (W1) and volume (V) 10 cm into the soil surface. The samples were oven dried at 105°C for 2 days, and weighed (W2). Then the bulk density was calculated as follows: $BD= \underline{(W2 - W1} / V)\ g/cm^3$ (Blake and Hartge, 1986).
3. Soil pH- pH was determined electrometrically using electometric method at a ratio of 1:2.5 v/v of soil to water suspension according to Gapta (1999).
4. Available phosphorus was determined using Bray No.11 and readings recorded as me/100g as described by Gapta (1999).

5. Total nitrogen was analysed using the Kjeldahl method with 0.42 g se (selenium) powder and 14 g Li_2S0_4. H_20 (Lithium sulphate) as soil digesters to convert organic nitrogen to ammonia and then Indophenol's blue method was used to determine amount of ammonia that gives the percentage of nitrogen content (Juo, 1978).
6. Exchangeable cations were extracted by 1N ammonium acetate. Calcium and magnesium were measured using atomic absorption spectrophotometer Page (1982) and Allen (1989) and readings were recorded as me/100g. Sodium and potassium were measured by flame photometer as described by Page (1982).
7. Percent total organic carbon was determined using Walkley-Black method with excess potassium dichromate as oxidizing agent (Allen, 1989; Gapta, 1999).
8. Total organic matter was calculated as percent total organic carbon multiplied by 1.724
9. Soil colour was determined according to USDA (1975).
10. Soil moisture was determined from the samples of the bulk density. The weight before and after drying was recorded and the moisture content is the difference between the two expressed as percentages.

4.4. Analyses of vegetation and environmental data

The data has been classified using the package SYNAX (Podani, 2000) with agglomerative hierarchical technique and correlation as a resemblance index. For each community type, the constituent species have been classified according to Raunkiaer (1934) system of plant life forms and life-form spectrum. The effect of seasons and landuses on the plant life form in relation to biomass and again in the comparisons of the number of species in each plant life forms occurring in four different treatments (i.e. open and enclosed sites, wet and dry seasons) was tested using ANOVA from SPSS statistical program. The means in both cases were separated using Turkeys high significant difference.

A paired t-test was used for statistical comparison of the soil data between enclosed and open plots for different parameters. T-test was again used to test for significant differences in total species richness, herbaceous richness, cover abundance for plant growth forms, density standing biomass for combined species and for herbaceous biomass across the four treatments.

The plant species diversity was calculated using the following Shannon-wieners diversity index (Magurran, 1988).

$H' = -\Sigma \text{ pi } \ln \text{ pi}$

Where H' = Shannon's diversity index

Pi= proportion of individuals or the abundance of the ith species expressed as a proportion of total biomass

$\ln = \log \text{ base}_n$

Species evenness were calculated using the Shannon Evenness Index, that is calculated by the equation;

$E = H' / H \max$ where;

$H \max = \ln S$

H' = Shannon diversity index

ln S = the natural logarith of the number of species

S= No. of species in a community

5. RESULTS

5.1. Biomass

The biomass has been plotted on a log normal scale for different treatments. The X-axis represent species in a descending order of biomass and Y-axis represent log biomass. Different slope of the log biomass portray different trend in the distribution of biomass among the species. The biomass for all the treatments was assessed (i.e. dry and wet seasons, open and enclosed sites). The biomass was compared using the trend of the slope for both seasons in enclosed site. The species corresponding to numbers in X-axis for (Fig. 3-9) are listed in (Appendix 3).

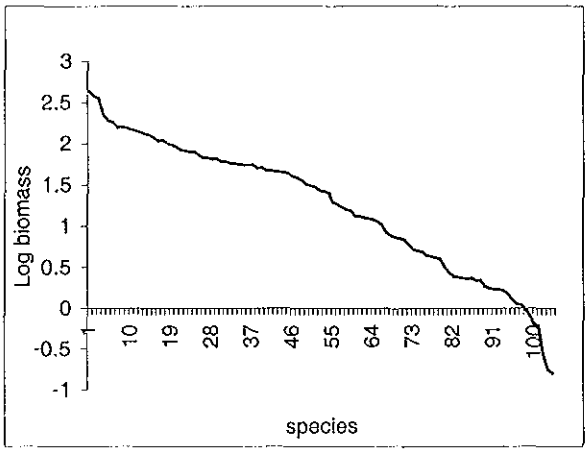


Figure 3. Lognormal plot of species & biomass for dry season in enclosed site

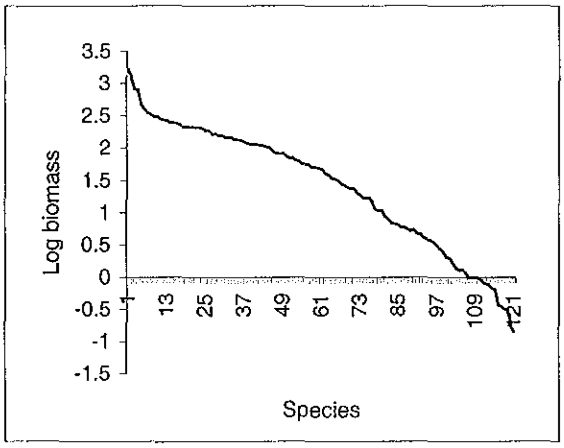


Figure 4. Log normal plot of species & biomass for wet season in enclosed site

When the species were plotted against the log biomass the results revealed that biomass is accumulated in some species which are the most dominant ones. Both (Fig.3) and (Fig. 4) show that resources were partitioned among the species. The curve for (Fig. 4) shows that most of the species occurring had higher biomass compared to those of (Fig.3). Again relatively more species were encountered during the wet season in enclosed site and biomass accumulation was hence higher. The figures for the dry and wet season in open site show that more herbage was accumulated in wet season (Fig. 6) as compared to the dry season (Fig.5). Figure 5 shows that biomass was accumulated in less than 70 species but the species increased considerably in the wet season.

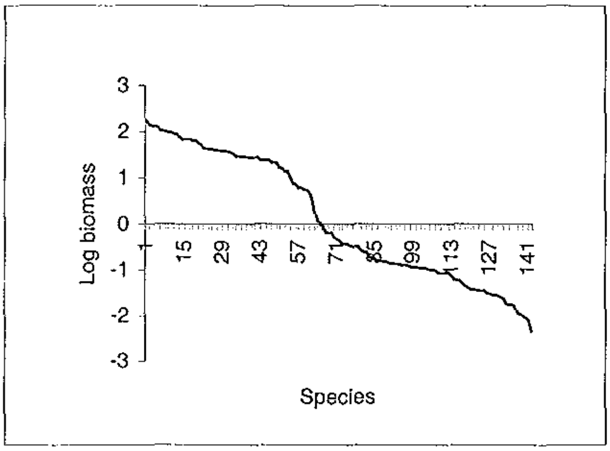


Figure 5. Log normal plot of species & biomass dry season in open site

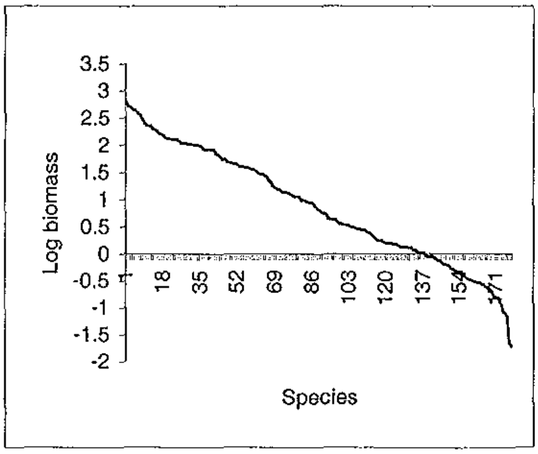
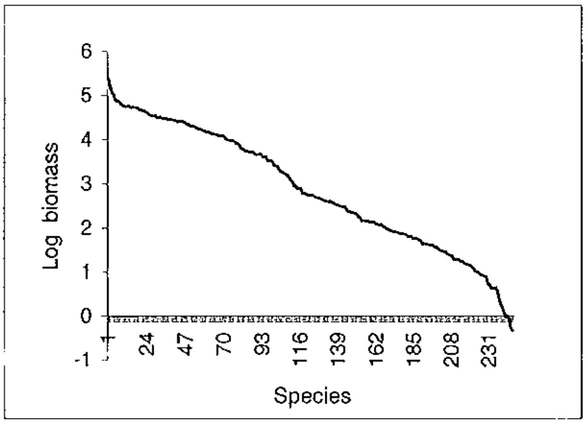


Figure 6. Log normal plot of species & biomass for wet season in open site

Biomass comparison of all the treatments when pooled together with that of single treatment shows different trends of the slope. When the biomass of the herbs, shrubs and trees is combined for all treatments and then plotted the slope is more slanting (Fig.7).



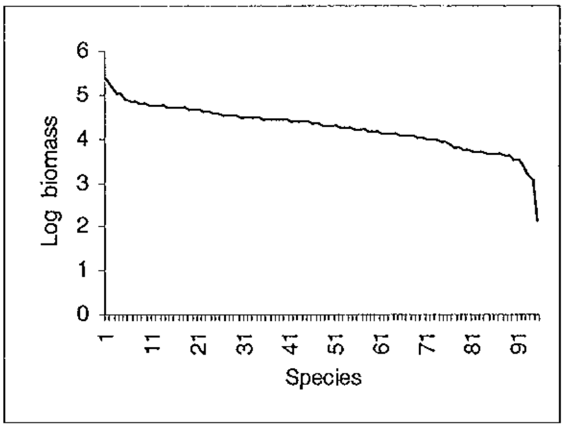


Figure 7. Log normal plot of species & their combined biomass for all treatments

Figure 8. Log normal plot of trees and shrubs & their biomass

When the herbs are excluded and the log biomass for shrubs and trees is plotted, the slope flattens (Fig.8). When the herbaceous biomass is plotted alone, the slope is less sharp as shown in (Fig. 9).

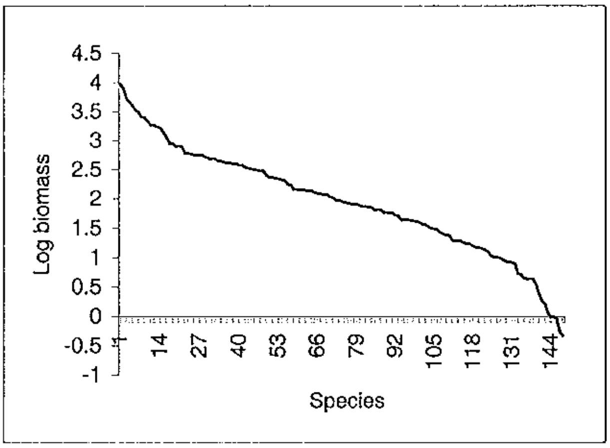


Figure 9. Log normal plot for herbaceous species & their biomass for all treatments

This figure also shows that herbaceous species are more variable and had an effect in biomass accumulation due to their high abundance.

5.2. Biomass of life forms and plant species diversity

There was a significant difference in biomass accumulated in the four treatments ($p<0.05$) in relation to plant life forms (Table 1).

Table 1. ANOVA comparisons of species life form biomass across treatments

Dry open			
Dry enclosed	0.037*		
Wet open	0.002*	0.173	
Wet enclosed	0.006*	0.406	0.578

* Means significant difference at ($p< 0.05$)

Biomass accumulated by life forms occurring during the dry season in open site was found to be significantly different ($p<0.05$) from the rest. It means that considerably less biomass was accumulated across all the life forms in that treatment. This is mostly due to environmental conditions in the field like lack of moisture and also heavy grazing during the dry season.

The biomass accumulated in the enclosed plots was significantly higher ($p<0.05$) than that of open plots (Table 2a). Total species richness in enclosed and open plots differed significantly ($P<0.05$) (Table 2a). Higher species richness was encountered in the open site than in the enclosed site. A total of 245 species were recorded from the study site

(Appendix 2). Species richness in enclosures varied from 122 to 129 species while in open site it varied from 167 to 201 species during the dry and wet seasons respectively. There were 93 and 18 plant species that were site specific in open site and enclosed site respectively.

Table 2a. Comparisons (t-test) between total species richness, herbaceous species richness and biomass (g m^{-2}) between the enclosure and open site

	Open	Enclosure	p
Total species richness	184	125.5	0.03*
Herbaceous species richness	91.5	49.5	0.03*
Total biomass	91.63	887.8	0.04*
Herbaceous biomass	429.09	387.24	0.48

* Means significant difference at ($p< 0.05$)

The enclosed plots accumulated an average above ground biomass of 654.78 g/m^2 to 1120.82 g/m^2 while the open plot had 28.47 g/m^2 to 154.78g/m^2 during the dry and wet seasons respectively.

Table 2b. Comparisons of plant species richness, diversity and evenness between four treatments

Treatments	Species richness (N)	Species diversity (H')	HMAX	Evenness (E)
Dry-open	143	2.939	4.963	.592
Dry-enclosed	119	2.620	4.779	.548
Wet-open	179	3.930	5.187	.758
Wet-enclosed	114	3.819	4.736	.806

The data of species richness (N), diversity (H') and evenness (E) of dry and wet seasons, open and enclosed sites are presented in (Table 2b). The wet seasons show higher species diversity and evenness than the dry seasons. High species richness was recorded in open sites. This is also supported by data in (Table 2a).

The species that were recorded were divided into two strata. The first stratum composed of all vascular plants in the community types and the second comprised of herbaceous species in the other community types. This was done to test if the strata respond differently to different treatments.

Table 3. Percent occurrence of all vascular plants of the community types in different treatments

	Community type	Dry open (%)	Dry enclosed (%)	Wet open (%)	Wet enclosed (%)
I	*Rhus natalensis-Combretum apiculeatum*	**42.11**	5.26	**42.1**	10.53
II	*Premna resinosa-Maytenus putterickoides*	6.38	**36.18**	14.89	**42.55**
III	*Lantana camara-Lannea schweinfurthii*	26.32	**31.57**	10.53	**31.58**
IV	*Abrus schimperi-Grewia bicolor*	29.41	**32.35**	17.65	**20.59**
V	*Zanthoxylum chalybeum-C. zeyheri*	**31.82**	13.64	**36.36**	18.18
VI	*Ozoroa insignis- M. putterickoides*	**40**	0	**60**	0
VII	*Boswellia neglecta-Albizia amara*	**36.37**	9.09	**45.45**	9.09
VIII	*Balanites aegyptica-Bauhinia thonnigii*	**50**	0	**50**	0
IX	*Acacia drepanolobium-E. matabelensis*	**50**	7.14	**42.86**	0
X	*Leonotis nepetifolia-Pavonia arabicum*	**33.33**	0	**66.67**	0

The results in (Table 3) show that site factors in fluence the formation of the community types when all the species are analysed together. The moisture regime did not show any effect. This result are further supported by (Table 2a and 2b) which show that, there is significant difference between the total species richness in open and enclosed site showing the variation in total contribution of species from different sites.

5.3. Herbaceous species richness and biomass

There is a significant difference in herbaceous richness between open and enclosed site ($p<0.05$) (Table 2a). There was no significant difference between the herbaceous biomass in the enclosed and open sites. The only difference is that there is large number of herbaceous species in the open site than in the enclosed site. Again more herbaceous species were recorded during the wet season in open site than in dry season as shown by percent occurrences in (Table 4) of the herbaceous stratum.

Table 4. Percent occurrence of herbaceous community in the four different treatments

	Community type	Dry open (%)	Dry enclosed (%)	Wet open (%)	Wet enclosed (%)
I	*Cenchrus ciliaris-Eragrostis ciliaris*	57.14	23.81	19.05	0
II	*Waltheria indica-Bothriochloa insulpta*	8.7	13.04	**60.87**	17.39
III	*Ipomoea kituensis-Cissus quadragularis*	28	36	20	16
IV	*Tephrosia pumila-Acanthosperma hispidium*	**25**	8.33	**16.67**	50
V	*Cissus rotundifolia-Indigofera lupatana*	25	**41.67**	0	**33.33**
VI	*Hibiscus vitifolius-Pavonia arabicum*	7.14	14.29	**35.71**	**42.86**
VII	*Cyphostemma sp.-Hibiscus vitifolius*	**28.57**	0	**71.43**	0
VIII	*Abutilon hirtum-Hibiscus meyeri*	**36.36**	0	**63.64**	0
IX	*Sida ovata-Desmodium sp.*	25	12.5	**50**	12.5
X	*Panicum maxima-Themeda triandra*	**50**	0	**50**	0

Results in (Table 4) show that there is higher number of representation of the community types during the wet season in open site. It means that rainfall had a significant influence in representation of species in this particular rangeland ecosystem. Data from (Table 2a) support these findings whereby herbaceous richness in open site was significantly higher ($p<0.05$) than in the enclosed site.

5.4. Life forms dominance and life-form spectra of the constituent species

The normal spectrum, the contribution of each life form class to the biomass in the 20 community types (10 each for all vascular and herbaceous species) as well as in different seasons has been determined. The life forms classes in these study site are represented by phanerophytes, chamaephytes, hemicrytophytes, crytophytes and therophytes which comprise 17.86%, 11.12%, 7.76%, 1.74% and 18.67% respectively. Their actual numbers in different sites and seasons in this study are shown in (Table 5) and the percent life form spectrum for different seasons and sites is the figures in parenthesis. The results show higher values for chamephytes and therophytes and lower values for phanerophytes, hemicrytophytes and cryptophytes than the Raunkier's normal spectrum of the entire vegetation of the world. In the table below the abbreviation are represented as follows; Ph- phanerophytes, Ch- chamaephytes, He-hemicrytophytes, Cr- crytophytes and Th- therophytes.

Table 5. Number of species in each lifeform between seasons and sites

Life form	Dry open	Wet open	Dry enclosed	Wet enclosed	Average
Ph	40 (16.34)	44 (17.96)	46 (18.78)	45 (18.37)	17.86
Ch	23 (9.39)	28 (11.43)	28 (11.43)	30 (12.24)	11.12
He	24 (9.81)	31 (12.65)	9 (3.67)	12 (4.9)	7.76
Cr	8 (3.27)	2 (0.82)	4 (1.63)	3 (1.22)	1.74
Th	47 (19.18)	72 (29.39)	33 (13.47)	31 (12.65)	18.67

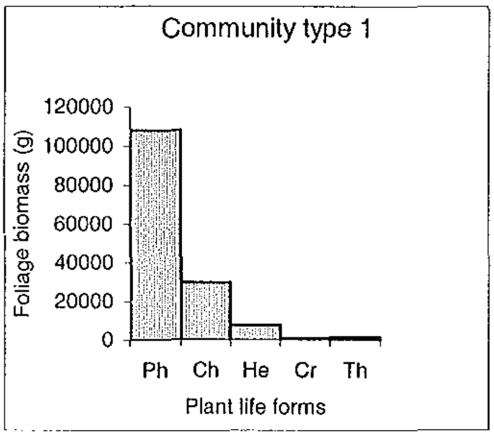
The protected and grazed sites were compared for significant differences in numbers of species in each life form class and biomass across the four treatments. The comparisons show that protected and grazed sites are significantly different ($P<0.05$) in some of their constituents' life forms as shown in (Table 6).

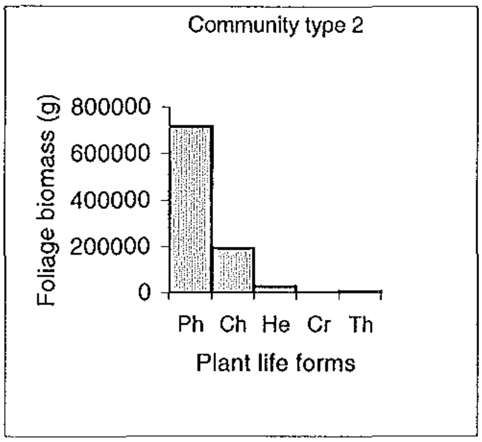
Table 6. ANOVA results comparing plant life form dominance

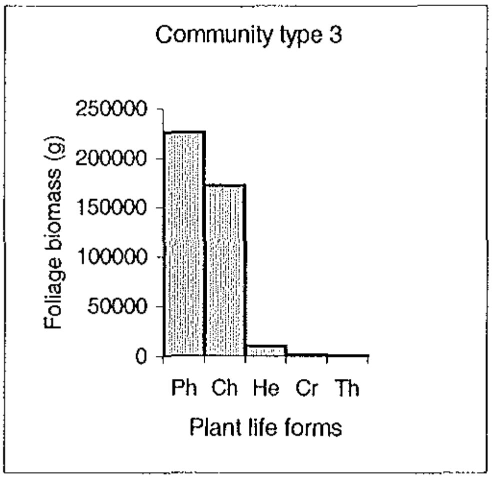
Plant life-forms					
Hemicryptophytes	0.914				
Cryptophytes	0.206	0.721			
Chamaephytes	0.03	0.848	1.00		
Phanerophytes	0.00*	0.00*	0.007*	0.004*	
Therophytes	0.00*	0.00*	0.003*	0.002*	0.999

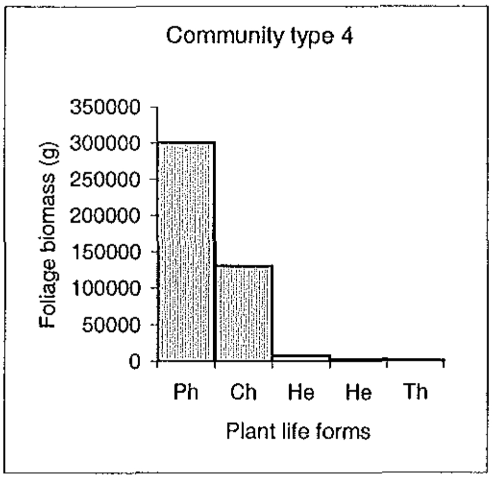
*Means significant difference at $p<0.05$

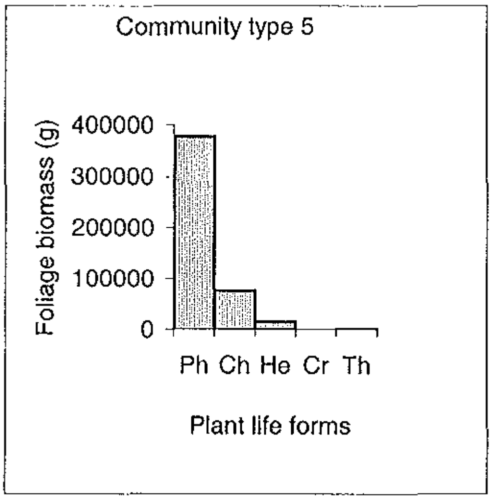
Phanerophytes and therophytes showed significant difference ($P<0.05$) from the rest of the life forms. There is no significant difference between the two landuses with respect to the number contributed by each life in cryptophytes, chamaephytes and hemicrytophytes. These groups are found to be homogeneous meaning that their total numbers in each were evenly distributed. The foliage biomass contributed by each life form in ten community types is represented in the following figures. The species used in naming the community types are indicated in (Table 3). The constituents' species and their biomass making each community type are in (Appendix 4).

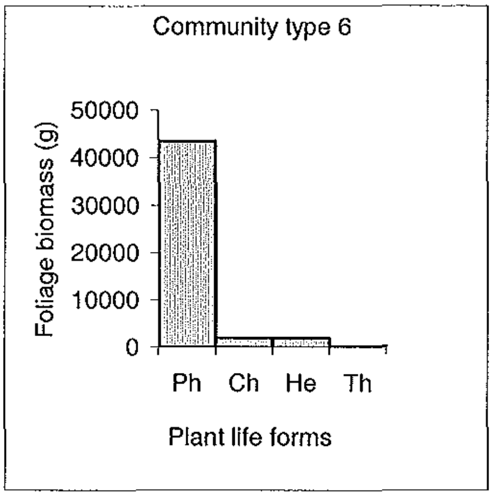

Community type 1
Foliage biomass (g)
120000
100000
80000
60000
40000
20000
0
Ph
Ch
He
Cr
Th
Plant life forms


Community type 2
Foliage biomass (g)
800000
600000
400000
200000
0
Ph
Ch
He
Cr
Th
Plant life forms


Community type 3
Foliage biomass (g)
250000
200000
150000
100000
50000
0
Ph
Ch
He
Cr
Th
Plant life forms


Community type 4
Foliage biomass (g)
350000
300000
250000
200000
150000
100000
50000
0
Ph
Ch
He
He
Th
Plant life forms


Community type 5
Foliage biomass (g)
400000
300000
200000
100000
0
Ph
Ch
He
Cr
Th
Plant life forms


Community type 6
Foliage biomass (g)
50000
40000
30000
20000
10000
0
Ph
Ch
He
Th
Plant life forms

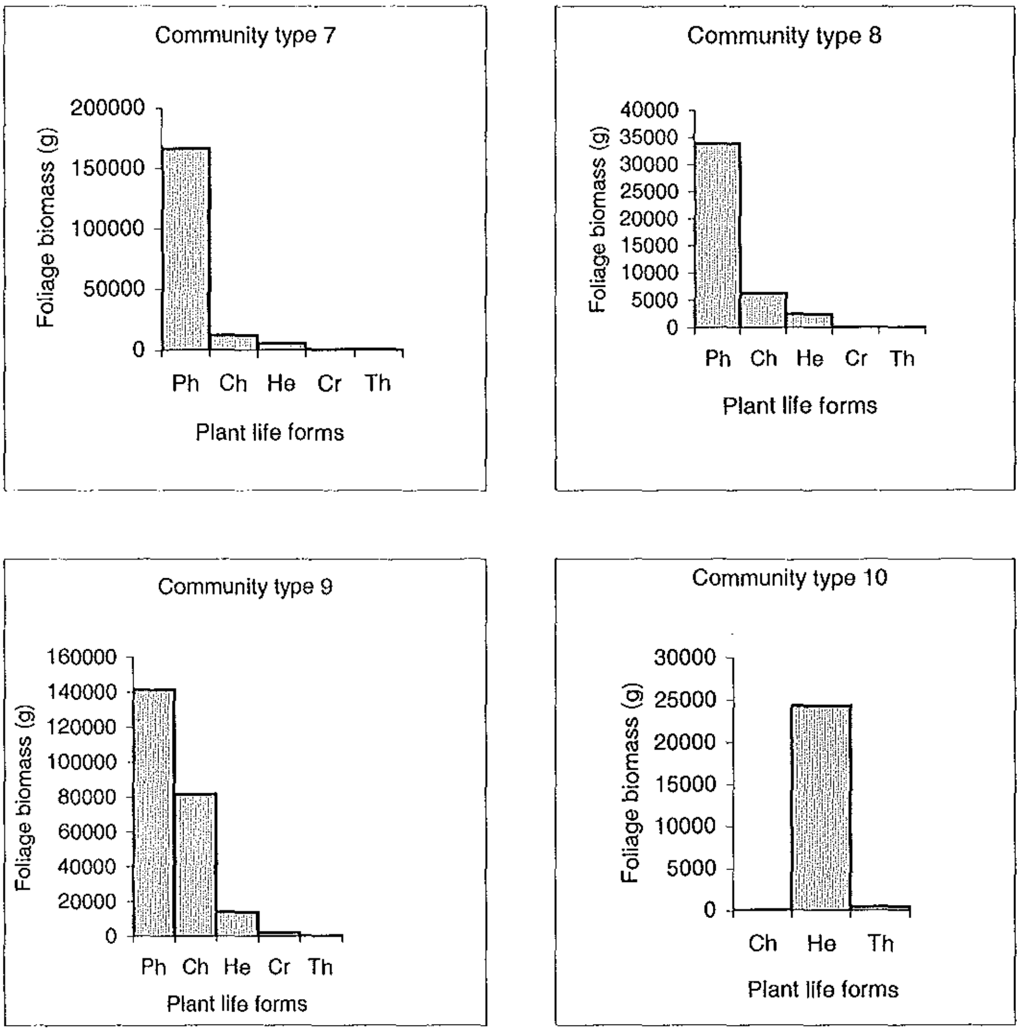
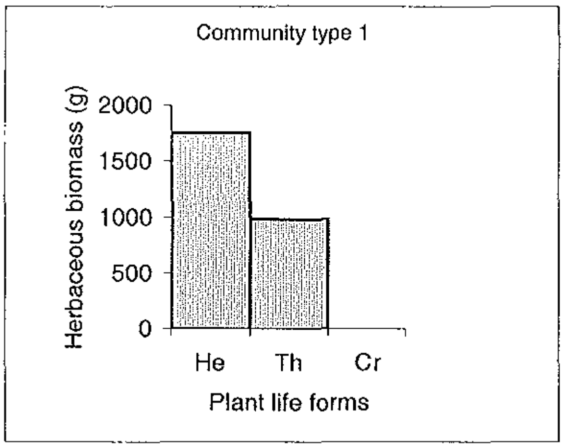
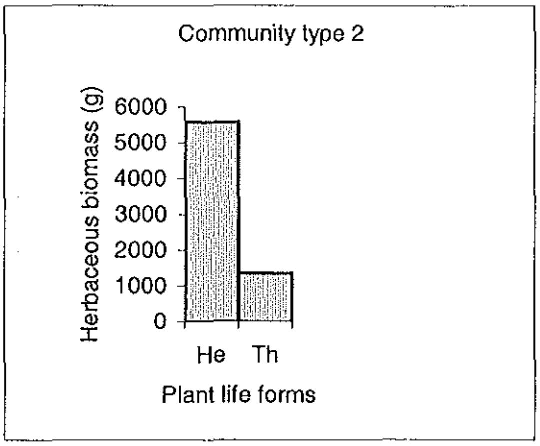


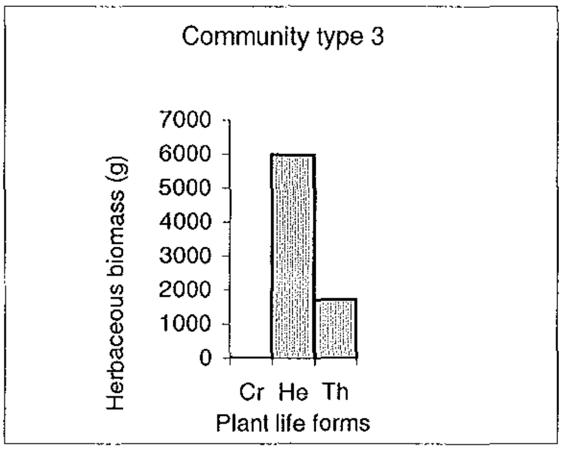
Figure 10. Biomass of life form spectrum of community types (1-10) for all plants

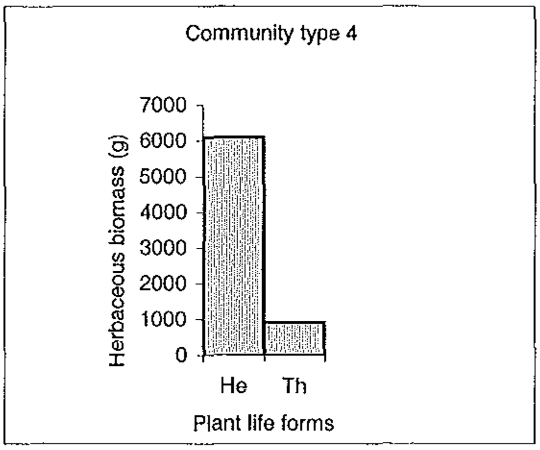
From the above figures phanerophytes is the most dominant life forms in all the community types except in community type 10. These suggest that there were more trees and shrubs especially in the enclosed site. Community types for herbaceous species were also compared in terms of biomass accumulated by different life forms. The species used in naming each community type are indicated in (Table 4). Constituents species with their biomass for each community types are in (Appendix 5.).

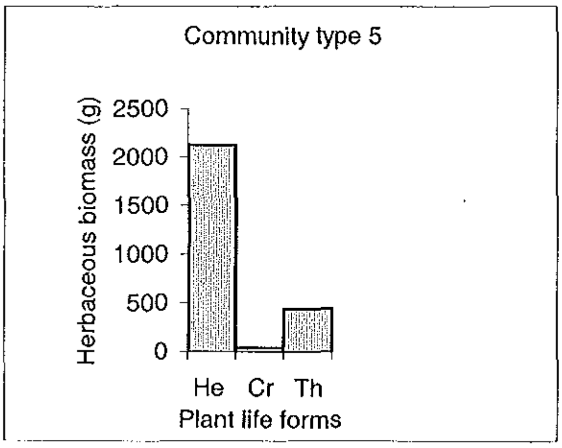
naming each community type are indicated in (Table 4). Constituents' species with their biomass for each community types are in (Appendix 5).

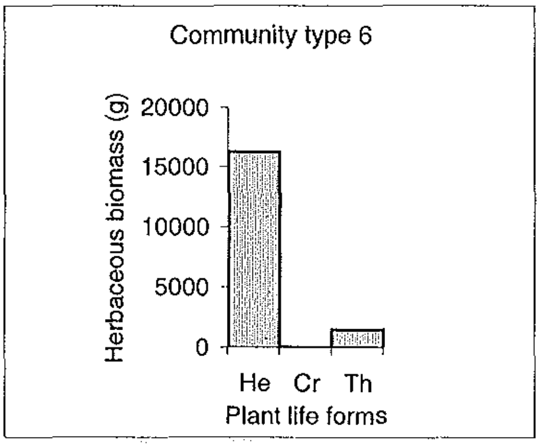












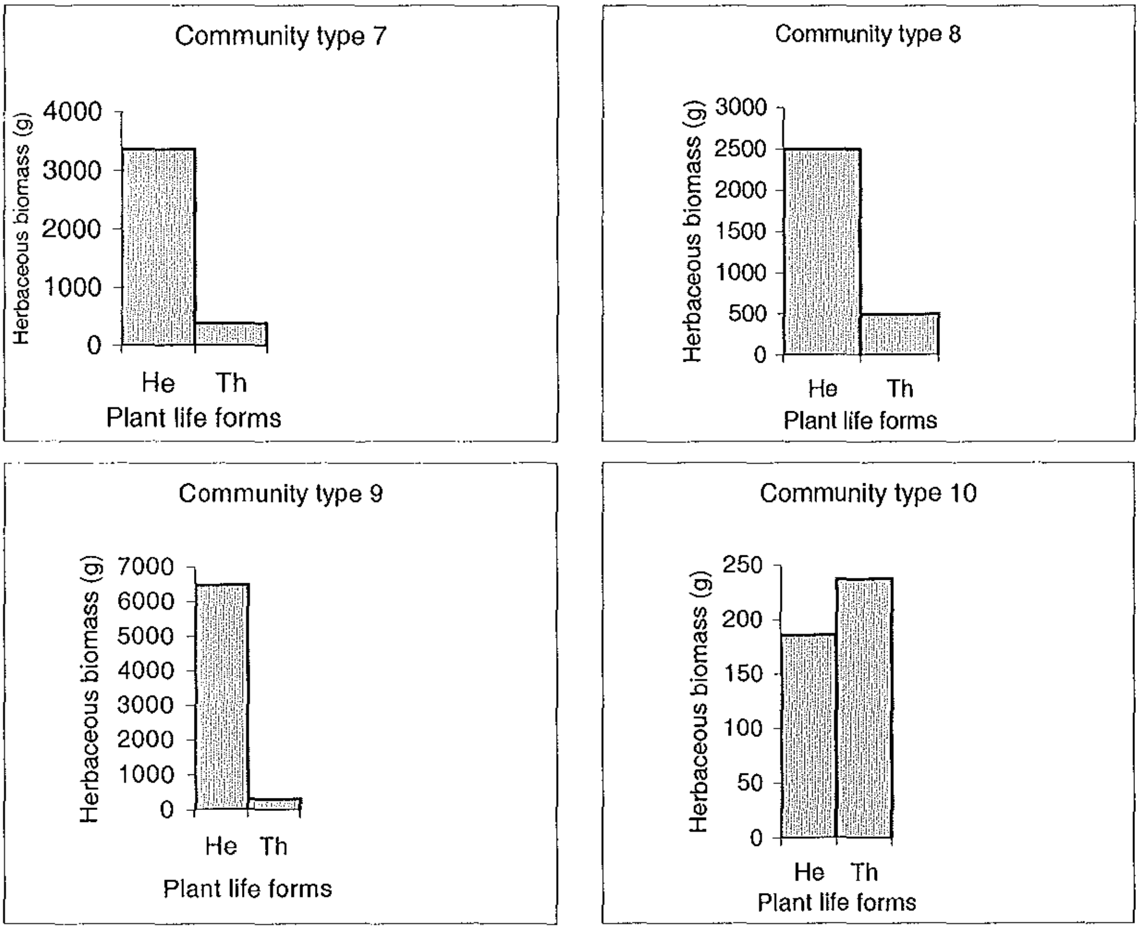


Figure 11. Biomass of life forms spectrum of community types (1-10) for the herbaceous plants

The results from (Fig.11) show that hemichrytophytes and therophytes dominated nine community types (1-9). This means that they had higher biomass accumulation than crytophytes. Therophytes was dominant only in community type 10. Community type 6 had the highest biomass as a result of hemicrytophytes. Crytophytes contributed less in all community types.

5.5. Canopy cover

The results show that, there is significant difference ($p<0.05$) in percentage cover for herbs and shrubs (Table 7). There is significantly more herbaceous layer in the open site than in the enclosed site during the wet season. Shrubs cover is high in the enclosed site than in the open site.

Table 7. Comparisons of % cover of growth form in enclosed and open sites

Growth form	Enclosed	Open	p
Herbs	17.4	72.5	0.04*
Shrubs	62.5	40	0.04*
Trees	62.5	25	0.12

* Mean significant difference at $p<0.05$

5.6. Density of woody species

The density of woody species was expressed in numbers of individuals per ha (No/ha). The range of mean density is 2.5-7786 and 2.5-710 number of individual per hectare in enclosed and open site respectively. In terms of total vegetation density there was 14465 and 7670 individuals per hectare in enclosed and open site respectively. As far as the individual species are concerned *Abrus schimperi* had the highest density in the enclosed site while *Hoslundia opposita* had the highest in open site. At the same time the *Abrus scimperi* was noted to have the highest frequency of 34%. This frequency is an indication of species dispersion in a community (Misra, 1974). *Abrus schimperi* was encountered in most of the plots more especially during the wet season in the enclosed site only.

Table 8. Percent occurrence of qudrats of community types based on density in the four treatments

	Community type	Dry open (%)	Dry enclosed (%)	Wet open (%)	Wet enclosed (%)
I	*Abrus schimperi-Lantana camara*	0	**50**	0	**50**
II	*A.schimperi-Premna resinosa*	0	**50**	0	**50**
III	*L. camara-Thunbergii holstii*	0	**41.67**	0	**58.33**
IV	*A. schimperi-Aspilia mossambicensis*	0	**50**	0	**50**
V	*A. mossambicensis-Commiphora africana*	**45.45**	0	**45.45**	9.09
VI	*A.schimperi--Commiphora schimperi*	**37.5**	12.5	**37.5**	12.5
VII	*A.mossambicensis-A. schimperi*	**41.67**	8.33	**41.67**	8.33
VII	*A. schimperi-Vitex strickeri*	10.53	**36.84**	15.79	**36.84**
IX	*A. schimperi-Premna resinosa*	**41.67**	8.33	**41.67**	8.33
X	*Indigofera erracta-Lantana viburnoides*	**43.48**	4.35	**47.82**	4.35
XI	*Acalypha fruticosa-Gnidia glauca*	**40**	10	**40**	10
XII	*A. mossambicensis.-I. erracta*	**46.15**	0	**53.85**	0

Twelve community types were identified from the dendogram of the density using correlation coefficient. This is summarized in (Table 8) giving percent occurrence of quadrats from different site and seasons. The species density distribution did not change with seasons as shown above. The results indicate that the community types are segregating in the enclosed or open sites. The slight variation is due to difficulty in identification of deciduous plant in dry season that were later identified in wet season, otherwise density remain the same across seasons. The high occurrence of *Abrus schimperi* in forming community types corresponds to it high frequency and density.

There were 66 and 70 woody species in open and enclosed site respectively. When the two sites were compared there was a no significant difference in the average woody species density. However the mean number of individuals per hectare in enclosed site (206.64) was relatively higher than that in open (116.21).

5.7. Forage preference and acceptance

In the current study, cattle and goats shifted between forage classes i.e. grass and browse as seasons changed. Goats preferred browse during the dry season and grass during the growing season. Cattle preferred grasses in both seasons, but browsed occasionally in the dry season.

5.8. Effect of grazing on soil properties

The soil analysis results are presented in (Table 9). The open site and the enclosed site were tested for significant differences in chemical and physical properties of the soils. From the results there was significant difference in soil pH, bulk density, nitrogen, moisture content, percent organic matter and organic carbon at ($P<0.05$) in enclosed and open sites.

Table 9. Comparisons (t-test) of physical and chemical variables of soil between open and enclosed sites

Variables	Open	Enclosed	P
pH	6.7	6.02	0.03*
Avail. P	17.37	24.72	0.229
Nitrogen	0.26	0.32	0.03*
Ex K	0.3	0.38	0.14
Ex Ca	4.5	5.76	0.159
Ex Mg	1.37	1.51	0.32
Ex Na	0.84	0.16	0.33
TOM	1.57	1.84	0.042*
% Carbon	8.65	15.91	0.036*
Sand	73.2	75.5	0.31
Silt	17.46	12.2	0.14
Clay	9.33	12.3	0.02*
Colour	3.3	3.9	0.08
Bulk density	1.81	1.46	0.002*
Moisture	1.1	5.32	0.03*

* means significant difference at $P<0.05$

6. DISCUSSION

6.1. Biomass

When the species were plotted in a graph against the log normal of the biomass the results revealed that the most dominant species contribute the highest amount of biomass. From the figures it is evident that more biomass was accumulated during the wet season than in the dry season as observed in (Fig. 3- Fig. 6). It means that resource is partitioned sharply among species with most of it being in the first few / tree and shrub species or herbaceous species where the trees and shrubs are excluded

More species were encountered in the wet seasons than in the dry seasons and hence higher biomass. In the pooled biomass especially in (Fig.8) show a trend whereby there is equitable distribution of biomass among tree and shrub species more clearly than in other figures. These means that there is equitability of biomass accumulated in browse species. This trend also shows that forage for browser was in plenty as compared to the herbaceous species. From (Fig. 7 & Fig. 9) it shows that resources are partitioned sharply among the species with most of the biomass being accumulated in the first few species. Herbs seem to acquire less in the biomass mostly due to competition from the higher plants. Their small size also cannot be ignored when it comes to contribution of the above ground biomass as trees and shrubs possess more foliage. Despite low acquisition of biomass by herbaceous layer, they play an important role in forage diversity. Their presence in the rangelands ecosystems increases the forage preference for the grazers as well as for the browsers. On the other hand good ground coverage protect soil erosion and soil fertility.

The trends of different slopes clearly show that wetter conditions contribute substantially to the biomass acquisition in this dry habitat. It shows that dependence on wetter conditions increases the herbage available for grazing animals, and more species for preference feeding. The log normal distributions represent a case where species of intermediate abundance in biomass are more dominant and ending in the conditions represented by the broken-stick models in which species are as equally abundant as observed in the real world (Magurran, 1988). This kind of arrangement can also be considered in terms of resource partitioning where the dominance/abundance of a species is in the same way equivalent to the portion of niche space it has occupied (Magurran, 1988).

In the log normal transformation there is sequential breakage where the resources are sequentially split within the species. The communities in which species falls are composed of patches which are created by biotic or abiotic conditions in the environment such as grazing, moisture content and mineral availability. This means that in these patches there will be variability in the availability of resources to different individuals. This is clearly observed from the figures plotted whereby species utilizing the same habitat and resources acquire totally different amount of biomass. Competitions for these resources actually determine the survival of the species as the less competitive species are eliminated and the dominants remain. This is reflected in the curve from the figures which shows that large proportion of biomass is accumulated in few species while some species accumulate negligible amount of biomass.

Short term changes in rainfall for instance, within and between seasons will primarily affect the annual herbaceous layer as shown in Fig. 3 & 5. In dry seasons the herbaceous layer is generally absent and if present with less biomass. When the rains come the annual sprout

quickly from the seedbank, giving the impression of recovery and increasing species richness and above ground biomass (Skarpe, 1991).

6.2. Biomass of life forms and plant species diversity

This study reveals that species richness increased monotonically with the increase in biomass in the grazing site. Oba *et al.* (2001) reported similar results. The expected increase in biomass as a result of enclosure was verified. An increase in biomass in the enclosed site did not automatically result in an increase in species richness. This is probably related to reduced disturbances from human and livestock interference in the enclosure, which allow species to develop large-scale local populations, i.e. they become dominant (Huston, 1979). This is the case with the high occurrences of *Abrus schimperi* and *Premna resinosa* in the enclosed site whereby they were encountered almost virtually in every plot sampled.

In comparing species diversity and evenness in different treatments analysed, the results show that the open site during the wet season had the highest diversity. These show that moisture had an influence in species diversity in both sites. More species were encountered during the wet seasons than in the dry seasons and hence high diversity in wet season. The enclosed site during the wet season has the highest evenness. It means that the species occurring in enclosed site in wet season were highly evenly distributed than the species in other treatments.

For all vascular plant species, the site factors seem to influence percents of the species forming the community types. It is clear that some community types are more represented in open sites while others are to enclosed site, suggesting that enclosure is more segregating than moisture regime. In this case it shows that most of the species were either from the open or enclosed site but the seasons did not have any influence in formation of the community types. Once again the issue of disturbances arises whereby high percent of occurrences of species forming the community were well represented in the open site.

6.3. Herbaceous species richness and biomass

The results show that grazing promotes herbaceous species richness though it depends on the pressure exerted on vegetation. The higher representation of herbaceous community types in the open site show that livestock play an integral role in the maintenance and dispersal of herbaceous species. Herbaceous species are easily dispersed through seed. Also the annuals species survive as seed during the unfavorable weather and sprout quickly after the rains and hence their high occurrence during the wet season sampling (Zerihun and Saleem, 2000). This means that herbaceous species are more influenced by the amount of rainfall and disturbance in a particular area. From these results it is evident that rainfall have an overriding effects in herbaceous species but more especially those occurring in the open sites. The stratum of herbaceous layer shows that when the shrubs and trees are removed, the herbs are more influenced by seasons.

From this study it is confirmed that herbaceous species richness decline in the protected area probably because of the period of enclosure, and this has also been demonstrated in the Serengeti grasslands (McNaughton, 1979). This decline could be related to an increase in shrubs, which are better competitors for nutrients and eventually eliminate most of the herbs which are poor competitor for sunlight. In contrast, diversity tends to decline in high productivity environments, due to competitive exclusion by competitive species that become abundant under these conditions (Grime, 1973).

6.4. Life forms dominance and life-form spectra of the constituent species

The results shows that the contribution of therophytes species was higher in communal grazing lands relative to protected area. The enclosed site had a greater proportion of phanerophytes and chamaephytes implying that bush encroachment could be in progress. Similar research findings were reported by Shackleton (2000) in South Africa. Phanerophytes and therophytes are homogeneous group with ($p<0.1$) as compared to other life form classes. This means that there were more trees and shrubs especially in the enclosed site as compared to other kind of life-forms (Table 7.). In this case it shows that the dominant life forms in this study area were phanerophytes and therophytes for enclosed and open site respectively.

The relatively high values of therophytes in life form spectrum as compared to the other types of life forms may indicate that the annual precipitation received and the moisture retained in this rangeland is more suitable for annual life form. Again high occurrence of therophytes that dominate the open site could be due to easy seed dispersal through manure (Osem *et al.,* 2002; Oba *et al.,* 2001; Zerihun & Saleem, 2000). Other factors such as soil erosion, human disturbances and cultivation also influence the dispersal of seeds. The high value of chamaephytes than in the normal spectrum could also be related to the tendency that this kind if life form is persistent even during harsh environmental conditions. Chamaephytes may have become successful under continued grazing since it depends on meristems at ground level and not on seeds for re-establishment (Zerihun, 1985).

From the life forms community types of all species (Fig.10) phanerophytes was the most dominant life form in the particular rangeland ecosystems in terms of biomass followed by chamaephytes. These community types reflect the amount of biomass accumulated by life forms either in the open or enclosed. Community type 2 had the highest biomass. This community type is well represented by species in the enclosed site confirming that enclosure had high biomass accumulation as compared to open site. This is again supported by (Table 2a) where more biomass was accumulated in enclosed site than in open site. Naturally browse species accumulate more biomass than any other type of life form. Most of the communities with high biomass were found to be segregating in the enclosed site meaning that grazing exclusions leads to accumulation of biomass.

In the herbaceous species community types (Fig.11) hemicrytophytes dominated in nine community types in relation to biomass accumulated. Hemicrytophytes being perennials are also found to depend on meristems for their re-establishment, which means that they are likely to be available throughout the year. Again this life form is persistent and do not die off completely. This implies that when compared with other life forms of crytophytes and therophytes it is observed to acquire more biomass due to its size. Again its high frequency than the other two kinds of life forms may also contribute in high biomass. More biomass was accumulated by life forms in community types that are more represented in the enclosed site. Although there was no significant difference in herbaceous biomass between the enclosed and open sites, there was relatively more biomass in enclosed site. The low amount of biomass in open site shows that continuous grazing have an effect on above ground biomass.

Biomass is a manifestation of net production. Species which possess more biomass and have higher production rate are dominant in the community and they also influence the appearance or physiognomy of the vegetation (Kershaw, 1973). The biomass profile indicates the amount of dry matter present at different heights of the vegetation cover. Such profiles differ in different communities and are influenced by the life-form of the plants. Grazing besides reducing total plant cover, its effect on species composition generally has been to handicap certain species and favour others (Zerihun, 1985).

6.5. Canopy cover

A high cover of herbaceous layer in open site than in protected site during the wet season is related to the sprouting of the annuals immediately after the rains. Annual and perennial grow fast and cover the area which was initially bare during the dry season.

Two shrubby species, *Abrus schimperi* and *Premna resinosa* dominated the enclosed site while *Zornia setosa*, *Eragrostis superba* and *Evolvulus alisionoides* dominated the continuously grazed site. The result also indicates that the secondary succession is still taking place in this rangeland protected since 1990 when grazing exclusion was started. Absence of grazing for a long time is also followed by an increase in bush cover (Oba *et al.*, 2000b). These show successful replacements of forbs and grasses as grasslands are slowly transformed into bushlands. Once established, bush cover accelerates the decline in grass cover, while intensification of grazing pressure reduces the fuel load required for fire to burn the bush cover.

These mechanisms reflect cyclic disturbance regimes (i.e. fire and grazing) are responsible for rangeland dynamics. If management alters disturbances, vegetation is changed as evidenced in this study. The open and enclosed sites portray different types of species composition. These findings support the more or less similar results of Tukel (1984) and Johnston *et al.* (1971). The high shrub cover compared to herbaceous cover in the enclosed site also suggests a progressive shift towards trees and shrubs in the absence of grazing (Roques *et al.*, 2001).

In general vegetation cover in arid and semi-arid rangelands may be regulated more by rainfall variability rather than by herbivore density (Oba *et al.*, 2000d). From this result it is evident that grazing exclusion did not increase the vegetation cover except for the shrubs and this was only during the wet season.

6.6. Density of woody species

The lack of a significant difference in both sites in relation to woody species density could be attributed to the fact that grazing increases the chances of seedling establishment. Visually the density of the enclosed site seemed to be high than that of the open site but statistically it is not. From the community types it is clear that density does not change with the seasons but remain constant unless there is cutting of trees. These trends of density correspond to that of biomass of all vascular plant which are constant and do not vary with seasons but with the site. Therefore the density and the biomass of woody species correlate and they influence the formation of the community types when considering all vascular species. With high density of species most likely, the community types formed will be more stable with less fluctuations. The high density of woody species will automatically lead into high biomass. The big difference between the biomass from the open and enclosed site is mostly attributable to browsing in the open site. This means that more herbage is removed from trees and shrubs through browsing Mwiliwa *et al.* (1996) while in the enclosed site it is conserved. . This means that woody species play a major role in provision of alternative forage (high quality and quantity) when the grasses are low in nutrients contents.

With increasing density the competition stress increases. This is reflected in poor growth and lower production capacity of the plants. This is well evidenced from this study in *Abrus scimperi*, which was encountered frequently, though it had the highest density, its biomass was expected to be abit higher than recorded. Crowding decreases the individual's productive capacity and vegetative growth due to competition of light. High number of individual woody species in enclosed site shows that bush encroachment is in progress. Intraspecific competition caused as a result of increasing density in trees and shrubs imposes an autoregulation of the population by influencing the reproductive capacity and reducing the vitality of the plants (Kershaw, 1973).

Woody species play a fundamental role in the ecological dynamics of the ASALs. Serious depletion of the shrubs and trees could result in permanent lose of productivity for these fragile ecosystems (Lusigi *et al.*, 1986). The high biomass in the enclosed site could also be attributed to high number of individual woody species which contribute a big portion of dry biomass. Combination of woody plants with grasses and other fodder plants is been widely spread throughout sub-Saharan Africa as animal feeds. The woody species are beneficial in that they trap nutrients from the deep soil profile and bring them to the top layer of soil where shallow rooted plants can utilize them. This is evidenced in the enclosed site where most of the plant nutrients were higher than in the open site. The highest frequency in the open was 37% which was grass mat, while the lowest was 1.1% for the *Apocynaceae* family.

6.7. Forage preference

Goats shifted their preference between browse in the dry season to grass during the wet season. These findings support those of (Kefa, 2000; Ekaya, 1991; Pfister & Malechek, 1986). Goats were observed to be capable of switching from one source of browse to another when the main browse sources declined. Again goats were observed to assume a bipedal stance, while feeding thus increasing their feeding height. These in effect increases the volume of browse potentially available to them. This can be seen as a resource utilization strategy by goats. These animals make maximum use of the grass when it is still growing and high in nutrient content before suddenly declining in quality with advancement in maturity. This might preserve the browse, which declines less in quality for the critical dry season. At the same time, goats can travel long distances in search of food and these makes them superior survivors in the arid zone compared to cattle.

Cattle were consistent in their preference for grass. Grass provided the base for the diet irrespective of season. Browse was more preferred during the dry season by goats while the cattle continued to nibble on the remains of the grasses. Cattle feeding were complementary to that of the goats and hence there was no competition between these two species. The shift between forage classes may have negative effects on the grass productivity. Grasses may experience heavy grazing pressure during the growing period and this may lead to decline in vigor and productivity considering that the animals are under continuous grazing system. After the rains it seems that the abundance of the herbaceous layers and its accessibility play a major role in diet preferences for both goats and cattle.

The dry season was observed to be a potential period of nutrients deprivation for range animals due to the maturity of most forage types and inevitable decline in quantity and quality. This was more so for the grasses than for the browse. One critical evaluation of how well animals can cope with the changing forage nutrient status is the temporal change in their diets. This is achieved by the ability of animals to be highly selective in feeding habits and to shift between forage classes. By doing so, it enables them to take advantage of plants with higher feed quality (Demment and Laca, 1993). The observed differences in the characteristic of the diets in cattle and goats are due to the nutrient dynamics of the forages preferred by the animals over the two seasons. The dependence on grasses by cattle is a great disadvantage in the dry season, as most have low protein content.

The feeding habits of cattle, sheep and goats whether as single species or together on the same range have been studied by several researchers in different environments. Some findings concur, with those in this study, while others conflict. These studies are crucial in extensive grazing systems where mixed livestock species such as camels, cattle, sheep, goats and donkeys utilized rangelands. In these way range managers or ecologists could apportion grazing resources to each species so as to determine optimal levels of grazing without degrading the range by determining dry matter intake and by considering relative animal biomass (Lusigi *et al.*, 1986).

6.8. Effect of grazing on soil properties

Available phosphorous remains more or less constant in both the grazed and ungrazed plots (Appendix 1), with an indication of possible decline in enclosed plots. Rock weathering may be the only significant source of additional phosphorous for range soils (Heady and Child, 1994). This uniformly low content is attributed to the fact that this element is stored in unavailable forms to plants Juo (1978) H_2PO_4 which becomes available to plants at low pH. It also suffers from fixation by hydrous oxides and silicate minerals. This element is doubly critical, because of low total amount and a very low availability.

Quantities of exchangeable cations were relatively low in both enclosed and grazed plots. The availability of the cations depends on the parent materials. This can be attributed to the fact that the soil in all the plots is more or less acidic with low pH values (Oba *et al.*, 2000a). Except for calcium that showed a slight increase in the enclosed plots all the other nutrients remain relatively low. These inorganic nutrients are only made available through the active release of cations from the additional litter accumulating under the trees (Skarpe, 1991; Hatton and Smart, 1984).

There is an appreciable increase in organic matter content in the enclosed plots as compared to grazed plots (Appendix1). Organic matter and organic carbon are correlated within any single type and as the results indicate there is an increase in the amount of organic carbon in the enclosed sites. Similar finding are reported by Hatton and Smart (1984). This is expected in the enclosed site which is dominated by trees and shrubs which deposits litter on the soil. Through decomposition, the organic matter is returned to the soil and hence the percent carbon also increases.

Both temperature and moisture regime affects the equilibrium of organic matter contents of soils. Increased temperature decreases organic matter content while increased moisture increases organic matter (Sikora and Stott, 1996). Again in sites where there is no disturbance it is expected that the microbial activity and other decomposer populations would be more intense, and the role of these organisms as agents of litter breakdown and humus formation is well known (Skarpe, 1990).

There was a significant difference in the percent moisture content with a range of 1.4-6.6% and 0.2-3.8 % in enclosed and open site respectively. This can be attributed to the fact that the soils in the enclosed sites are not directly exposed to the sun due to the canopy cover which prevents evaporation rates. Litter deposition/accumulation from the trees and shrubs additionally keep soil covered most of the time and hence reduces heating of the soil which would cause the reserved water to evaporate. In addition, the shade from the trees and shrubs play a major role in moisture retention (Skarpe, 1991). Again, the high amount of organic matter in the enclosed site maintains the moisture at a higher level. In most cases grazing induces shortage of moisture, reduces infiltration rate and other nutrients and to some extent causes soil erosion.

Total nitrogen was higher in the enclosed site (Appendix 1) than in the open site. The increase in the total nitrogen is as a result of the increase in organic matter content of the soils in the protected sites. The low level of nitrogen content in the grazed sites can be attributed to low nitrate content which are easily lost through soil erosion (Belsky *et al.*, 1989). The total nitrogen is often a good indicator of the degraded rangelands and in this it indicates a higher level of land degradation in the grazed sites as opposed to the enclosed sites.

Bulk density is higher in the grazed plots than in the enclosed plots. The soils with high proportion of pore space to solids have lower bulk densities than those that are more compact and have less pore space. In the enclosed sites due to high proportion of organic matter the pore space is higher hence the low bulk density. The bulk density range in the enclosed site was 1.2-2.3 g/cm^3 while in the open site it was 1.3-3.0 g/cm^3. In the communal grazing sites grazing increases bulkiness of the soil through the soil compaction and hence the higher bulk density. Due to exposure of the soils in open sites the evaporation rate is high reducing moisture content and soil density changes with moisture content (Sikora and Stott, 1996).

The composition of the particle size assay was relatively uniform except slight variations in the clay contents. The high amount of clay content in the enclosed site can be attributed to the hydropower dam which spills off water during the rainy season to the adjacent enclosed site. This water is always carrying different types of soil which is eventually deposited in the study site. Again river Thiba that borders the study site is another potential source of clay soil. In general all the soils in both sites were either loamy sand or sandy loam.

There is no significant variation in the soil colour. In all the soil samples the hue (the dominant spectral colour or quality is consistently 5YR. The value (apparent lightness as compared to absolute white) varies significantly from 3-8. The chroma (the apparent degree of divergence from neutral grey or white) varies from 3-7. The general colour of the soil ranged from red to brown.

The comparison of the soil data from the grazed and ungrazed plots indicates that nutrient enrichment of the soils in enclosed site, in part is due, to nutrient inputs by tree litter. On the other hand, trees transport nutrients from the surrounding surface and subsurface soils to their canopy and drop the nutrients in leaf and stem litter (Belsky *et al.*, 1989). 12 years of grazing exclusion can conclusively be said to be useful in relation to the soil properties whereby most of the nutrients are relatively higher in the enclosed site than in the open site. Poor nutrients content, is a symptom of land degradation in the open site. This was more pronounced in the plots which were falling in the more degraded area.

Low soil nutrients values indicates that natural process such as weathering are unable to replenish soil nutrients at a sufficient rate to replace those lost by the direct or indirect effects of grazing. Nitrogen and cation concentrations decline at a more rapid rate than can be explained by grazing effects (McIntosh, 1997). Processes like nutrient loss, continued grazing without nutrient inputs are unsustainable. To maintain or improve soil nutrient balance, new approaches to soil and vegetation management will be required.

From the ongoing discussion, the study results are consistent with the general pattern that pastoral development enhances richness of plant species at a local scale providing opportunities for increasers species to establish. Conversely, it has the potential to decrease it at a regional scale by removing the most grazing sensitive decreasers species from the regional species pool (Landsberg *et al.,* 2002). Those species, which were substantially less abundant in open sites than in the enclosed sites, were presumably the most sensitive to grazing overall.

Some plant species, such as *Andropogon greenwayi* and *Sporobolus ioclades* (*poaceae*) and *Indigofera cliffordiana* Herlocker (1999) and *I. spinosa* (dwarf shrub) have adapted to grazing and browsing to the extent that they depend on it for their existence (Oba, 1995). However, overgrazing reduces ground cover vegetation, plant height, forage quality and productivity. The impact of grazing on rangeland vegetation depends on three factors. First, the type of herbivores (grazers and browsers), secondly the number and type of animals utilizing an area, and lastly the distribution of use in time and space (Pratt and Gwynne, 1977). Cattle and sheep, which are primarily grazers and goats and camels, which are primarily browsers directly affect the herbaceous and woody components of the vegetation respectively.

Walker (1993) suggested that in arid rangelands lack of grazing is ineffective in inducing revegetation until the right combination of weather conditions occurs. Grazing has a greater influence on species composition, perhaps suggesting a better adaptation of vegetation of the study site to grazing as a result of the long association of plants and livestock and to some extent small mammals like rabbits and dik dik.

Long term grazing exclusion studies attempt to test the hypothesis that grazing causes degradation. Several studies comparing the effects of excluding grazing with those of continuous grazing have been conducted world wide, including in arid zones of sub-Saharan Africa, for more than a century (Oba *et al.,* 2000c). According to the current study grazing exclusion did not improve or increase range production any more than continuous grazing. This is because forage production is influenced more by rainfall than by herbivory. These studies support the findings of Oba *et al.*(2000d).

Areas of rangeland where grazing has ceased have been invaded with woody plants and a ban on livestock grazing in the rangeland would almost certainly result in the loss of this species-rich habitat. A similar trend was observed in the study site where grazing exclusion did not increase species richness though there was substantial increase in above ground biomass. The hypothesis that grazing history is the main factor determining plant community composition in the rangeland was supported by the species richness, vegetation cover and high level of organic matter and moisture contents because these factors are likely consequences of herbivory (Crawley, 1997).

Variations in the amount of biomass in the different sites may be related to topography, soil characteristic, species characteristic and grazing pressure. The reduced yield under grazing is attributed to soil compaction and concurrent decrease in porosity and aeration, and to a drop in water infiltration. Hoof and grazing action injure the shoots and trampling must have contributed greatly in decreasing yield (Edroma, 1981).

The forage yield of the grazed rangelands was significantly less than that of the ungrazed ranges in both seasons. The most interesting fact concerning the dried forage yields of the investigated rangelands was that the yield differences in the grazed areas for both seasons (i.e.dry and wet) were negligible. This lack of difference is another indication of the heavy and uncontrolled grazing taking place in the common grazing lands in both seasons. Heavy grazing would not allow the more palatable grasses to regrow during the growing period (Tukel, 1984). Dried forage yield was appreciably different in the ungrazed areas between the seasons. This difference may be explained on the basis that the enclosed site is dominated by shrubs and trees which provide high biomass during the wet seasons. In the dry season most of them are deciduous and hence shed off their foliage parts giving low biomass.

6.9. Management implications

This study has shown that the influence of livestock on rangelands is expressed through their effect on vegetation. This is expressed through the reduction of above ground biomass and cover. The open site had less above ground biomass as compared to enclosed site. On the other hand livestock on the free grazing systems has a very important role in the maintenance of plant diversity. This is normally through the dispersal of readily germinating seeds in their manure. This is reflected in the species richness between the open and enclosed sites. Open site had high species diversity than the enclosed site and the livestock influences this. Again some plants of the arid lands also survive well through regular herbivory and hence livestock removal will have major consequences on them.

Grazing is apt to have a greater negative impact when the vegetation of an area is grazed continuously than when it is grazed only periodically. In the latter, the vegetation has an opportunity to rest and maintain its vigor. From the results grazing in adequate frequency and intensity play an important role in maintaining diversity of the rangelands. In the absence of grazing, shrubs gradually replace the grasses as evidenced in this study. The competitive effects of shrubs and trees on herbaceous plants are obvious. The canopies of woody plants shade and alter the productivity of understorey herbaceous species. Woody plants may have larger competitive effects than herbaceous species. This may simply be caused by the higher shoot mass of shrubs and hence greater reductions in light availability for under canopy layer.

Control of animal numbers is the most important rangeland management principle. As each animal grazes, it reduces available herbage both in quantity and quality, thereby changing the habitat for itself and altering future animal/habitat relations. Excessive forage utilization by either livestock or game animals reduces growth rates, weight gains and animal values (Heady and Child, 1994).

7. CONCLUSION AND RECOMMENDATIONS

The rangelands of eastern Africa are characterized by a high biodiversity that is economically important both locally and nationally and their conservation is of paramount importance. This study area was found to be rich in plant species with diverse classes of plant life forms. High diversity of plant species as well as other living organisms is considered to be a desirable characteristic in any particular rangeland. They clearly indicate that rangeland ecosystems are vigorous and in good health and can sustain high forage productivity. In this case it means that livestock play a major role in the maintenance of biodiversity of the rangelands.

Although grazing is important for preserving species diversity in rangelands through the maintenance of species-rich grasslands, long-term effects must be considered in the formulation of future management plans. Species from the open site represent a significant component of the plant diversity of the rangeland and hence their survival depends on the amount of grazing pressure exerted in this rangeland. Moderate grazing pressure will not alter the species composition up to a certain degree but the carrying capacity of the site is also an important determinant of the number of the herbivores to be stocked in a certain area.

From the results it is evident that forage is not always available during the dry season and hence the farmers should look for alternative to supplement the little available forage. Planting forage species that thrive well in these rangelands is highly recommended. Again the farmers can introduce the systems of hay and silage whereby the grasses can be cut during the wet season and preserved for the unpredictable dry season. In doing so, the livestock will not always have available feeds.

The diet preferences and acceptance by goats and cattle that are kept in this rangeland are complementary rather than competitive as they favor different feed resources within the same area of rangeland and have adapted differently to seasonal changes in amount and quality of forage. Therefore, the use of mixed herds can considerably increase productivity in rangeland areas, minimize production risks and reduce environmental impact compared to single species production systems.

Pastoralists have over many generations developed communal tenure and land use practices, which helped them to successfully use the rangelands on a sustainable basis. Over the last few decades, rapidly increasing human populations, changing socio-economic conditions, frequent droughts, inappropriate land use practices, unfavorable government policies and a degrading environment have caused the abandonment of many traditional rangeland practices. These practices include seasonal movements of livestock and rotational grazing which play an important role in maintaining rangeland biodiversity. This is more especially when blended with modern scientific rangeland conservations and management practices

New strategies of resources utilization should be developed with the aim of making pastoralism more sustainable means of production. These strategies should take care of the stability of the ecosystems, means of sustainable use of the available resources i.e. vegetation, economically oriented and social acceptability. In the long run sustainable commercial use of the range vegetation, owing to its abundance, may be the most logical basis for any initiative that can lead to economic diversification. The multi-purpose use of the dominant vegetation type (woody species) may infact help in its improved management and conservation. There are indeed a number of plants in the rangelands that are a source of commercially exploitable products. For example sustainable exploitation of *Acacia senegal* for commercial gum Arabic production which is a commodity of international commerce (Doyo and Farah 1998).

Research should focus on thr relationship between livelihood and rangeland biodiversity more especially in relation to harmonized pastoral and forage communities. Priorities for research include; Inventory and monitoring genetic, species, ecosystem and landscape diversity. Also analyzing human impact on rangeland ecosystem, economic exploitation of biodiversity. Studies in rangelands should be encouraged and should be more intensive covering large areas in order to increase the sampling area. With large sampling sites there is possibility of capturing rare, threatened or even endemic species. For this study one rare species *Vernonia fischeri* was recorded and only two individuals were found in the enclosed site. This species was last collected in 1931 in Kenya and has been designated as rare. Again two more species *Euphorbia matabelensis* and *Lannea schweinfurthii* were also recorded from the study site. Initially these species were known to occur in areas bordering the coastal areas mostly in Tana River district, south east of Kenya. Species like *Euphorbia matabelensis* was last recorded in 1920 in north eastern region of Kenya.

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9. APPENDICES

Appendix 1. Raw data for environmental variables

Parameter	pH	Avai P Me/L	N %	Ex K Me/L	Ex Ca Me/L	Ex Mg Me/L	Ex Na Me/L	TOM%	Particle Size assay			Textural class	Bd g/cm^3	% M	colour code
Field ID									Sand %	Silt %	Clay %				
Open	6.6	9.4	0.27	0.6	3.6	1.1	0	1.9	80	7	13	Sandy loam	2.4	2.2	1
Open	6.9	25.7	0.47	0	0.5	0.02	8.5	1.5	85	2	13	Loamy Sand	1.9	1.8	2
Open	5.9	20.8	0.2	0.1	2	0.5	0.3	1.4	60	30	10	Sandy loam	1.5	1.3	3
Open	6.2	97.9	0.4	0.4	10.6	3.1	0	2.5	80	17	3	Loamy Sand	2.2	2.1	1
Open	6.1	10.4	0.23	0.2	3.3	0.9	0	1.2	65	27	8	Sandy loam	1.7	1.3	4
Open	6.7	48.9	0.23	0.3	10.3	3	0	1.1	36	44	20	Loam	1.9	2.9	1
Open	6.1	24.3	0.37	0.2	7.3	1.4	0	2.8	89	1	10	Loamy Sand	1.4	1.3	4
Open	6.6	16.8	0.6	0.3	4.4	1.8	0.01	2.4	90	0	10	Sand	1.5	1.4	4
Open	6	11.7	0.2	0.2	2.6	0.9	0.7	1.3	90	8	2	Sand	2.8	2.2	1
Open	6.1	17.7	0.3	0.2	6.7	1.8	0	1.9	79	8	13	Sandy loam	2.8	2.1	5
Open	6.3	14.7	0.3	0.2	9.2	2.3	0	1.5	90	2	8	Sand	3	2.1	2
Open	6.9	44.7	0.3	0.2	3.1	0.7	0	1.3	60	30	10	Sandy loam	1.5	3.8	1
Open	6	5	0.23	0.1	1.9	0.9	0	1.6	90	10	0	Sand	1.5	1.4	4
Open	6.7	5.6	0.17	1.4	5.3	1.8	0	2	49	46	5	Sandy loam	1.6	1.8	4
Open	6.6	9.8	0.2	0.5	3.7	1.5	0	1.4	29	58	13	Silt loam	1.4	2.4	4
Open	6.1	7.9	0.23	0.1	1.9	0.5	1	1.4	84	10	6	Loamy Sand	1.4	2.2	6
Open	6.2	7.3	0.17	0.3	2.7	1.5	0	1.5	87	5	8	Loamy Sand	1.4	1.3	1
Open	5.9	8.4	0.13	0.2	5.5	0.5	5.4	0.9	45	47	8	Sandy loam	1.6	0.8	4
Open	5.7	4	0.17	0.1	0.8	0.3	0.8	0.8	92	3	5	Sand	1.7	1	4
Open	5.9	8.8	0.17	0.1	0.9	0.4	0	0.8	70	22	8	Sandy loam	1.6	0.3	4
Open	6	13.5	0.33	0.2	1.5	0.8	0	2.1	87	3	10	Loamy Sand	1.3	1.6	4

Parameter	pH	Avai P Me/L	N %	Ex K Me/L	Ex Ca Me/L	Ex Mg Me/L	Ex Na Me/L	TOM%	Particle Size assay			Textural class	Bd g/cm^3	% M	colour code
Open	6.6	11.1	0.3	0.5	9.7	2.4	0	1.9	75	5	20	Sandy loam	1.7	0.2	4
Open	6.3	4.1	0.2	0.4	2.6	0.9	0.3	1.3	82	13	5	Loamy Sand	1.6	1.7	4
Open	5.6	23.5	0.1	0.4	4.8	1.9	0	1.3	49	41	10	Loam	2.2	1	4
Open	6.7	9.1	0.17	0.5	3.9	2	0	1.7	82	5	13	Loamy Sand	1.6	2.6	6
Open	6.4	21	0.4	0.1	13.3	4.6	0	2.5	87	3	10	Loamy Sand	1.8	1.2	6
Open	6.5	17.9	0.23	0.6	2.1	1	1.1	1.4	85	12	3	Loamy Sand	1.7	0.9	4
Open	5.7	8.9	0.17	0.1	2.6	0.4	5.4	1	45	47	8	Loam	2.4	2	2
Open	5.7	6.4	0.2	0.2	4	1.3	0	1.4	87	5	8	Loamy Sand	1.5	1.2	4
Open	7	5.7	0.2	0.2	3.9	1	1.6	1.3	67	13	20	Sandy loam	1.6	1.2	1
Enclosed	6.1	13.7	0.25	0.1	2.8	0.4	0.4	1	92	3	5	Sand	1.3	5.7	6
Enclosed	6.4	12	0.43	0.4	11.3	1.5	0.8	2.3	77	9	14	Loamy Sand	1.4	2.8	4
Enclosed	5.9	15	0.37	0.7	5.5	1.3	1.6	2.1	69	18	13	Sandy loam	1.2	4.2	3
Enclosed	5.1	6.6	0.27	0.4	2.4	0.7	2.1	1	80	8	12	Loamy Sand	1.3	4.8	4
Enclosed	6.3	7.1	0.27	0.2	3.4	0.8	1.1	2.6	59	26	15	Sandy loam	1.5	5.1	2
Enclosed	6.1	7.2	0.4	0.3	3.4	0.8	0	1.5	87	3	10	Loamy Sand	1.4	3.8	4
Enclosed	5.7	7.1	0.23	0.2	2.8	0.8	2	1.4	87	3	10	Loamy Sand	1.2	3.9	3
Enclosed	5.9	6.8	0.3	0.2	2.1	0.7	1.3	2.5	90	5	5	Sand	1.3	2.8	1
Enclosed	6.1	8.5	0.23	0.3	2.9	0.8	0	1.4	85	7	8	Sandy loam	1.4	6.6	4
Enclosed	5.4	8.2	0.17	0.3	3.2	1.1	2.7	1.5	87	3	10	Loamy Sand	1.3	2.1	4
Enclosed	6.2	10.4	0.33	0.8	1.9	2	0	1.5	55	34	11	Sandy loam	1.4	3.5	4
Enclosed	6.2	10.1	0.2	0.8	4	1	0.8	1.5	63	29	8	Sandy loam	1.3	2.4	5
Enclosed	6.2	7.1	0.6	0.2	3.3	1	2.5	2	84	8	8	Loamy Sand	2.3	2.7	3
Enclosed	6.8	223.9	0.57	0.2	18.7	4	0	2.7	89	1	10	Loamy Sand	1.4	1.4	3
Enclosed	6.9	39	0.4	0.5	18.2	3.8	0	2.1	67	14	19	Sandy loam	2.1	6.6	6
Enclosed	6.2	8	0.17	0.8	7.6	2	2.7	1.3	71	13	16	Sandy loam	2.1	2.9	5
Enclosed	6.4	16.1	0.33	0.5	9.9	3.1	0	2.8	65	14	21	SCL	1.4	3.7	4
Enclosed	5.7	8.5	0.23	0.1	3.9	1.9	0	2.2	50	37	13	Loam	1.3	4.6	4
Enclosed	4.7	67.3	0.27	0.2	2.1	0.8	1.4	1.5	74	3	23	SCL	1.3	3.1	5

Appendix 2. A List of species recorded for biomass at the study site

Species	Author	Family
Acanthaceae		Acanthaceae
Acanthosperma hispidum	DC.	Acanthaceae
Asystacia laticapsula	C.B.Cl.	Acanthaceae
Barleria acanthoides	Vahl	Acanthaceae
B. alisinoides		Acanthaceae
Blepharis maderaspatensis	(L.) Roth	Acanthaceae
Crabbea velutina	S.moore	Acanthaceae
Crossandra nilotica	Oliv.	Acanthaceae
Duosperma macroblephara	(Lindau) Dayton	Acanthaceae
Dychoriste radicans	Nees	Acanthaceae
Isoglossa laxa	Oliv.	Acanthaceae
Justicia matammensis	Oliv.	Acanthaceae
J. uncinulata	Oliv.	Acanthaceae
Neuracanthus ukambensis	C.B. Clarke	Acanthaceae
Ruellia patula	Jacq.	Acanthaceae
Ruttya fruticosa	Lindau	Acanthaceae
Thunbergia alata	Sims	Acanthaceae
T. holstii	Lindau	Acanthaceae
Acanthus sp.		Acanthaceae
Asystacia verticillata		Acanthaceae
Peristrope sp.		Acanthaceae
Actiniopteris semiflabellata	Pic.Ser.	Actiniopteridaceae
Cheilanthes inequalis		Adiantaceae
Sanseveria sp.		Agavaceae
Aloe secundiflora	Engl.	Aloeceae
Achyranthes aspera	L.	Amaranthaceae
Aerva javanica	(Burm.f.) Juss. Ex Schult.	Amaranthaceae
Alternanthera pungens	Kunth	Amaranthaceae
Celosia schweinfurthiana	Schinz	Amaranthaceae
Pupallia luppacea	(L.) A. Juss.	Amaranthaceae
Lannea rivae	(Chiov.) Sacl.	Anacardiaceae
L. schweinfurthii	(Engl.) Engl.	Anacardiaceae
Ozoroa insignis	Del.	Anacardiaceae
Rhus longipes	Engl.	Anacardiaceae

R. natalensis	Krauss	Anacardiaceae
R. tenuinervis	Engl.	Anacardiaceae
R. vulgaris	Meikle	Anacardiaceae
Lannea alata	(Engl.) Engl.	Anacardiaceae
Apocynaceae		Apocynaceae
Ceropegia sp.		Apocynaceae
Edithcolea glandis	N.E. Br.	Asclepiadaceae
Aspilia mossambicensis	(Oliv.) Willd.	Asteraceae
Bidens pilosa	L.	Asteraceae
Bothriocline shagayuensis	C.Jeffrey	Asteraceae
Helichrysum globosum	Sch.Bip.	Asteraceae
Hirpicium diffusum	(O.Hoffm.) Roessler	Asteraceae
Sphaeranthus ukambensis	Vatke & O. Hoffm.	Asteraceae
Tridax procumbens	L.	Asteraceae
Vernonia fischeri	O.Hoffm.	Asteraceae
V. galamensis	(Cass.) Less	Asteraceae
Klenia klinoides		Asteraceae
Balanites aegyptica	(L.) Del.	Balanitaceae
Markhamia lutea	(Benth.) K. Schum	Bignoniaceae
Cordia monoica	Roxb.	Boraginaceae
Heliotropium steudneri	(Vate) Verdc.	Boraginaceae
H. strigosum	Willd.	Boraginaceae
Boswellia neglecta	S.Moore	Burseraceae
Commiphora africana	(A.Rich.) Engl.	Burseraceae
C. campestris	Engl.	Burseraceae
C. edulis	(Klotzsch) Engl.	Burseraceae
C. schimperi	(O.Berg) Engl.	Burseraceae
Wahlenbergia scottii		Campunulaceae
Boscia angustifolia	A.Rich.	Capparidaceae
B. coriacea	Pax	Capparidaceae
Capparis tomentosa	Lam.	Capparidaceae
Cleome sp.		Capparidaceae
Maerua decumbens	(Brogn.) Dewolf	Capparidaceae
Thylachium africanum	Lour.	Capparidaceae
Maytenus putterlickoides	(Loes.) Exell & Mendoca	Celastraceae
C. aculeatum	Vent	Combretaceae
C. apiculetum	Sond.	Combretaceae
C. hereroense	Schinz	Combretaceae
C. molle	R.Br. ex G.Don	Combretaceae
C. zeyheri	Sond.	Combretaceae
Terminalia brownii	Fresen	Combretaceae
Aneilema johnstonii	K. Schum.	Commelinaceae
Aneilema sp		Commelinaceae

Commelina benghalensis	L.	Commelinaceae
C. erecta	L.	Commelinaceae
C. latifolia	A.Rich.	Commelinaceae
Murdannia simplex	(Vahl) Brenan	Commelinaceae
Evolvulus alisinoides	(L.) L.	Convolvulaceae
Ipomoea arachnosperma	Welw.	Convolvulaceae
I. jaegeri	Pilger	Convolvulaceae
I. kituensis	Vatke	Convolvulaceae
I. wightii	(Wall.) Choisy	Convolvulaceae
Merremia ampelophylla	Hall.f.	Convolvulaceae
Kalanchoe sp.		Crassulaceae
Kedrostis hirtella	(Naud.) Cogn.	Cucurbitaceae
Kyllinga erecta	Schum.	Cyperaceae
Acalypha fruticosa	Forssk.	Euphorbiaceae
Bridelia micrantha	(Hochst.) Baill.	Euphorbiaceae
Croton dichogamus	Pax	Euphorbiaceae
Euphorbia crotonoides	Boiss.	Euphorbiaceae
E. hirta	L.	Euphorbiaceae
E. matabelensis	Pax	Euphorbiaceae
E. scheffleri	Pax	Euphorbiaceae
Phyllanthus reticulatus	Poir	Euphorbiaceae
P. maderaspatensis	L.	Euphorbiaceae
Abrus schimperi	Hochst.	Fabaceae
Acacia brevispica	Harms	Fabaceae
A. drepanolobium	Harms ex Sjostedt	Fabaceae
A. etbaica	Schweinf.	Fabaceae
A. mellifera	(Vahl) Benth.	Fabaceae
A. nilotica	(L.) Del	Fabaceae
A. senegal	(L.) Willd.	Fabaceae
A. tortilis	(Forssk.) Hayne	Fabaceae
Albizzia amara	Schult.	Fabaceae
A. anthelmintica	(A.Rich.) Brogn.	Fabaceae
Cassia mimosoides	L.	Fabaceae
Crotalaria goodiformis	Vatke	Fabaceae
Crotalaria sp.		Fabaceae
Dalbergia melanoxylon	Guill. & Perr.	Fabaceae
Delonix elata	(L.) Gamble	Fabaceae
Desmodium sp.		Fabaceae
Dichrostachys cinerea	(L.) Wight & Arn.	Fabaceae
Entada leptostachya	Harms	Fabaceae
Indigofera errecta	Hochst.ex A.Rich.	Fabaceae
I. lupatana	Bak.f.	Fabaceae
I. schimperi	Jaub. & Spach	Fabaceae

Indigofera sp.		Fabaceae
Lonchocarpus eriocalyx	Harms	Fabaceae
Ormocarpum kirkii	S. Moore	Fabaceae
Bauhinia thonnigii	(Schumach.) Chiov.	Fabaceae
Senna siguena	(Del.) Lock	Fabaceae
Styrosanthes fruticosa	(Retz.) Alston	Fabaceae
Tephrosia noctiflora	Bak.	Fabaceae
T. pumila	(Lam.) Pers.	Fabaceae
T. submolis		Fabaceae
Zornia setosa	Bak.f.	Fabaceae
Mucuna gigantea	(Willd.) DC.	Fabaceae
Vigna sp.		Fabaceae
Geranium sp		Geraniaceae
Ornithogalum donaldsonii	(Rendle) Greenway	Hyacinthaceae
Leonotis mollisima	Gurke	Lamiaceae
Leucas grandis	Vatke	Lamiaceae
Becium obovatum	(E.Mey.) N.E.Br.	Lamiaceae
Leonotis nepetifolia	R.Br.	Lamiaceae
Leucas mollis	Baker	Lamiaceae
Ocimum basilicum	L.	Lamiaceae
Orthosiphon suffrutescens	(Thonning) J.K. Morton	Lamiaceae
Plectranthus barbatus	Andr.	Lamiaceae
P. igniaris	(Schweinf.) Agnew	Lamiaceae
P. sylvestris	Gurke	Lamiaceae
Tinnea aethiopica	Kotschy & peys.	Lamiaceae
Hoslundia opposita	Vahl	Lamiaceae
Geniosporom viridis		Lamiaceae
Asparagus racemosus	Willd.	Liliaceae
A. setaceus	(Kunth) Jessop	Liliaceae
Nuxia congesta	Fres.	Loganiaceae
Abutilon hirtum	(Lam.) Sweet	Malvaceae
A. mauritianum	(Jacq.) Medic.	Malvaceae
Hibiscus calyphyllus	Cav.	Malvaceae
H. meyeri		Malvaceae
H. micranthus	L.f.	Malvaceae
Hibiscus sp.		Malvaceae
H. vitifolius	L.	Malvaceae
Pavonia arabica	Hochst. & Steud. Ex Boss	Malvaceae
P. patens	(Anr.) Chiov.	Malvaceae
Sida ovata	Forssk.	Malvaceae
Ekerbergia capensis	Sparrm.	Meliaceae
Chasmanthera dependens	Hochst.	Menispermaceae
Cissampelous mucronata	A.Rich.	Menispermaceae

C. pareira	L.	Menispermaceae
Boerhavia diffusa	L.	Nyctaginaceae
Commicarpus plumbagineus	(Cav.) Standl.	Nyctaginaceae
Ochana ovata	F.Hoffm.	Ochnaceae
Ximenia americana	L.	Olacaceae
Jasminum sp.		Oleaceae
Schrebera alata	(Hochst.) Welw.	Oleaceae
Orobanche sp.		Orobanchaceae
Oxalis corniculata	L.	Oxalidaceae
Sesasum angustifolium		Pedaliaceae
Aristida adscensionis	L.	Poaceae
Bothriochloa insculpta	(Hochst.ex A.Rich.) A.Camus	Poaceae
Bracharia reptans	(L.) C.A.Gardner & C.E. Hubb	Poaceae
Cenchrus ciliaris	L.	Poaceae
Chloris gayana	Kunth	Poaceae
C. roxburghiana	Schult.	Poaceae
C. mossambicensis	K.Schum.	Poaceae
Cynodon dactylon	(L.) Pers.	Poaceae
Dactylotenium aegyptium	L.Willd.	Poaceae
Digitaria macroblephara		Poaceae
Eragrostis ciliaris	(L.) R.Br.	Poaceae
E. superba	Peyr.	Poaceae
Fimbriostylis dichotoma		Poaceae
Hyparrhenia hirta	E. Fourn.	Poaceae
Microchloa kunthii	Desv.	Poaceae
Panicum maximum	Jacq.	Poaceae
Pennisetum schimperi	A. Rich.	Poaceae
Rhynchelytrum repens	(Willd.) C. E. Hubb	Poaceae
Setaria verticulata	Bearv.	Poaceae
Sporobolus pyramidalis	P. Beauv.	Poaceae
Tetrapogon villosus	Desf.	Poaceae
Themeda triandra	Forssk.	Poaceae
Tragus berteronianus	Schult.	Poaceae
Enteropogon macrostachyus	(Hochst. Ex A. Rich.) Munro ex Benth	Poaceae
Grass mat		Poaceae
Heteropogon contortus	(L.) P.Beauv.ex Roem. & Schult.	Poaceae
Polygala sphenoptera	Fresen.	Polygalaceae
Oxygonum sinuatum	(Meisn.) Dammer	Polygonaceae
Portulaca foliosa	Ker-Gawl.	Portulacaceae
Talinum portulacifolium	(Forssk.) Schweinf.	Portulacaceae

Helinus integrifolius	(Lam.) Kuntze	Rhamnaceae
Hymenodictylon parvifolium	Oliv.	Rubiaceae
Oldenlandia corymbosa	L.	Rubiaceae
Otomeria oculata	S. Moore	Rubiaceae
Pavetta crassipes	K. Schum.	Rubiaceae
Pentas longiflora	Oliv.	Rubiaceae
P. parvifolia	Hiern	Rubiaceae
Tennantia sennii	(Chiov.) Verdc. & Bridson	Rubiaceae
Teclea nobilis	Del.	Rutaceae
Zanthoxylum chalybeum	Engl.	Rutaceae
Allophyllus ferrugineus	Taub.	Sapindaceae
Haplocoelum foliolosum	(Hiern) Bullock	Sapindaceae
Striga asiatica	(L.) Ktze	Scrophulariaceae
Harrisonia abyssinica	Oliv.	Simaroubaceae
Solanum incanum	L.	Solanaceae
S. renchi	Vatke	Solanaceae
Withania somnifera	(L.) Dunal	Solanaceae
Hermannia exappendiculata	(Mast.) K. Schum.	Sterculiaceae
Melhania ovata	(Cav.) Spreng.	Sterculiaceae
M. velutina	Forssk.	Sterculiaceae
Sterculia africana	(Lour.) Fiori	Sterculiaceae
Waltheria indica	L.	Sterculiaceae
Gnidia glauca	(Fres.) Gilg	Thymelaceae
Grewia bicolor	Juss	Tiliaceae
G. similis	K.Schum.	Tiliaceae
G. tembensis	Fresen.	Tiliaceae
G. villosa	Willd.	Tiliaceae
Triumfetta tomentosa	Boj.	Tiliaceae
Conchrus triloquralis		Tiliaceae
Steganotaenia araliacea	Hochst.	Umbrelliferae
Lantana camara	L.	Verbenaceae
L. viburnoides	(Forssk.) Vahl	Verbenaceae
Premna resinosa	(Hochst.) Schauer	Verbenaceae
Rotheca myricoides	Verdc.	Verbenaceae
Vitex strickeri	Vatke and Hildebr.	Verbenaceae
Hyptis sp.		Verbenaceae
Priva adhaerens	(Forssk.) Chiov.	Verbenaceae
Cissus quadrangularis	L.	Vitaceae
C. rotundifolia	(Forssk.) Vahl	Vitaceae

Appendix 3. Species corresponding to numbers in X-axis for figures 3-9

Nos	**Figure 3**	**igure 4**	**Figure 5**	**Figure 6**	**Figure 7**	**Figure 8**	**Figure 9**
1	Entada leptostachya	Premna resinosa	Melhania ovata	C zeyheri	Premna resinosa	Premna resinosa	Tephrosia pumila
10	Combretum aculeatum	0	0	0	0	0	0
11	0	0	0	0	0	Grewia bicolor	0
13	0	Sterculia africana	0	0	0	0	0
14	0	0	0	0	0	0	Cenchrus ciliaris
15	0	0	Abutilon hirtum	0	0	0	0
18	0	0	0	Lannea rivae	0	0	0
19	Albizzia amara	0	0	0	0	0	0
21	0	0	0		0	Acacia drepanolobium	0
24	0	0	0	0	Sterculia africana	0	0
25	0	Phyllanthus reticulatus	0	0	0	0	0
27	0	0	0	0	0	0	Mucuna gigantea
28	Combretum molle	0	0	0	0	Ochana ovata	0
29	0	0	Withania somnifera	0	0	0	0
31	0	0	0		0	Tinnea aethiopica	0
33	Combretum apiculeatum	Acacia etbaica	0	0	0	0	0
35	0	0	0	Grewia villosa	0		0

Nos	Figure 3	Figure 4	Figure 5	Figure 6	Figure 7	Figure 8	Figure 9
40	Boscia coriacea	0	0	0	0	B. aegyptica	P. luppacea
41	0	0	0	0	0	Tinnea aethiopica	0
43	0	0	Microchloa kunthii	0	0	0	0
47	0	Rhus natalensis	0	0	Ruttya fruticosa	0	0
51	0	0	0	0	0	Leonotis nepetifolia	0
52	0	0	0	Cordia monoica	0	0	0
53	Cissus rotundifolia	0	0	0	0	0	Ipomoea kituensis
55	0	Plectranthus barbatus	0	0	0	0	Themeda triandra
57			C.apiculeatum	0	0	0	0
61	Commiphora edulis	0	0	0	0	Gnidia glauca	0
66	0	0	0	0	0	0	O.suffrutescens
69	0	0	0	Rhus natalensis	0	0	0
70	Bothriochloa insculpta	Ipomoea kituensis	0	0	Indigofera errecta	0	0
71	0	0	Asystacia verticillata	0	0	Schrebbera alata	0
73	0	0	0	0	0	0	T. noctifolia
79	0	0	0	S. angustifolia	0	0	E. hirta
81	Barleria acanthoides	0	0	0	0	Pentas parvifolia	0
82	Chloris sp.	0	0	0	0	0	M. kunthii
85	0	0	C.schweinfurthii	0	0	0	0

Nos	Figure 3	Figure 4	Figure 5	Figure 6	Figure 7	Figure 8	Figure 9
86	0	0	0	H.contortus	0	0	0
91	0	0	0	0	0	A. racemosa	0
92	0	0	0	0	0	0	C. nilotica
93	0	Cassia mimosoides	0		Eragrostis superba	0	0
97	Ocimum basilicum	0	0	0	0	0	0
99	0	0	D. cinerea	0	0	0	0
103	0	0	0	Portulaca foliosa	0	0	0
105	0	0	0	0	0	0	A.laticapsula
106	0	Desmodium sp	0	0	0	0	0
109	0	Jasminum sp.	0	0	0	0	0
113	0	0	Bidens pilosa	0		0	0
116	0	0	0	0	Panicum maxima	0	0
118	0	Vigna sp.	0	0	Vigna sp.	0	E.alisinoides
120	0	0	0	Barleria acanthoides	0	0	0
127	0	0	P.adhaerens	0	0		0
129	0	0	0	0	0	0	Duosperma sp
137	0	0	0	Crotalaria sp.	0	0	0
139	0	0	0	0	H.exappendiculata	0	0
141	0	0	S.fruticosa	0	0	0	H.steudneri
154	0	0	0	Bothriocline ss	0	0	0
162	0	0	0	Priva adhaerens	Ipomoea gaegeri	0	0
171	0	0	0	Mucuna gitantea	C. tomentosa	0	0
185	0	0	0	0	P. schimperi	0	0
193	0	0	0	0	S. fruticosa	0	0
208	0	0	0	0	Oxalis corniculta	0	0
231	0	0	0	0	Aerva javanica	0	0

Appendix 4. Plant species with biomass in the different community types identified considering all vascular plant species

			Community types							
Species	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
Abrus schimperi	10343.5	10343.5	2983.19	83542.26	4671.05	0	0	0	0	0
A. hirtum	0	32.85	25.62	1060.7	642.31	0	0	0	0	813.5
A. mauritianum	3.56	0	0.32	4.66	0	0	0	0	0	0
A. brevispica	1581.45	27514.5	2581.75	5319.27	17241.62	0	2351.6	948.4	0	0
A. drepanolobium	0	0	0	0	0	0	0	0	47958	0
A. etbaica	0	5135.73	0	1268.11	2440.88	0	4296.9	0	0	0
A. mellifera	2935.02	12152.5	5498.32	14848.04	18531.86	0	619.47	150.88	893.46	0
A. nilotica	59.28	3937.26	1475	7208.29	2337.86	2091.5	2724.5	0	1660	0
A. senegal	772.3	0	0	0	0	0	27.26	27.26	428.5	0
A. tortilis	2499.74	5765.38	3891.42	4606.17	0	0	1001.6		685.31	0
Acalypha fruticosa	517.01	1541.68	2.58	0	143.74	1154	8.54	8.54	0	0
Acanthaceaea	0	0	5.36	0	141.65	0	0	0	0	0
Acanthosperma hispidum	187.83	0	0	104.62	0	0	0	0	0	28.05
Acanthus sp.	0.43	0	0	0.43	0.46	0	0	0	0	0
Achyranthes aspera	28.73	0	0	0	1.39	17.17	29.52	26.96	10.86	2.75
Actiniopteris semiflabellata	16.15	0	2.12	5.84	0	0	2	0	0	0
Aerva javanica	0	0	0	0	0	0	0	0	0	15.06
Albizzia amara	18268.68	18268.68	668	7912.68	312.25	0	9266.8	0	436.65	0
A. anthelmintica	0	8432.05	2209.74	2782.54	14213.97	0	3288		980.87	0
Allophyllus ferrugineus	638.38	7183.92	0	7218.24	760.45	0	0	0	0	0
Aloe secundiflora	0	0	0	0	3526.45	0	1074	0	0	0
Alternanthera pagens	8.24	0	0	0	0	0	0	0	0	0
Aneilema johnstonii	0.12	0	0	0.12	0	0	0	0	0	0

Species	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
Aneilema sp	0	84.62	0	10.39	0	28.36	0	0	0	0
Apocynaceae	0	0	0	83.62	0	0	0	0	0	0
Arsitida adscensionis	54.28	268.02	96.45	65.54	101.84	0	35	35	0	0
Asparagus racemosa	0	33.26	8.34	4.56	17.69	0	0	0	1.98	0
A. setaceus	17.84	405.65	125.9	35.61	0	0	231.78	6.47	0	0
Aspilia mossambicensis	812.81	4843.48	6313.58	17086.75	786.43	67.32	0	0	672.4	0
Asystacia laticapsula	0	22.02	7.73	0	0	0	0	0	0	0
A. verticillata	9.19	228.85	2.52	196.61	0	0	0	0	20.36	0
Balanites aegyptica	0	0	1102.23	0	0	0	21447	21447	0	0
Barleria acanthoides	16.84	183.83	2.99	77.66	111.14	0	0	0	13.41	0
B. alisinoides	0	24.91	0	1.87	0	0	0	0	0	0
Bauhinia thonnigii	432.91	0	432.91	1026.87	0	0	7909.9	4866.6	0	0
Becium obovatum	35.09	105.02	0.54	23.64	16.08	15.36	116.54	45.58	5.27	566.78
Bidens pilosa	32.46	0	0	0	0	0	0	0	0	0
Blepharis maderaspatensis	44.17	54.35	0	19.34	82.27	4.07	3.5	0	2.14	0
Boerhavia diffusa	1.9	0	2.48	1.02	0	0	0	0	0	0
Boscia angustifolia	2361.67	0	0	482.2	7134.98	0	0	0	0	0
B. coriacea	0	49865.26	1795.54	4070.81	0	0	0	0	849.33	0
Boswellia neglecta	0	0	765.43	0	3072.67	0	49988	0	0	0
Bothriochloa insculpta	65.42	169.52	65.3	233.35	185.55	0	0	0	42.12	47.01
Bothriocline somalenis	0	0	0	0	0	0	14.83	0	0	0
Bracharia reptans	67.27	33.7	0	33.7	0	0	4.56	0	0	0
Bridelia micrantha	0	8202.87	2740.28	9039.81	2528.31	0	1886.2	0	0	0
Capparis tomentosa	0	4632.92	0	0	0	0	0	0	0	0
Cassia mimosoides	19.23	163.24	89.53	84.3	2.71	9.8	6.22	0	5.37	3.07
Celosia schweinfurthii	0	0	0	0.54	0	0	0	0	0	0
Cenchrus ciliaris	487.25	130.46	0	160.86	190.74	0	72.3	0	65.16	0

Species	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
Ceropegia sp.	0	19.56	0	0	0	0	0	0	0	0
Chasmanthera repens	0	0	0	4.39	0	0	0	0	0	0
Cheilanthes inequalis	0	52.93	1.11	26.76	0	0	0	0	0	0
Chloris gayanus	0	156.18	113.52	25.61	0	0	6.84	6.84	67.09	43.78
C. roxburgiana	0	24.29	35.66	29.36	20.14	0	0	0	0	0
Chloris sp.	2.37	31.46	21.21	4.88	26.11	11.38	0	0	0	0
Cissampelous mucronata	0	53.72	28.08	58.72	18.54	0	0	0	0	0
C. pareira	25.78	266.2	8.54	6.03	18.02	0	5.56	2.87	8.47	0
Cissus quadrigularis	85.97	666.04	677.22	915.76	580.18	0	293.17	65.49	36.35	0
C. rotundifolia	0	855.87	193.4	494.03	62.3	23.67	17.47	17.47	0	0
Cleome sp.	0	59.2	0	0	0	0	0	0	0	0
Combretum aculeatum	26135.802	26135.802	4766.78	15295.71	3612.62	0	5239.2	0	532.76	0
C. apiculeatum	40069.36	19767.72	917.69	3128.56	1136.27	116.25	2061.9	0	2227.5	0
C. molle	0	18235.59	2146.3	11449.92	2439.95	0	0	0	0	0
C. zeyheri	0	0	0	378.5	74301.21	3482.4	1273.6	0	0	0
C. hereroensis	0	8919.36	12294.38	5312.83	959.05	0	0	0	821.45	0
Commelina benghalensis	56.58	140.69	19.66	8.46	0	0	0	0	0	132.96
C. erecta	11.4	19.7		4.02	6.65	0	9.28	9.28	16.86	0
C. latifolia	24.98	26.84	12.87	35.79	92.33	0	25.55	0	20.64	0
Commicarpus plumbagineus	0	0	0	0	0	0	0	0	0	4.33
Commiphora africana	0	11338.95	3445.96	3521.39	0	0	16239	0	0	0
Commiphora campestris	0	4879.77	2508.74	1648.85	3057.38	0	0	0	1421.9	0
C. edulis	0	0	0	5767.73	0	0	0	0	0	0
C. schimperi	4420.76	19586.23	7775.97	12800.26	1838.86	2014.1	0	0	1050.1	0
Conchrus triloquralis	0	0	0	0	0	0	0.45	0	1.38	0
Cordia monoica	2721.02	7491.5	5896.91	4525.55	869.75	0	488.97	488.97	36.54	0
Crabbea velutina	4.32	292.22	42.23	84.84	28.99	7.63	98.17	6.87	8.4	0

Species	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
Crossandra nilotica	20.86	24.21	0	0	0	0	0	0	0	0
Crotalaria goodiformis	29.64	837.23	147.03	643.74	156.54	523.87	147.54	0	0	0
Crotalaria sp.	12.87	268.55	60.89	73.74	19.97	0	21.63	0	0	12.65
Croton dichogamus	1647.87	0	0	1218.13	0	0	0	0	0	0
Cynodon dactylon	32.65	220.34	0	309.65	0	110.28	110.37	110.37	0	0
Cyphostema sp	127.45	127.45	1016.23	206.48	0	0	171.8	171.8	360.54	0
Dactylotenium sp.	11.65	24.06	0	0	0	0	0	0	24.06	0
Dalbergia melanoxylon	0	4676.81	0	7829.78	4303.05	0	0	0	0	0
Delonix elata	0	0	0	0	17328.85	0	0	0	0	0
Desmodium sp	0	442.96	17.92	0	137.78	0	0	0	0	0
Dichrostachys cinerea	2528.25	91529.28	312	1038.36	10202.25	0	412.41	0	0	0
Digitaria macroblephara	0	0	0	6.65	0	0	0	0	1.27	0
Duosperma sp.	3.79	0	3.79	5.01	0	0	5.49	0	0	0
Dychoriste radicans	0	4.45		6.54	0	0	0	0	20.7	0
Edithcolea glandis	0	0	0.38	3.98	0	0	0	0	0	0
Ekerbergia capensis	0	0	0	3649.61	0	0	0	0	1506.8	0
Endostemum tereticaulis	7.54	104.42	11.86	45.64	3.32	0	0	0	7.6	0
Entada leptostachya	0	194.63	1667.86	265.87	0	0	0	0	0	0
Enteropogon macrostachys	27.25	1269.14	15.96	171.7	239.65	0	31.59	20.65	36.82	0
Eragrostis ciliaris	234.49	164.54	0	253.88	464.91	19.8	218.5	20.61	180.99	45.76
E. superba	257.73	0	0	76.3	35.45	29.67	68.48	68.48	26.45	128.54
Euphorbia crotonoides	0	0	4.47	0	0	0.37	6.1	0	0	0
E. hirta	0.98	0	0.43	0	0	0	0	0	0	16.54
E. matabelensis	0	6193.24	0	0	0	0	0	0	46453	0
E. scheffleri	927.19	0	0	178.32	2885.72	0	0	0	0	0
Evolvulus alisinoides	27.75	35.87	0	7.92	34.38	0	8.9	0	0	0
Fimbriostylis dichotoma	23.49	152.62	3.65	0	29.63	0	0	0	16.98	0

Species	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**	**C10**
Geniosporom viridis	0	138.23	0	0	0	0	167.94	0	0	0
Geranium sp	0	0	0	0	0	0	1.14	0	0	0
Gnidia glauca	1356.09	5141.14	2119.94	682.82	0	0	3157.2	3157.2	0	0
Grass mat	10.6	267.43	66.11	175.43	43.3	0	205.16	0	26	0
Grewia bicolor	0	14559.35	5208.19	20233.55	13123.72	2999	0	0	1361.5	0
G. similis	627.92	10648.97	2955.81	3226.63	3003.51	1303.8	2501.7	0	1875.1	0
G. tembensis	1423.17	8588.22	1300.41	4625.06	4019.85	0	4060.4	1906.3	1898.4	0
G. villosa	2828.64	13100.74	8631.2	2243.54	4299.82	455.28	1103.2	0	192.64	0
Haplocoelum foliolosum	0	3847.41	11566.43	865.43	0	0	14539	0	14534	0
Helichrysum globosum	0	0	0	0	3.97	0	0.43	0	5.49	0
Helinus integrifolia	0	10.86	0	2.76	0	0	0	0	0	0
Heliotropium steudneri	2.54	0	0	0	0	0	0	0	0	46.4
H. strigosa	0	23.02	0	0	25.21	0	0	0	25.06	0
Hermannia exappendiculata	55.42	48.79	0	42.33	56.05	0	37.45	15.98	46.47	151.48
Heteropogon contortus	29.26	5.32	0	35.71	0	22.72	163.5	46.6	53.82	0
H. calyophyllus	6.15	156.15	0	57.81	33.22	0	4.38	4.38	0	0
H. meyeri	0	2144.4	399.75	307.41	963.78	0	238.43	0	206.04	0
H. micrantha	0	44.2	31.3	140.35	136.61	0	30.48	0	0.92	0
Hibiscus sp.	0	7.72	0	5.86	0	0	0	0	0	0
H. vitifolius	668.4	0	403.1	0	0	0.49	14.18	4.76	0	2298
Hirpicium diffusum	0	2058.3	0	481.35	0	0	0	0	0	0
Hoslundia opposita	3651.92	589.88	0	487.84	0	0	2585.1	2585.1	0	93.76
Hymenodictylon parvifolium	0	12414.21	1214.47	12982.21	1184.31	0	0	0	0	0
Hyptus sp.	1.16	0	0	0	0	0	0.43	0.43	0	0
Indigofera lupatana	15.32	233.33	12.39	94.43	30.99	0	17.71	17.71	0	0
I. schimperi	0	0	7.57	0	0	0	32.43	0	0	0
Indigofera sp.	0	43.49	16.19	22.74	10.1	0	0	0	0	0

Species	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
Ipomoea arachnosperma	32.87	1.2	7.8	12.56	24.3	0	3.99	0	0	0
I. gaegeri	24.2	0	0	0	0	0	0	0	42.18	0
I. kituensis	90.43	1235.48	136.33	992.02	1045.74	0	0	0	432.69	0
I. wightii	8.34	3.71		19.05	0	0	0	0	0	0
Isoglossa laxa	0	16.55	15.75	18.72	4.67	0	14.21	0	14.77	0
Jasminum sp.	10.72	31.33	6.78	0	0	0	4.76	4.76	0	0
Justicia matammensis	5.4	103.65	27.54	3.01	0	30.45	9.76	9.76	0.98	0
J. uncinulata	4.97	55.11	0	39.46	84.32	0	123.1	0.47	0	0
Kalanchoe sp.	0	4.54	0	0	0	0	0	0	0	0
Kedrostis sp.	0.39	0	0	0.42	1.07	0	3.29	0	0	0
Klenia klenoides	251.3	251.3	29.03	151.77	0	0	116.07	0	298.6	0
Kyllinga erecta	7.54	0	0	0	32.21	4.32	0	0	0	0
Lannea alata	0	0	15339.99	3675.03	0	0	0	0	853.28	0
L. rivae	0	14634.14	1545.32	18828.45	2189.65	0	0	0	5299.6	0
L. schweinfurthii	0	13806.96	31496.81	0	0	0	0	0	0	0
Lantana camara	1153.32	6679.28	125176.1	176.65	851.94	0	0	0	0	0
L. viburnoides	1825.92	0	0	0	13297.77	0	0	0	0	0
Leonotis nepetifolia	32.96	0	0	0	0	0	1580	0	0	15195
Leucas grandis	0	10.32	0	0	0	0	0	0	3.45	0
L. mollis	27.44	0	0	0	0	0	0	0	27.44	5.87
Lonchocarpus eriocalyx	4506.4	28922.52	458.54	5736.45	1255.2	0	1876.3	0	0	0
Maerua decumbens	0	1682.33	457.21	165.34	0	947.14	0	0	898.6	0
Markhamia lutea	3703.97	0	2051.42	0	7612.5	0	0	0	0	0
Maytenus putterlickoides	1416.13	64910.11	2869.25	1388.87	0	3475.7	32.02	0	3475.7	0
Melhania ovata	20.86	117	0	70.09	130.54	1.23	30.99	8.98	37.57	0
M. velutina	52.71	37.84	77.46	24.81	12.56	7.12	11.75	5.86	0	0
Meremia amelophylla	0	12.09	0	0	0	0	0	0	0	0

Species	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
Microchloa kunthii	11.49	12.61	0.47	1.65	1.74	0	0	0	29.86	0
Mucuna gigantea	0	15.15	0	4.05	0	0	0	0	0	0
Mundania simplex	50.89	0	0	49.18	0	0	0	0	0	0
Neuracanthus tereticaulis	0	84.89	29.92	28.4	15.35	15.45	26.38	0	11.28	0
Nuxia congesta	0	0	0	10291.16	0	0	0	0	0	0
Ochana ovata	1055.68	17924.2	6265.44	4646.47	1068.17	0	553.39	553.39	2980.8	0
Ocimum basilicum	18.54	87.49	120.97	88.12	18.78	16.79	43.38	0.25	52.67	0
Oldenlandia caesapritosa	64.76	19.26	29.5	46.54	56.92	13.87	11.59	0	0	0
Ormocarpum kirkii	0	7879.66	3296.37	2424.41	0	0	0	0	0	0
Orobanche sp.	0	0	0	0	0.48	0	0	0	0	0
Orthosiphon suffrutescens	0	12.39	0	5.92	0	6.03	0	0	0	0
Otomeria oculata	0	0	5.45	0	40.14	0	0	0	6.15	0
Oxygonum simatum	3.68	37.63	0	4.83	0	0	0	0	0	0
Ozoroa insignis	37.34	0	37.34	68.54	0	24738	0	0	0	0
Panicum maxima	0	540.71	197.6	231.17	0	0	44.56	0	0	0
Pavetta crassipes	0	136.68	0	0	25542.4	0	0	0	0	0
Pavonia arabicum	3198.15	0	0	69.82	0	2.38	0	0	0	4801.5
P. patens	15.65	0	0	5.67	0	0	6.92	0.38	0	0
Pennisetum schimperi	0	0	0	43.57	0	0	0	0	0	0
Pentas longiflora	1548.32	0	0	1051.3	0	0	943.38	943.38	8935.2	0
Pentas parvifolia	824.19	3266.16	1115.32	178.66	105.37	0	0	0	0	0
Peristrope sp.	0.32	0	0	0.41	0	0	0	0	0.26	0
Phyllanthus reticulatus	7830.71	7830.71	12816.16	1264.32	0	1087	3480.3	0	469.43	0
P. maderaspatensis	24.77	24.77	5.86	0	0.65	0	10.45	10.45	0	0
Plectranthus barbatus	0	2491.23	978.51	601.8	3036.36	0	817.12	0	0	0
P. igniaris	5314.41	2144.11	0	47.54	204.5	0	0		567.32	0
P. sylvestris	0	4704.46	390.08	357.45	0	0	0	0	0	0

Species	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
Polygala sphenoptera	4.29	20.79	0	11.84	0	0	0	0	0	0
Portulaca foliosa	0.54	0	2.48	32.28	0	0	0	0	105.43	0
Premna resinosa	2179.18	159265.95	25293.13	30876.77	22668.35	0	4039	3720.6	4193.8	0
Priva adhaerens	12.12	54.56	0	0	6.97	0	13.12	7.72	2.54	0
Pupalia luppacea	50.68	0	64.24	4.42	13.34	0	4.52	4.52	16.98	0
Rhus longipes	0	9103.57	2343.19	1457.08	14166.69	0	847.29		906.24	0
R. natalensis	29985.44	0	0	0	0	0	0	0	0	0
R. tenuinervis	0	0	0	4701.45	0	0	0	0	0	0
R. vulgaris	0	1265.49	0	1554.05	1273.84	0	0	0	32733	
Rhyncheltrum repens	17.85	17.85	118.59	55.06	0	17.85	86.49	0	17.76	136.02
Rotheca myricoides	2333	0	0	912.08	0	0	0	0	3159.5	0
Ruellia patula	35.64	224.93	112.38	111.77	25.45	14.57	0	0	12.09	0
Ruttya fruticosa	0	21221.6	6167.41	785.08	1391.47	0	0	0	0	0
Sanseveria sp.	0	0	1.38	7.03	0	0	0.25	0	0	0
Schrebbera alata	0	4799.42	1608.87	1783.24	1335.54	0	0	0	0	0
Senna siguena	0	876.2	0	2507.53	0	0	345.56	0	0	0
Sesamum angustifolia	3.4	7.69	4.32	8.54	3.91	0	2.75	2.75	5.86	112.64
Setaria verticulata	0	0	0	0	0	2.39	0	0	0	0
Sida ovata	4950	0	0	0	526.2	0	3.29	0	0.55	0
Solanum incanum	8331.04	1484.95	389.6	204.26	2948.8	0	334.07	87.54	15.14	0
S. renchii	0	1790.78	711.3	0	1977.49	239.21	273.91	0	487.43	0
Sphaeranthus ukambense	2.25	0	0	0	0	2.25	1.25	1.25	0	0
Sporobolus pyramidalis	17.69	13.97	58.51	0	259.76	0	168.19	0	0	58.06
Steganotaenia araliacea	3291.89	3291.89	2950.53	11845.44	3884.31	0	3419.9	0	0	0
Sterculia africana	0	2706.33	0	2990.18	41915.15	0	0	0	0	0
Striga asiatica	0	10.3	0	0	0	0	0	0	0	0
Styrosanthes fruticosa	0	0	11.09	0	0.48	0	14.07	7.31	7.74	0

Species	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
Talinum portulacifolium	0	0	0	0	8.54	0	18.54	18.54	0	0
Teclea nobilis	266.25	5595.55	23.55	5502.14	5832.78	625.73	0	0	0	0
Tennantia sennii	0	453.23	0	3600.21	0	0	365.69	0	0	0
Tephrosia noctifolia	31.91	0	13.29	0	8.87	0	0	0	13.3	17.92
T. pumila	1.23	3973.2	1279.86	0	4305.49	0	0	0	10.06	0
T. submolis	7.92	4.88	9.05	0	3.36	0	10.64	4.21	30.38	0
Terminalia brownii	5634.69	5634.69	40259.66	12880.06	5066.39	0	3474.7	0	0	0
Tetrapogon villosus	46.26	0	0	92.48	0	0	0	0	0	0
Themeda triandra	4.69	39.65	0	10.71	29.3	0	33.63	8.08	26.33	0
Thunbergia alata	101.64	101.64	25.45	2.45	0	0	0	0	0	0
T. holstii	824.87	824.87	308.11	297.76	147.21	0	0	0	15.54	0
Thylachium africanum	0	7425.94	356.722	0	0	0	0	0	0	0
Tinnea aethiopica	2238.26	15124.29	6056.44	4508.28	448.28	0	0	0	143.29	0
Tridax procumbens	3.37	0.84	0	0	0	0	0	0	0	19.56
Triumfetta tomentosa	43.44	3913.6	19.85	24.42	0	0	836.28	0	0	0
Vernonia fischeri	0	12429.87	0	0	0	0	0	0	0	0
V. galamensis	0	12.38	0	0	0	0	12.38	0	20.16	0
Vigna sp.	0	444.17	111.72	3.08	0	0	0	0	0	0
Vitex strickeri	0	16173.16	4279.94	3426.64	8996.49	0	0	0	0	0
Walenbergia scotii	1.48	25.75	50.45	12.48	32.93	0	0	0	2.41	0
Waltheria indica	55.11	0	0	10.05	119.54	0	48.89	31.03	1948.8	0
Withania somnifera	0	0	12.59	0	0	0	0	0	0	0
Ximenia americana	1543.12	5345.91	1968.11	4431.63	3607.56	0	0	0	3141	0
Zanthoxylum chalybeum	0	0	0	0	61658.65	0	0	0	0	0
Zornia setosa	15.58	220.89	0	11.36	8.49	29	136.49	21.15	27.16	37.37

Appendix 5. Biomass of herbaceous species in the different community types identified

				Community types						
Species	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
Abutilon hirtum	0	0	28.07	19.36	6.26	813.5	0	1668.36	31.98	0
A. mauritianum	0	0	4.66	0	0	0	0.32	0	0	3.56
Acanthaceaea	0	0	0	0	0	0	5.36	0	0	0
Acanthosperma hispidum	0	0	0	166.42	0	28.05	0	104.62	104.62	0
Acanthus sp.	0	0	0.46	0	0	0.43	0	0	0	0
Achyranthes aspera	3.21	0	0	31.83	0	10.86	0	47.22	11.84	0
Actiniopteris semiflabellata	1.96	0	4.77	1.05	3.67	6.74	0	0	0.43	0
Aerva javanica	0	0	0	0	0	15.06	0	0	0	0
Alternanthera pagens	0	0	0	16.48	0	0	0	0	0	0
Aneilema johnstonii	0	0	9.08	0	0	0	0	0	0	0
Aneilema sp	37.29	0	0	0	40.51	0	0	0	0	0
Arsitida adscensionis	205.49	36.97	115.97	0	45.54	0	35	0	63.56	14.44
Asparagus racemosa	1.98	0.4	60.8	0	0	0	0.54	0.43	0	0
A. setaceus	8.56	0	55.12	112.78	13.12	549.3	28.17	0	0	0
Asystacia laticapsula	9.75	0	0	0	0	4.92	0	0	0	0
A. verticillata	19.15	0	291.1	2.52	0	33.45	0	73.59	0	0
Barleria acanthoides	20.23	1.48	23.3	38.14	45.99	123.51	0	12.57	17.8	0
B. alisinoides	0	0	24.91	0	0	0	0	0	0	0
Becium obovatum	31.55	104.58	107.41	0	0	566.78	0	0	34.64	2.62
Bidens pilosa	3.48	0	0	66.5	0	36.62	0	0	0	0
Blepharis maderaspatensis	3.56	0	85.07	60.84	4.26	8.32	1.45	0	16.67	0
Boerhavia diffusa	1.9	0	0	2.48	0	0	0	0	0	0
Bothriochloa insculpta	12.24	552.6	24.55	0	0	109.55	0	0	0	0

Species	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
Bothriocline somalenis	0	0	0	0	0	0	0	0	0	14.83
Bracharia reptans	4.56	0	0	134.54	0	0	33.7	0	0	0
Cassia mimosoides	19.23	0	47.05	0	46.24	92.6	0	0	2.71	0
Celosia schweinfurthii	0	0	0.54	0	0	0	0	0	0	0
Cenchrus ciliaris	665.52	101.54	95.37	95.37	29.08	32.58	0	0	108.42	0
Chasmanthera repens	0	0	4.39	0	0	0	0	0	0	0
Cheilanthes inequalis	0	1.44	0	0	47.28	2.93	0	0	0	0
Chloris gayanus	0	14.13	54.64	107.15	14.13	21.89	3.42	0	0	0
C. roxburgiana	0	39.45	42.9	0	0	16.85	0	0	0	0
Chloris sp.	2.37	0	39.27	0	10.1	0	0	0.54	26.85	0
Cissampelous mucronata	12.33	23.54	56.73	0	31.79	0	0	0	0	0
C. pareira	0	0	2.87	8.54	63.4	8.47	0	0	11.14	2.69
Cissus quadrigularis	88.44	0	1360.29	235.87	0	301.96	75.41	0	26.61	0
C. rotundifolia	5.67	12.65	0	0	970.93	105.65	0	0	0	0
Cleome sp.	0	0	0	0	59.2	0	0	0	0	0
Commelina benghalensis	7.23	0	0	163.86	20.53	160.18	0	0	0	0
C. erecta	2.9	6.65	15.66	0	0	5.5	9.28	0	0	0
C. latifolia	3.8	0	11.2	12.87	0	29.1	0	75.23	42.08	0
Commicarpus plumbagineus	0	0	0	0.4	3.93	0	0	0	0	0
Conchrus triloquralis	0.45	0	0	0	0	0	0	0	0	0
Crabbea velutina	19.59	0	194.15	8.54	70.45	28.94	0	36.99	0	0
Crossandra nilotica	0	0	12.43	0	0	0	0	0	0	0
Crotalaria sp.	34.09	0	50.54	68.77	55.51	0	0	0	91.11	0
Cynodon dactylon	0	89.31	0	65.3	0	0	330.71	0	0	0
Cyphostema sp	22.95	0	0	0	150.36	280.32	1261.49	0	0	0
Dactylotenium sp.	0	0	24.06	23.3		24.06	0	0	0	0
Desmodium sp	0	7.98	0	0	0	17.92	0	0	467.58	0

Species	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
Digitaria macroblephara	0	0	6.65	0	0	0	0	0	1.27	0
Duosperma sp.	5.49	0	3.21	0	1.51	0	0	0	0	0
Dychoriste radicans	0	0	1.39	0	0	4.45	0	0	0	0
Edithcolea glandis	0.38	0	3.98	0	0	0	0	0	0	0
Endostemum tereticaulis	46.79		71.83	0	0	0	0	0	23.76	0
Enteropogon macrostachys		10.94	16.13	57.71	108.89	143.5	50.19	10.86	0	0
Eragrostis ciliaris	961.57	961.57	197.75	0	0	170.66	110.06	76.12	0	0
E. superba	52.02	12.78	169.31	10.56	0.48	186.26	34.26	29.26	0	35.45
Euphorbia hirta	0.98	0	0	0	0	16.54	0	0	0	0
Evolvulus alisinoides	2.48	41.76	38.42	0	0	26.17	0	0	4.72	1.29
Fimbriostylis dichotoma	87.65	89.36	41.32	0	0	0	3.65	0	0	0
Geniosporom viridis	0	0	38.44	0	0	0	0	0	0	0
Geranium sp	0	1.14	0	0	0	0	0	0	0	0
Grass mat	408.57	37.87	52.87	6.88	50.34	0	0	0	0	0
Helichrysum globosum	5.49	3.97	0	0	0	0	0	0	0	0.43
Helinus integrifolia	0	0	0.54	0	2.76	0	0	0	0	0
Heliotropium steudneri	2.54	0		0	0	46.4	0	0	0	0
H. strigosa	0	0	0	0	0	0	24.25	25.21	0.81	0
Hermannia exappendiculata	13.14	0	90.21	66.5	36.18	187.93	0	7.56	0	0
Heteropogon contortus	0	135.3	0	0	29.26	15.31	100.42	0	0	0
Hibiscus calyophyllus	0	6.15	0	32.12	4.38	0	0	13.65	0	0
Hibiscus calyophyllus	0	0	0	32.12	4.38	0	0	1.1	0	0
H. meyeri	3.04	151.23	31.56	143.98	89.04	2154.11	0	286.32	0	0
H. micrantha	43.93	15.89	18.86		129.46	0	0	0	0.92	0
Hibiscus sp.	0	0	1.75		0	4.11	0	0	0	0
H. vitifolius	9.42	0	0	0	0	2298	1076.26	0	0.49	0
Hirpicium diffusum	0	0	4.39	0	0	0	0	0	0	0

Species	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
Hyptus sp.	1.16	0	0	0	0	0	0	0	0	0
Indigofera lupatana	7.94	38.34	72.14	0	170.86	0	43.13	18.54	0	12.45
I. schimperi	12.43	7.57	0	0	0	0	7.57	0	0	12.43
Indigofera sp.	5.98	4.3	15.65	0	10.1	36.07	0	0	0	0
Ipomoea arachnosperma	32.87	0	0	0	0	2.65	0	0	0.65	0
I. gaegeri	0	0	24.2	0	0	0	42.18	0	0	0
I. kituensis	0.64	167.26	3230.76	0	12.36	106.48	0	103.87	0	0
I. wightii	0	0	0	0	0	0	8.34	0	0	0
Isoglossa laxa	12.54	0	41.82	4.67	0	4.02	11.44	0	0	0
Jasminum sp.	0	0	15.47	6.78	0	0	0	0	0	0
Justicia matammensis	9.76	0	0	0	10.81	40.71	16.73	7.31	3.87	0
J. uncinulata	2.69	0	0	0	0	52.93	0.47	0	0	0
Kalanchoe sp.	4.54	0	0	0	0	0	0	0	0	0
Kedrostis sp.	3.29	0	0	0	0.42	0	0	0.39	1.07	0
Klenia klenoides	300.88	121.34	26.41	2.49	9.17	0	48.43	0	0	1.48
Kyllinga erecta	7.54	0	0	0	0	32.21	0	0	0	0
Leucas grandis	0	0	10.32	0	0	3.45	0	0	0	0
L. mollis	0	0	0	0	0	33.31	0	0	0	0
Melhania ovata	14.55	0	25.91	130.54	1.23	110.9	8.98	0	2.2	0
M. velutina	47.96	0	7.81	0	31.95	16.43	50.17	22.78	21.14	0
Meremia amelophylla	0	0	12.09	0	0	0	0	0	0	0
Microchloa kunthii	11.49	21.93	0	0.47	0	0	0	1.74	0	0
Mucuna gigantea	0	4.05	0	0	0	0	0	0	15.15	0
Mundania simplex	0	0	50.89	0	0	0	0	0	0	0
Neuracanthus tereticaulis	22.35	0	33.61	0	24.57	4.28	0	0	42.99	0
Ocimum basilicum	36.84	0	16.5	4.37	1.72	76.61	28.9	98.25	0	0
Oldenlandia caesapritosa	8.1	42.81	20.2	14.19	0	0	3.63	6.62	5.76	5.68

Species	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
Orobanche sp.	0	0	0	0	0	0	0	0.48	0	0
Orthosiphon suffrutescens	0	0	0	0	0	0	0	6.03	0	0
Otomeria oculata	0	0	0.85	0	0	0	5.45	0	0	0
Oxygonum simatum	0	0	32.8	0	0	0	4.83	0	3.68	0
Panicum maxima	57.77	0	0	0	30.41	109.35	0	197.6	0	44.56
Pavonia arabicum	70.95	0	0	0	70.95	7767.2	0	0	0	0
P. patens	2.48	15.65	0	0	0.7	0	0	0	0	6.54
Pennisetum schimperi	0	0	21.15	0	0	0	0	0	0	0
Peristrope sp.	0.58	0	0	0	0	0	0	0	0	0
Phyranthus malvacea	0.32	0	0.32	20.21	0	88.15	0	5.69	0	0
Polygala sphenoptera	16.13	0	20.79	0	0	0	0	0	0	0
Portulaca foliosa	0.54	0	0	2.48	0	105.43	0	0	0	0
Priva adhaerens	13.76	22.31	38.3	0.58	0	0	0	0	0	0
Pupalia luppacea	24.84	0	1.48	64.24	4.52	0	24.46	0	0	1.38
Rhyncheltrum repens	23.43	136.69	13.78	0	0	222.17	17.85	0	0	0
Ruellia patula	22.15		51.23	21.01	37.82	53.21	52.74	17.56	2.79	0
Sanseveria sp.	0.52	0	0	0	6.51	0	0	0	0	0.25
Setaria verticulata	0	0	0	0	2.39	0	0	0	0	0
Sida ovata	5.78	0	0	0	0	0	0	0	5476.75	0
Sphaeranthus ukambense	0	0	0	0	0	0	0	1.25	0	0
Sporobolus pyramidalis	0	443.08	13.97	0	0	58.06	0	0	61.07	0
Striga asiatica	0	0	0	0	0	10.3	0	0	0	0
Styrosanthes fruticosa	7.11	0	0	0	0	0	11.67	7.79	0	0
Talinum portulacifolium	0	0	18.54	0	0	0	0	0	8.54	0
Tephrosia noctifolia	0	26.59	0	0	0	17.92	9.01		22.9	0
T. pumila	0	3.55	3.61	4883.5	5.1	10.06	0	0	0.54	0
T. submolis	6.43	0	41.66	0	4.21	0	0	0	4.88	0

Species	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
Tetrapogon villosus	0	0	138.74	0	0	0	0	0	0	0
Themeda triandra	0	21.41	1.25	0	0	39.65	8.08	0	0	36.88
Thunbergia alata	0	0	0	0	8.56	0	0	0	0	0
Tridax procumbens	2.11	0	0	0	0	19.56	0	2.1	0	0
Vernonia galamensis	24.76	0	0	0	0	10.08	0	0	0	0
Vigna sp.	9.66	0	231.53	111.72	0	0	0	0	0	0
Walenbergia scotii	2.41	0	25.75	0	0	0	50.45	12.48	0	1.48
Waltheria indica	0	2082.04	11.88	0	0	0	48.63	0	28.75	11.09
Withania somnifera	0	0	0	0	0	12.59	0	0	0	0
Zornia setosa	75.19	0	153.66	0	0.29	37.37	0	29.02	2.16	2.28