LUCID's Land Use Change Analysis as an Approach
for Investigating Biodiversity Loss and Land Degradation Project

Influence of Land Use Patterns on Diversity, Distribution and Abundance of Small Mammals in Gachoka Division, Mbeere District, Kenya

LUCID Working Paper Series Number: 8

by

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October 2002

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The Land Use Change, Impacts and Dynamics Project

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ABSTRACT[1]

This study was conducted in Gachoka division of Mbeere district Kenya, between the months of September and December year 2001. The aim of the study was to establish how patterns of land use influences the diversity, distribution and abundance of small mammals. The study also sought to determine how land use practice influences habitat conditions by identifying indicator species that characterize different habitats. Various habitat factors, namely: vegetation diversity and composition of plant species, percentage vegetation cover, burrows, mounds and hedge fences, all of which influence diversity, distribution and abundance of small mammals were measured in various land use types in Mbeere district.

Data on rodent abundance was collected through rodent captures on square grids of 64 live traps, set out over an area of 70m x 70m. Traps were positioned at 10m intervals, following the methods of Delany & Roberts (1978) and Cheeseman & Delany (1979). All sampled rodents were identified to species level. Data on vegetation parameters was obtained through a habitat survey conducted using belt transect method. The number and composition of woody plant species, number of burrows, mounds and hedge fence were estimated in each transect. Grass species composition, percentage cover and soil depth were measured in 1m by 1m quadrants placed at 10 meter intervals along a transect line. The area sampled for habitat parameters corresponded with trapping points of small mammals. A total area of 840 square meters was covered in each habitat.

A total of 213 rodents comprising of five species of Murids were recorded. Three species namely, *Lemniscomys barbarus, Otomys thomasi* and *Acomys percivalis* were the most abundant with percentage abundance values of 35.6%, 35.2% and 16.4% of total captures respectively. Burrows were found to occur more frequently near the hedge fences in cultivated areas while burrows were situated under trees and shrubs alongside mounds in uncultivated (fallow and bushy grassland) sites. Distribution of mounds was associated with distribution of woody plants. However, no relationship between mounds or burrows to particular species of plants was distinguished although both tended to occur less frequently under trees than shrubs. Unlike burrows, vegetation cover related to abundance of rodent species.

The diversity and distribution of species of rodents were found to correlate with microhabitat parameters occurring in sites with different land use. Bushy grassland and fallow sites provided greater diversity of plant and small mammal species than cultivated and grazed lands. Abundance of *Lemniscomys* and *acomys* species was found to be greatest in uncultivated (bushy and fallow) sites, while *Otomys* species was dominant in cultivated and grazing sites. The fallow land, which is considered intermediate between cultivated and bushy sites (based on measured habitat parameters), had the highest diversity of both plants and small mammal species. This site hosted at least all of the five species of rodents in varying proportions. The rodent species composition in Mbeere was found to be comparable to that of other semi-arid areas in East, Central and part of Southern Africa, 15^0 N and S of equator.

[1] This report is derived from a M.Sc. thesis by the author from the University of Nairobi Department of Zoology.

CHAPTER ONE: INTRODUCTION, STUDY AIM AND SPECIFIC OBJECTIVES

1.1 INTRODUCTION

The term land use refers to two aspects of habitat condition; it includes the patterns of actual use of land (immediate activities that change habitat conditions) as well as the ecological consequences of these activities to both fauna and flora. It is commonly assumed that opportunistic species particularly pests would increase with increased agricultural activities and deteriorating habitat conditions while specialized non-pest species decreases (Primack, 1993). However, different studies on distributional behaviour of small mammals have observed conflicting results where species considered opportunistic are also observed to decrease alongside land use (Gilpin, *et al.,* 1982). Although there is a general consensus that diversity of species decrease in such sites, it is no longer sufficient to assume a simple correspondence between patterns of land use to diversity and distribution of flora and fauna, particularly that of small mammals. That link must be studied explicitly to advance our understanding of coping behaviour, variable survival strategies and selection (Donn & Lifjeld, 1994). When the research subjects are small mammals, their biology make it even more imperative to measure diversity and distribution rather than infer it.

Loss of habitat is one of the primary threats of maintaining biological diversity (Harris, 1984; Wilcox and Murphy, 1985). Isolation and diminishing size of remaining habitats increases the probability of extinction through demographic, environmental or genetic stochasticity (Wiens, 1976; Harris, 1984; Soulé, 1986; Goodman, 1987; Aden, 1994; Wilcove *et al.*; Noss & Cooperrider, 1994). A major cause of loss and modification of these habitats is land use practice and has increasingly been implicated in declining biodiversity in recent decades (Soul'e, 1991). Direct loss of species from land varying in use may result from altered habitat conditions or may occur indirectly when animals move out into remaining habitats, where competition for resources is likely to intensify.

There is a growing realization that ecological consequence of land use on a wide range of habitats has direct influence on the diversity and distribution of vertebrate species such as reptiles (Kool, 1990), birds (Fuller *et al.*, 1985; Wiens & Rotenberry, 1985; Hill *et al.*, 1991; Lauga & Joachim, 1992), and mammals (McAthur & Pianka, 1966; Struhsaker 1975; Chanov, 1976; Clutton-Brock *et al.*, 1977; Wrangham, 1980; Crompton, 1984; Harcourt, 1986; Boinski, 1987; Chapman and Chapman, 1990; Spencer *et al.*, 1990; Remis, 1997). Like other animals, small mammals must obtain sufficient energy, nutrients and vitamins and escape predators to survive and reproduce. Their patterns of distribution may thus be influenced by the distribution and abundance of habitat resources. Food (Bennett, 1986), location of burrows (Davies, 1984; Ajayi, & Tewe, 1978), interaction between conspecifics (Sekulic, 1982) territoriality (Whitten, 1982) and weather conditions (Isbell, 1983) are some of these factors. Ajayi (1977) observed that the distribution of African giant rat (*Cricetomys gambianus*) was strongly influenced by occurrence of burrows in its environment. Other studies have reported correlations of varying extent between habitat condition and distribution of species. In birds (Wiens & Rotenberry, 1985; Lauga & Joachim, 1992), vertical distribution of sympatric species was observed to correspond with canopy strata while in primates distribution and abundance of resources explained group densities (Kingdon, 1974; Struhsaker, 1981; Hamilton, 1982; Cords, 1987; Butynski, 1990). Since rodents are faced with an array of potential habitats and must select which ones to use, their choice may depend on physical and chemical characteristics of the habitat itself, food availability and the species in question (Kincaid & Cameron, 1985; Odhiambo, 2000). As the abundance of preferred habitat decreases, less preferred habitat is taken up from the environment in accordance with the resource optimization hypothesis (Hilbert *et al.*, 1981). However, there is often a wide overlap in the distribution of resources used by different species (Maarel & Titlyanova, 1989). On the other hand, the choice of habitat by species is not always pegged to a particular habitat attribute, so that a species may be present in widely varying habitats. Consequently, the overall diversity and distribution of rodent species may vary markedly across sites under varying land uses.

Surveys on distribution of population of small mammals demonstrate that patterns of population change associated with the disturbance of habitat are complex and difficult to assess since the specific requirements of most species cannot largely be emphasized in detail (Hooven & Black, 1976). This is because data concerning the unknown variables are often missing (Odhiambo, 2000). A major cause of loss of species is the alteration of the ecosystems in which they live. Such changes influence the behaviour of small mammals, particularly their numbers, distributions and population dynamics. One category of mammals that is likely to respond to changing habitats is rodents (Cheeseman, 1977; Neal, 1984). While variation in food types, activity patterns and dispersion in response to resources have been reported, few researchers have attempted to assess quantitatively the effects of land use patterns on the behaviour of small mammal species. Monadjem (1997) studied the distribution of small mammals over a wide geographical range. He did not measure resource abundance but assumed it would decrease in dryer climates. Although this assumption is probably correct, it is still imperative that resource abundance be measured in order to understand precisely its empirical influence on behaviour of small mammals.

1.1.1 Influence of habitat alteration on ecology of small mammals

Habitat factors have pervasive effects on behaviour and spatial organization of organisms (Crook, 1970; Altmann & Altmann, 1970; Kummer, 1971; Wrangham, 1993), and are believed to be key factors determining the richness of small mammal communities and the abundance of particular species (Bourliere, 1975; Oates *et al.*, 1990; Davies, 1994; Reed & Fleagle, 1995). Recent studies have examined variability in patterns of distribution and abundance of small mammals and the extent to which flexibility occur in relation to habitat characteristics. For example, alteration in site fidelity in adult cotton rats occurred when food plants were more widely dispersed (Spencer *et al.*, 1990), less abundant (Radolph & Cameron, *unpub.*), or of poor nutritional quality (Radolph *et al.*, in press). Monadjem (1997) indicated that both biomass and diversity of small mammals correlated positively with vegetation density particularly in tall grasslands. Neal (1984) and Martin (1985) observed seasonal variation in numbers of small mammal species and that species distribution correlated with different microhabitat parameters. Other investigators (Brambell & Davis, 1945; Chapman, Chapman & Robertson, 1959; Coetze, 1965; Delany and Neal, 1969; Sheppe, 1972; Taylor and Green, 1976; Neal, 1977; Cheeseman & Delany, 1979; Swanepoel, 1980; and Chidumayo, 1984) reported similar observations while Ajayi (1978) noted a correlation between location of burrows with physical and chemical characteristics of soil. However, Martin (1985) argues that neither food nor microhabitat partitioning completely explained the coexistence of small mammal species and suggests that populations are highly transient, moving from refuge areas into temporarily favourable areas.

A major component in human land use is habitat alteration and fragmentation, the process of modifying and subdividing a continuous habitat into smaller patches. This process also occurs in natural systems through fire (Wright, 1974; Pickett & Thompson, 1978), windfall (Foster, 1980), flood and volcanicity (Eldredge, 1998). However, the most important and large-scale cause of habitat modification is the expansion and intensification of land use by humans (Burgess & Sharpe, 1981; Adren, 1994).

Ecologists have long been aware that species ecology may not be a fixed attribute, so that two groups or populations of the same species may show differences in some aspects of their ecology or behaviour even within the same habitat. However, persistent variation in population structure of small mammal communities on a site subjected to myriad land uses, suggests a disruption of ecological balance. Loss of original habitat, reduction in size of habitat patch and increasing isolation of habitat (Wilcox, 1980; Wilcox & Murphy, 1985; Adren, 1994) are major ecological consequences of human land use that culminate in alteration of population dynamics of small mammal species.

A wide range of studies provides evidence that the distribution of ecological resources is important in determining diversity and distribution patterns of mammals (McAthur & Pianka, 1966; Struhsaker 1975; Chanov, 1976; Clutton-Brock *et al.*, 1977; Wrangham, 1980; Crompton, 1984; Harcourt, 1986;

Boinski, 1987; Chapman and Chapman, 1990; Spencer *et al.*, 1990; Remis, 1997). Other works demonstrate that habitat structure determines dispersion amongst small mammals (Rosenzweig & Winkur, 1960; Neal, 1984), primates (Harrison, 1983), birds (MacArthur & MacArthur, 1961; Pianka, 1967), desert lizards (Rosenzweig & Winkur, 1960).

The existence of intra- and inter- specific variation in small mammal distribution raises several questions. What factors lead to these variations? Is the observed variation the result of natural and/or anthropogenic ecological constraints in the habitats that different populations live in, or of genetic differences or of socially learned traditions?

Many studies of terrestrial vertebrates have shown that habitat characteristics are important in regulating diversity of species and population size. Plant and animal species tend to be sensitive to the quality of their habitats (Rosenzweig & Winakur, 1960; MacArthur & MacArthur, 1961; Pianka, 1967; Ajayi, 1974). For instance, burrows of giant rats are mostly located under objects such as roots of trees, piles of dead trees and stones to provide insulation against heat (Hill *et al.* 1955). However, other factors such as season and territoriality may have significant influence in the diversity and distribution of small mammals.

In view of the fact that most vertebrate species depend on terrestrial habitat (Wolfheim, 1983) and that most of this habitat is being fragmented into small-disturbed patches, the ability of mammals to survive in such areas are of great importance in formulating conservation strategies. Measure of habitat diversity reflects the degree of habitat suitability to numerous species of rodents. A major form of habitat alternation in Mbeere is replacement of natural vegetation by agricultural plots. Most biologists are aware that the survival of species is influenced by the size and conditions of their habitat (Bond *et al.*, 1988). Consequently, if large extensive areas of habitat become fragmented into small isolated parts, the local extinction of species may follow. Loss of species is perhaps due to either a combination of vegetation structural changes or lack of connectedness of remnant fragments between managed lands.

1.1.2 Taxonomy and Diversity of Rodents

Rodents range in size from the crested porcupine (Hystrix cristate) weighing 20 kg to the small African pigmy mouse (*Mus minutoides*) weighing only 5g. The order Rodentia is arguably the most diverse taxonomic group in the class of mammals and represents about 40% of all mammal species (Kingdon, 1997). More than 28 families, 330 to 443 genera and 1800 to 2300 species, have been described (Bourlere, 1975; Hartenberger 1985; Wilson and Reader 1993; Fiedler 1994; Cole and Wilson, 1996). Cole and Wilson (1996) put the number of rodent species to be 2,015, which is more that twice the 925 species described for the next largest order, Chiroptera. This is reflected by the fact that Rodentia is represented by 28 families and 8443 genera compared to the 17 families and 177 genera in Chiroptera. Both orders occur naturally on all major landmasses except the Antarctica.

1.1.3 Global Distribution of Rodents

Rodents occupy a wide range of habitats ranging from arid savanna grasslands to wetlands, scrubland to secondary and primary forests (Delany 1974; Kingdon, 1974; Nel & Rautenbach, 1975; Nel, 1978). The species are widely distributed over different parts of the world with different continents being endowed with different genera and families. The success of this group is due in part to its adaptability to new food sources and habitats, and its relatively brief reproductive cycles (Grzimek, 1991).

The genus Apodemus, Clethrionomys and Microtus are widespread and common in Europe while the genus Dipodomys, Microdipodops and Cynomys are found in North America. Dormice, for example *Muscardinus avellanarius* and *Typhlomys cinereus* are well represented in Europe and Asia. *Praomys* is one of the commonest and most widespread rodents in Africa and is known to flourish on land that has been recently burned or cultivated. Similarly the genus *Cricetomys* is typically African (Delany, 1974; Martin, 1984; Ajayi, 1980). Africa has about 89 genera and 290 species of rodents belonging to 14 families. A number of rodent species have been reported to be edemic to different areas. For instance Odhiambo (2000) describes *praomys taitae* as endemic species in the Taita hills in Kenya.

East Africa contains about 62 genera and 101 species found in 12 of the 14 rodent families found in Africa (Fiedler, 1994). The three major rodents divisions; squirrel forms (Sciuromorphs), porcupine form (Hystricomorph) and rat forms (Myomorphs), have distinctly different arrangements of chewing muscles, orbits and teeth. The anomalures, springhares and blesmols are ancient African groups that are so specialized that their affinities with the three main rodent groups remain unclear.

In general, comparison between rodent distributions in different continents is difficult due to the fact that many tropical areas are not adequately sampled (Seldon *et al.,* 1996). The most critical factors that have been found to influence their distribution are thought to be the food and shelter (Cooney *et al.,* 1982). However, though some species are opportunistic and others appear to have specialized diets, food availability may be a limiting factor for majority of rodent species.

Relatively little is known of the factors that determine the distribution and abundance of small mammals in tropical grassland although the habitats often support a rich and varied assemblage of small mammals compared to the temperate (Kingdon, 1974; Delany, 1975; Delany & Happold, 1979; Soddart, 1979). Although many species are herbivorous, majority appears to be omnivorous and opportunistic (Cheeseman, 1975; Cheeseman & Delany, 1979; Delany & Happold, 1979). However, resource partitioning occurs in relation to microhabitats rather than food (Christian, 1980; Meserve, 1981).

1.1.4 Conceptual Framework of the Study

Measuring habitat factors in relation to patterns of land use is critical in understanding their ecological consequence on demography of small mammals. Data on habitat factors enable us to monitor changes occurring as a result of anthropogenic influence and the impacts these changes have on population dynamics of both plant and animal communities living there. Understanding the consequence of land use on habitat quality help ecologists to determine if the diversity and distribution of particular species is affected or threatened as predicted by population models. In theory, animals optimize utilization of resources and will select those habitats whose resource base is wide (Pyke, 1984). According to the marginal value theorem, a species will leave a given habitat when critical resources drop to the average for that habitat for non-gregarious and non-migratory species this change may be gradual such that the number of individual animals decrease as resources diminish (Charnov, 1976).

Population studies of small mammals particularly rodents, play a key role in enhancing our understanding of population dynamics in general and providing a testing ground for hypothesis about population processes. The critical importance of examining rodent population dynamics in this study is to understand aspects of human land use practices with direct or indirect bearing on populations of small mammals, some of which are important agricultural pests and vectors of diseases to humans (Krebs, 1998).

Data on habitat factors also provide a basis for assessing whether observed population pattern is actually regulated by these environmental factors (Hamilton, 1985). Deaths and low density of some small mammal population are reported to coincide with severe conditions of habitat (Cheeseman, 1977; Neal, 1984). In order to compensate for fluctuating resources, some species of small mammals are reported to alter reproductive behaviour (Neal, 1984) or switch to alternative habitats of poor quality (Gurskey, 2000). Finally, measurement of habitat factors may provide critical information in designing conservation management plans for small mammals and other animals. One approach of assessing habitat quality is by determining densities of populations across the site. Distribution of burrows and vegetation cover are important aspects of habitat that may influence densities and distribution of small mammals (Ajayi & Tewe, 1978; Martin & Dickinson, 1985; Spencer *et al.*, 1990; Monadjem, 1997).

For instance, removal of vegetation cover through agricultural cultivation reduces the species diversity of small mammals (Ajayi, 1978).

In this study, information on diversity and distribution of small mammals was needed to understand how variation in land use patterns and subsequent distribution of habitat resources impacts on biodiversity. Many studies have investigated the diversity and distribution of small mammals (Delany, 1964; Delany & Neal, 1966; Neal, 1970; Cheeseman, 1977; Martin & Dickinson, 1985; Monadjem, 1997) but none of them has investigated the influence of land use., . In order to elucidate the extent of human influence, this study sought to establish the population size, diversity and distribution of small mammals in various habitats types under varying human influence and assess which of the measured habitat parameters strongly influence diversity of rodents.

Like in most other areas, rodents are an important component of the ecosystem in Mbeere District, Kenya. They are ecologically important in their feeding behaviour as herbivores, granivores and insectivores. They occupy a significant ecological position in the food chain, as they are an important source of food to a number of vertebrates including snakes, toads and birds of prey. In addition, they may be a potential source of proteins to humans (Ashford, 1970; Ajayi & Tewe, 1978; Fitzgibbon *et al.,* 1995). However, rodents compete for resources with human beings. Perhaps the importance of rodents as facultative pests arises from encroachment on their natural habitat by man.

The fact that the area is under intensive agriculture whose expansion threatens future biodiversity conservation makes knowledge of small mammal species composition, diversity and ecology important. The results can then be used in understanding the general ecological influence of land use patterns on species of small mammals and other animals in general in the long term planning, conservation and management of Mbeere district as well as other semi-arid regions in East Africa. Currently, no comprehensive ecological data exists on the effects of land use particularly on species of small mammals.

1.2 STUDY AIM AND SPECIFIC OBJECTIVES

This study aims at obtaining an accurate understanding of the species composition, diversity, and distribution of small mammals. It also seeks to contribute to the development of management plans for the area and its environs. The study addresses several questions. First, how do habitat factors influencing the composition and distribution of small mammals vary with land cover types in the study areas? And second, how does each or a combination of such habitat factors influence diversity, distribution and abundance of small mammal species in the site of study?

The specific objectives of this study were:

(i) To determine the diversity and abundance of small mammals in Mbeere district, Kenya.
(ii) To determine microhabitat factors in the major land use types in the study area.
(iii) To establish how land use factors influence diversity, distribution and abundance of small mammals.

HYPOTHESES

(i) The population of small mammals in the study area is affected negatively by the intensity of cultivation and grazing activities there.
(ii) The frequency of habitat variables i.e. barrows, mounds, trees/shrubs, plant species and grass cover in the study site varies with intensity of land use.
(iii) Diversity of plants and small mammal species decreases with intensity of land use.
(iv) Diversity of rodent species in the site of study correlates with the diversity plant of species.

CHAPTER TWO: STUDY AREA AND THE STUDY SPECIES

2.1 STUDY AREA

2.1.1 Location and Climate

This study was conducted in Gachoka division, Mbeere district, Kenya (Figure 1a, b & c.). Gachoka division, latitude $0^0$20' and $0^0$50'S and longitudes $37^0$16' and $37^0$56'E, is one of the four divisions forming Mbeere district which is located in the Kenyan Eastern province. Its altitude ranges from 570m to 1560m above sea level and is largely semi-arid like the rest of the district.

Rainfall is bi-modal in distribution with long rain from March to June, and short rains between October to December. Average rainfall in the region varies between 550 and 1100 mm annually and is highly unpredictable. Most parts receive less than 600 mm of rainfall per year giving the area its marginal status. Mean monthly temperature ranges between 20^0C and 32^0C. August is usually the coldest month whereas March is the hottest month (GoK, 1997).

2.1.2 Agro-Ecological Zones

Two main agro-ecological zones cover the study area, the marginal cotton zone (LM4) and lower midland livestock millet zone (LM5). The marginal cotton zone corresponds to the transitional zone from semi humid to semi arid zone. It rises 980-1130 meters above seal level and rainfall ranges between 800-900 millimeters per annum. The lower midland livestock millet zone presents the semi arid area. The zone rises 830-1130 meters above seal level. Rainfall ranges between 700-800 millimeters per annum.

2.1.3 Topography and Drainage

The area slopes in a northwest to the southeast direction. The slope is however broken by existence of Kianjiru and Kiambere hills, which raises 1560 and 1525 meters above sea level respectively. The lowest part is the Tana valley that falls below 600 meters, reaching its lowest point at the confluence of Tana and Mutonga Rivers at approximately 570 meters. The area is characterized by rugged topography, which is pronounced by low resistance of the sandy soils to water, coupled with overgrazing of livestock. Gulleys, resistant rocks and soil outcrops are a common feature, left outstanding on the bare white earth (Njeru, 1978).

Numerous seasonal streams drain into Tana, Thiba and Rupingazi, which are perennial rivers. The most important of seasonal rivers are Itabua, Nguu and Thura. A number of springs along the foothills of Kianjiru and Kiambere hills also occur (Figure 3).

2.1.4 Soils and Geology

Influence of altitude and climate on the nature of underlying geology has given rise to varying soil type, which generally impact on land use patterns. The soils have been derived through exfoliation and are generally sandy, stony and shallow. Where rainfall is higher, soils are very friable and porous and have high infiltration capacity .

Figure 1.1. Embu and Mbeere Districts in the national context

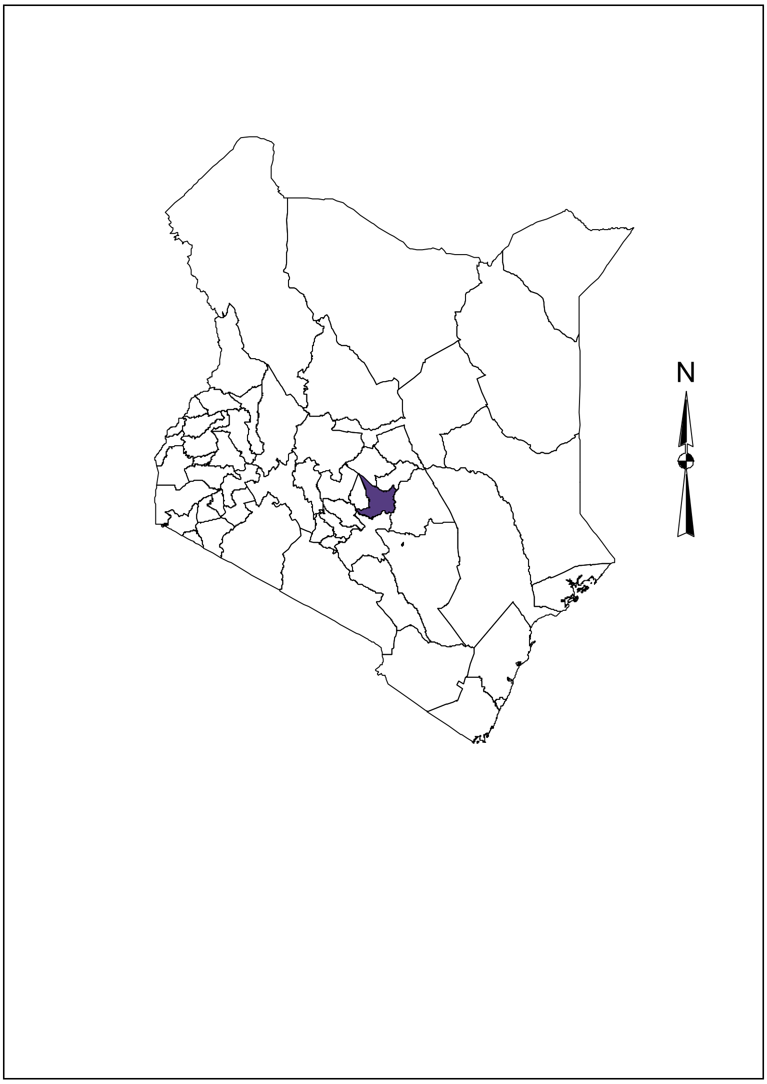


Figure 1.2. Study area and its environs: Administrative and regional settings

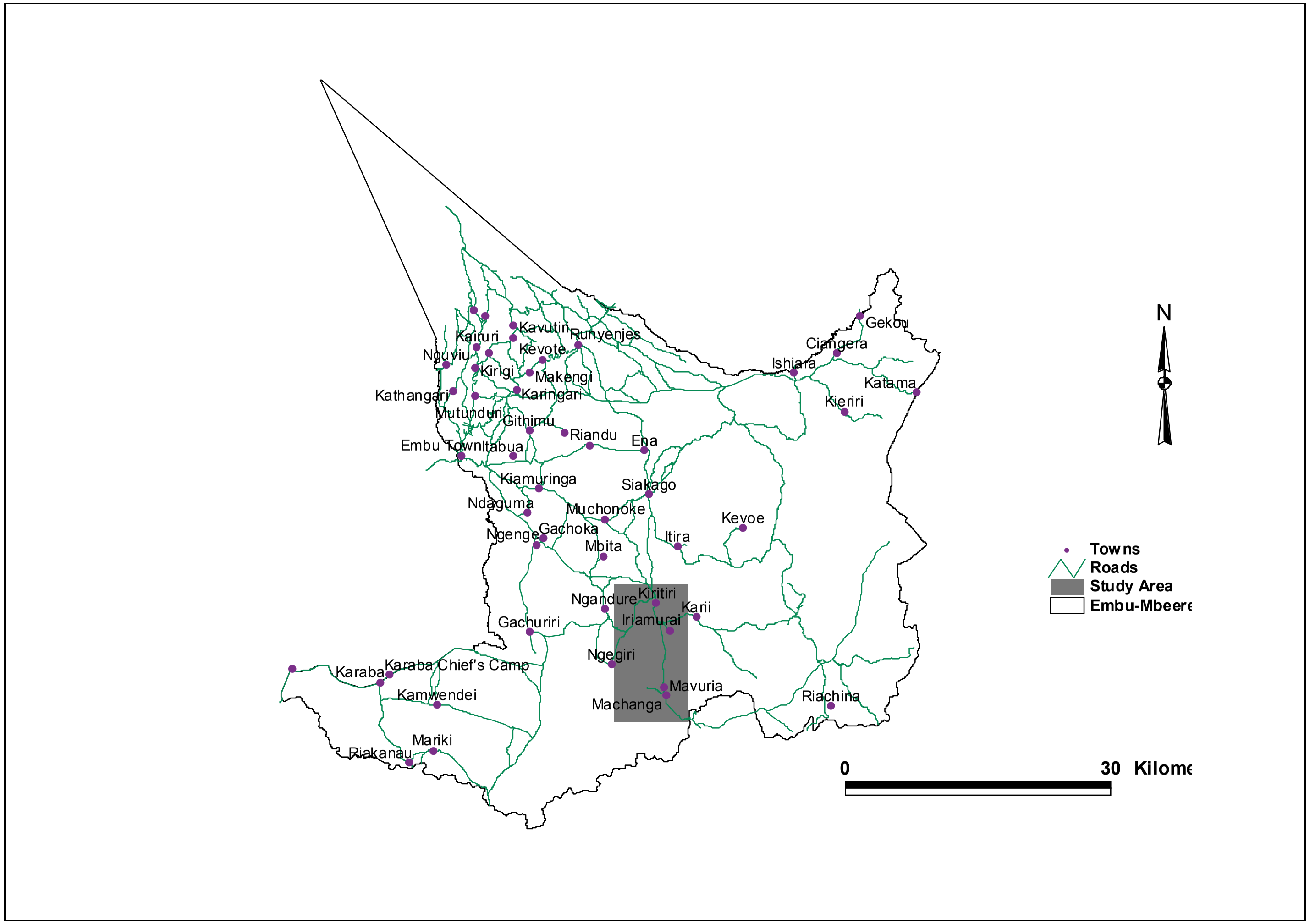
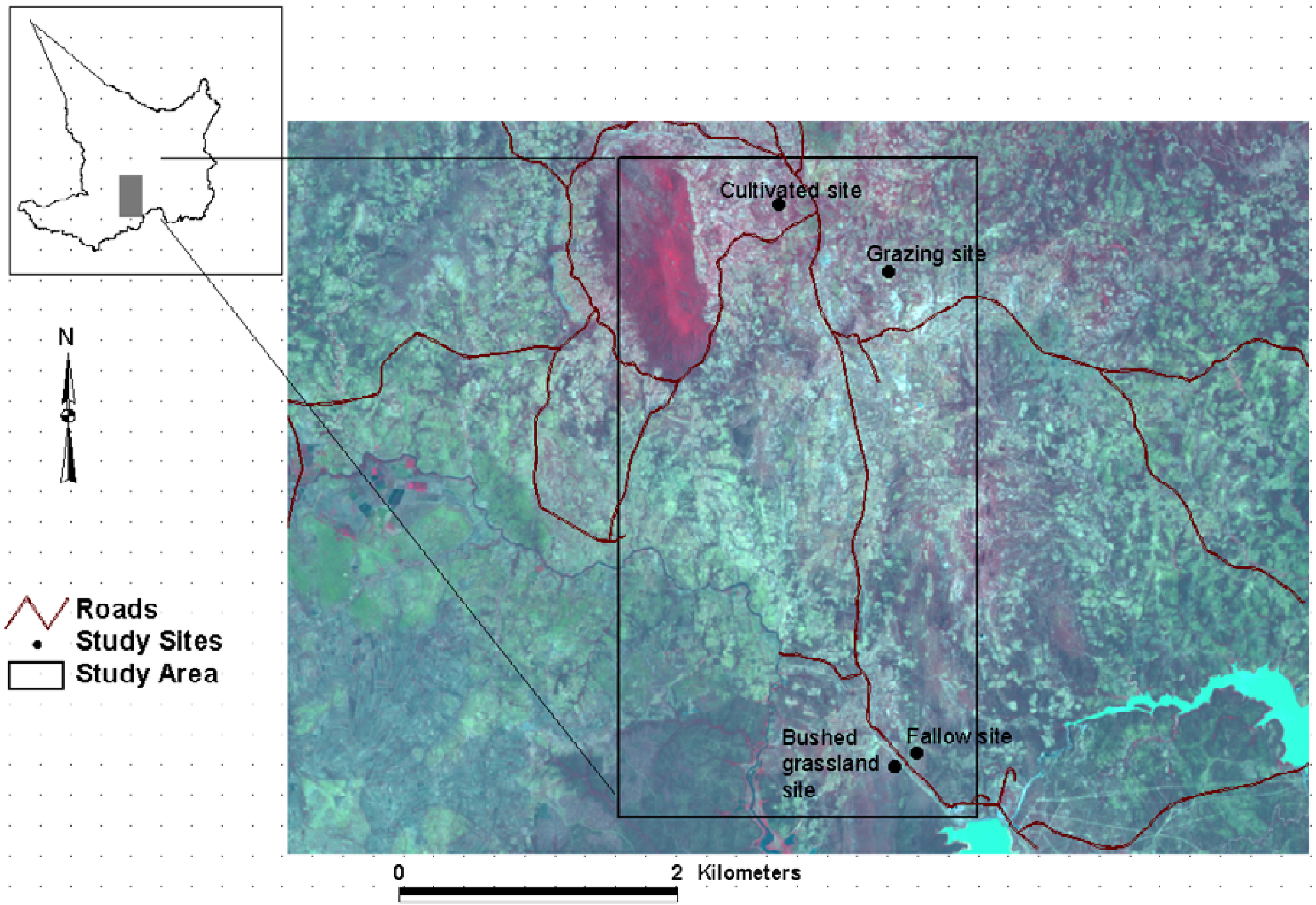


Figure 1.3. Satellite image of vegetation cover patterns and the study sites



Rocks of Precambrian systems, which include grainitoid gneisses, gneisses schist, granulites and crystalline limestone, form the basement of this site. Most of the rocks are ancient sediments which have been metamorphosed and highly altered and have undergone folding, shearing and faulting during the past geological periods (Njeru, 1978). However igneous rocks associated with the Mount Kenya volcanic also occur. The rock types are mostly Mount Kenya phonolites, kenytes and tracytes. The Precambrian series are characterized by a series of intrusive of Meta dolerites and quartzites, which have given rise to some hills in the area because of their resistance to erosion.

The period between the Precambrian and tertiary was largely marked by large-scale erosion affecting the whole area. The metamorphosed series are mostly varieties of gneisses and crystalline limestone. These gneisses have a high content of silica and consequently are resistant to chemical erosion and disintegration. This property results in slow rate of soil formation and explains why basement system areas tend to be covered by shallow soil. Also their permeability is low resulting in rain being converted rapidly into surface runoff. This does not allow sufficient time for soil regeneration (G.o.K, 1997)

2.1.5 Plant and Animal Communities

The natural vegetation is savannah type with *Comiphora, Acacia, Combretum* and numerous grass species. Mwea National Reserve is the only gazetted National Parkin the area. However, there are 1647 ha of natural forest reserve under the Mbeere county council. These are Kianjiru forest (1004 ha.) and Kiambere forest (643 ha) (G.o.K, 1997). The river valleys and hills are covered by dense bushes and isolated woodland, where little human activity takes place. Most of the available forest resource provides woodfuel and timber. However population pressure in some parts of the study area has led to clearance of the natural vegetation for cultivation and pastureland. This combined with charcoal burning poses a serious threat to the environment.

The biodiversity of Mbeere district in general is unique in the context of other semi-arid regions in Kenya given its diverse mammalian and avian species as exemplified by the Mwea National Reserve. The reserve has large mammals like African elephant (*Loxodonta africana)*, giraffe (*Camelopardis reticulata*), zebra (*Equs burchalii*), hippopotamus (*hippopotamus amphibius*), primates such as Sykes (*Cercopithecus mitis*), vervet monkeys (*cercopithecus aethiops)*, Olive baboons (*Papio anubis*). Common duiker (*Sylvicapra grimmia*), rock hyrax (*Procavida johnstoni*), numerous species of small mammals, and a wide range of reptiles also occur (Appedix 1). Similarly, the avifauna is remarkably diverse and perhaps hosts a rich assemblage of dry land species of birds.

2.1.6 General Land Use

Mbeere district is situated in an area of intensive agriculture especially in its northern parts. A mosaic of active and fallow agricultural fields has largely replaced natural vegetation in the district. The district is generally a low potential agriculture zone although agriculture is the most important economic activity in the region. Small-scale farming is widely practiced and the farm sizes range between 5 and 7 ha. per family. About 81% of the districts total area of 209,700 ha, is moderately suitable for agriculture and livestock activities. Of this land, more than 56% (95,120 ha.) is currently under food crop cultivation. Low scale horticulture is practiced in some parts of Gachoka division (GoK, 1997).

Cultivation occurs mostly in lower midland marginal cotton zone (LM4) and is made up of subsistent farms that are regularly tilled. Common types of crops grown are maize (*Zea mays*), beans (*Phaseolus vulgaris*), millet (*Eleusine coracana*), sorghum, cowpeas (*Vigna unguiculata*), mangoes (*Mangifera indica*), cassava (*Minihot esculenta*) and pawpaws (*Carica papaya*). Cotton (*Gossypium* sp.) and tobacco (*Nicotina tabacum*) are the main cash crops in the district. Natural vegetation is largely replaced by selected plant varieties determined by farmers. Most of these plots have been under cultivation since adjudication of land in the early 1970s. Another common use of land in this category is human settlement. Most family households and associated infrastructure are located here. Human population is relatively higher compared to other land use categories.

Livestock production is an important activity undertaken by residents of the district, second only to agriculture in intensity and importance. Grazing land is burned regularly though not tilled, and is used exclusively for pasture. Land under this practice is patchy and is surrounded largely by cultivated plots located in the lower midland livestock millet zone (LM5). The main livestock reared include cattle, sheep, goat and poultry. Fallow farms are common in LM5 where cultivation of crop is no longer in practice. Such land is readily accessible to people in search of honey, firewood, hunting and occasional grazing. Vegetation composition in this category is quasi natural even though it hosts more species of plants than cultivated and grazing lands.

Overall, some tract of land has been left un-cleared since adjudication particularly on the lower eastern zones of the district due its marginal nature. This constitutes the bushy grassland site with little or no human influence. The northern side of this site is bound by tarmac road. Tana River and Mwea national reserve form the other boundary to the south. The natural vegetation is savannah type dominated by *Comiphora* sp., *Acacia* sp., and *Combretum* sp. No cultivation occurs on this site but wild fire is a common phenomenon.

2.1.7 Historical perspective in the current conservation needs

Prior to land adjudication of 1970s the area maintained a wide range of wildlife species. Large mammalian communities recorded in the early 1970s have disappeared except in the protected Mwea National Reserve, which is an important biodiversity conservation area for the region today (Olson pers com). The disappearance coincide with the period that the land tenure system gave way to private holdings of subsistence farming as opposed to the traditional communal holdings that existed earlier (Njeru, 1978). The dichotomy between these systems of land ownership is that the former promoted communal herding of cattle with minimum tillage while the later encourages intensive subsistence agriculture. Up to now, very little is known about the influence of these land use changes to the basic ecology of mammals, their distribution, diversity and little attention has been paid to their potential use as indicators of the impact of the current land use management practices. Studies have mainly concentrated on a few species, which are either pest, potential sources of food or those that are of medical importance overlooking the significance of biodiversity and its conservation in the area. Mbeere district is largely marginal, suited for livestock and bee keeping while cultivation of crops is considered unsuitable. In general, the consequence of changes in land use on local flora and fauna has remained ill documented.

2.2 STUDY SPECIES

In this study, the term "small mammal" refers to free-living, small non-flying rodents and insectivores found on the ground surface and amongst vegetation in natural and semi-natural habitats. The lowest size limit is set by Etruscan shrew (*Crocidura etruscus*), the smallest known mammal, weighing as little as 2 g (Delany, 1974) and the upper limit is an arbitrary measure, that includes mammals up to about 120g, and approximates the largest size that can be regularly caught in commercial break-back rat traps. These size limits includes shrews, among the insectivores and rats, mice, lemmings, gerbils, dormice and some of the smaller squirrels among the rodents.

CHAPTER THREE: MATERIALS AND METHODS

3.0 INTRODUCTION

Measurement of habitat parameters is based on estimating their frequency of occurrence in the site of study. Parameters measured here are those reported elsewhere as having important influence on the diversity and distribution of small mammals (Cheeseman, 1977; Delany, 1977; Ajayi & Tewe, 1980; Dickson et al. 1984; Spencer *et al.*, 1990; Oguge, 1996; Monadjem, 1997; Odhiambo, 2000) although their specific influence may vary between species and geographic range. While the principle behind measuring habitat factors within varying land use categories is simple, measurement of the impacts these have on diversity and distribution of small mammals may in practice be difficult, especially if quantitative accuracy is the goal. This is because the actual response of a species is confounded by diverse internal and external factors some of which cannot be measured. This makes it difficult to determine their relative importance. Further more, the actual behavioral response cannot be measured accurately in field conditions except by inference. Even deciding which reactions result from which environmental stimulus is sometimes difficult (Gathua, 2000). For example Dickson (1984) found it difficult to determine whether vegetation cover and not food abundance for herbivorous rodent species was the critical factor influencing their distribution, without a detailed analysis of dietary composition.

The population size for most wildlife species can be estimated by either making a total count or sample count (Norton-Griffiths, 1978; Kiringe, 1993). The choice of method depends on a number of factors such as the cost involved in a particular method, the behaviour of the species to be studied, availability of resources, objective of the study, size of species, terrain and vegetation type of the study area (Norton-Griffiths, 1978; Kiringe, 1993). The study of rodents requires a range of techniques because it is also influenced by the above-mentioned factors. For instance the size of rodents (Kingdon, 1997); behaviour, climate and lifestyle (Pimack, 1993); and the habitat type (Oguge, 1996; Monadjem, 1997) are known to influence the choice of rodent sampling method. An example of how lifestyle can affect the technique used in sampling rodents is demonstrated by the cryptic nature of rodents and insectivores which make direct field observation impracticable. The use of traps becomes the most suitable alternative for obtaining the required information. Diurnal species like *Lemniscomys striatus* (Field 1975) and nocturnal species like *Cricetomys gambianus* (Delany 1974) have varying sampling requirements. Whereas it is sufficient to lay open traps during the day in order to obtain *Lemniscomy* sp., it is more appropriate to lay them overnight in order to sample both diurnal and nocturnal species adequately. Some rodents are considered to have very poor eyesight and a strong sense of smell (Delany 1974), which makes baiting of traps desirable. However, their response to traps can be very erratic.

Vegetation density may also influence the method of sampling rodents due to its effect on the quality of the habitat and hence the type of species to be found in it. Dense vegetation tends to form closed ground cover making it a more favourable habitat for rodents than an area with scarce vegetation (Monadjem, 1997). In addition due to their favourable microclimatic conditions, bushed / tall grassland and forests have been found to support a large number of rodents species. For example in a mixed grass and bushy habitat in Zaire, Dieterlan (1977) recorded twelve species of rodents which collectively had an average density as high as 361 individuals / hectare, admittedly amongst the highest densities in the world (Delany, 1979) Changes in climate as well as variations in seasons and weather may also have an influence on the distribution of rodents and hence the approach of sampling. For example, some crepuscular rodent species are active much earlier in the day after rains when the ambient moisture and temperature sufficiently reduces the danger of desiccation (Neal, 1984). Some barrowing species of rodents hibernate during very hot conditions by moving deep into their burrows. Other rodents hide beneath large boulders while others climb up trees where they may also nest. As such an attempt to sample rodents in all these places would require the use of a combination of sampling techniques such as direct and indirect nest search method in order to be successful in sampling.

In this study, data on rodent species composition and diversity, soil depth, percentage plant cover, occurrence of burrows and mounds, vegetation species composition and growth forms were collected in four sites selected from the four most common land use practices in the study area. These methods were chosen because they allowed sampling of a fairly adequate area within a short time without jeopardizing the results of the study objectives. In addition it has relatively low requirements in terms of manpower and equipments.

Methods of sampling rodents populations rely on assumptions and the following assumptions were therefore made before the start of this study.

(i) Sampling of rodents was done in uniform weather conditions.
(ii) All rodents responded in the same way to the baited traps and to the handling of specimens.
(iii) All individual rodents irrespective of species had equal chances of being trapped.

3.1 METHODS

Estimates of relative abundance in different habitats provided the required information. In this case, an index of abundance was obtained by using live traps positioned at 10 intervals. The traps were sufficiently numerous to ensure that no animal was ever excluded due to prior occupancy. Captures above 80% would have necessitated additional traps at each point according to Delaney (1974) and Southern (1964). Traps were located within the same habitat and the same types of trap were used throughout. This approach has also been used by Oguge (1995), Monadjem (1997) and Ferreira (2000).

Studies on microclimatic factors have shown that altitude is an important factor in determining the type of microhabitat (Trapnell & Brunt, 1987; Beentje, 1990; Bussmann, 1994). This was determined using a topographical map (1:50,000) and a geographical positioning system (GPS). However, altitude factor did not vary much across the four study sites. Its effect on microclimate was therefore controlled in this study. All plots were at least 50m from roads and the replicate plots were selected from a homogenous vegetation type.

Trapping focused on species of small mammals occupying four categories of land use. In each site, a square grid of 64 live traps was set out over an area of 70m x 70m with traps positioned at 10m intervals, following the methods of Delany & Roberts (1978) and Cheeseman & Delany (1979). Each trap (Mammal's wire gauge traps measuring 26 x 18 x 31 cm) was set and inspected twice a day, for 3 consecutive days per month. All specimens captured were identified to species level and marked using a toe clipping technique. Weight and body length (measured from the tip of the snout to anus) was recorded for each specimen caught. The traps were baited using peanut butter on fried coconut cubes. The type of traps ensured that only mammals smaller than 10cm were caught (Odhiambo, 2000).

Habitat survey was conducted using belt transects extending 5m on either side (thus 10m wide) of gridlines. A set of three parallel transects separated by 20m were sampled in each grid. Habitat variables namely the number and composition of woody plant species, number of burrows, mounds and hedge fences were measured. Measurement of grass species composition, percentage cover and soil depth were carried out in 1m x 1m quadrats, placed at 10m intervals in each transect. The area sampled for habitat parameters corresponded with trapping points of small mammals. A total area of 840 square meters was sampled in each land use type.

3.1.1 Data Analysis

Comparison of ecological processes between sites is one of the oldest methods used by ecologists and remains a valuable approach to understanding ecological phenomena (Cole *et al.,* 1991). It is sufficient to have relative estimate of numbers in order to compare the changes in a particular place at the same time under different land uses or in different periods. In this study, comparison of microhabitat variables in cultivated, grazing, fallow farms and bushed grassland sites was employed to infer implications of land use on factors influencing small mammal community. The premise for contrasting microhabitat variables is that sufficient variation exist in ecological conditions among land use types to permit detection of differences in response variables of small mammals. Such small-scale contrasts may be more sensitive at detecting ecological determinants arising from land use since unmeasured ecological parameters (e.g. climatic factors) are less likely to differ among sites. Nevertheless, it is difficult to make critical comparisons between different species, as their behaviour patterns may not be similar even between individuals of the same species in time and space.

At each site the total number of individuals of each species caught was used as a relative measure of abundance. Species diversity of plants and small mammals was calculated using the Shannon index of diversity, H = -Σpi ln pi, where pi is the proportion of the i^{th} plant species in the habitat (Shannon and Weaver, 1949; Pielou, 1975; Ludwig and Reynolds, 1988). H is influenced both by the number of categories (species) as well as by the evenness with which plants are distributed within those categories. Equal H values may thus be obtained if one habitat contains fewer and evenly distributed species of plants. The evenness of use of the plant species was calculated as, $J = H/H_{max}$ where $H_{max} = \ln(s)$, and s is the number of species. This measure varies between 1 (complete evenness) and 0 (complete unevenness).

Rodent abundance was expressed as proportion of captures relative to the number of traps set over a given period (Telford, 1989). Chi Square (X^2) was used to detect differences between sites, while correlation coefficient (r) was used to relate various habitat factors to distribution of rodents across sites. Analysis of Variance (ANOVA) was also performed on vegetation density in order to find out how it varied in different sampling sites.
All tests are 2 tailed with significance level of 0.05. Statistical analyses are based on Zar, (1984).

CHAPTER FOUR: SPECIES COMPOSITION, DIVERSITY AND ABUNDANCE OF RODENTS IN MBEERE DISTRICT, KENYA

4.0 INTRODUCTION

Rodents are reported to occupy a wide range of habitat types from human settlements, grasslands to secondary and mature forests (Kingdon, 1997). Habitat preference of both rodents and shrews is determined primarily by the type of cover available to them (Rowe-Rowe & Meeter, 1982; Iyawe, 1988). Some species such as *Rhabdomys pumilio* and *Otomys* sp. have been shown to correlate strongly with the presence of grass cover (Bond, Ferguson & Frosyth, 1980), while others such as *Gerbillurs poeba* have been shown to correlate negatively to it (Kerley, 1992; Monadjem, 1997).

The economic importance of rodents to man range from being vectors of plant and animal diseases including humans, to a number of agricultural and scientific values. For instance, giant and cane rats have been used widely as a source of proteins in East African region including Kenya. Rodents have considerable ecological benefits that range from carbon and energy flow to recycling of nutrients within the ecosystem. This serves to maintain ecological balance in such ecosystems. Further more due to their sensitivity to changes in the environment such as ground cover and food resource base, they are potentially useful indicators of changes in local environmental conditions such as habitat modifications caused by man (Kuhnelt, 1976). A quick survey of the diversity of the species in a certain ecosystem could help to know whether the ecosystem is stable or not (Wilson *et al.,* 1993). Moreover, the evolution of craniametric, morphological, and cytogenetic factors serves an important function in enhancing our understanding of biological concepts such as radiation and/or evolution among members of a population (Swanepoel *et al.,* 1978; Odhiambo 2000).

Moreover, several species of rodents cause significant damage to agricultural crops. Surveys on the effects of rodents to crop production indicate potential losses exceeding 30% in pre-harvest and over 50% post harvest losses in regions where rodents are common (Fiedler, 1994). Other species are involved in disease transmission. Important diseases in East Africa affecting humans or livestock and involving rodents include plague, leptospirosis, boutonneuse fever (African tick typhus), murine typhus and Q-fever. Lassa fever is a western Africa viral disease in which multimammate rats are the known reservoirs, but an African pigmy mouse and possibly the black rat have hosted the virus (Fiedler, 1994). In addition, viruses closely related to the Lassa virus have been isolated from *Praomys* in Mozambique (Wulff *et al.,* 1977). High seroprevalences to antibodies to Lassa virus have also been found in *Praomys* and *Arvicanthis* species in Tanzania and antibodies were found in 12 to 13% of human sera from western Sudan (Gratz, 1988). Hantaan or Hantaan related virus causes haemorrhagic fever with renal syndrome disease, which is contracted from excretions of infected wild rodents. Hanta virus presence in Eastern Africa has been demonstrated in serological studies in humans and in unidentified rodents from Kenya and Uganda (Vander-Groen & Lee, 1989). Several other diseases such as Rift Valley fever are thought to involve rodents but their role as a reservoir and/or vector is less understood or has not been confirmed.

Despite their importance, documentation of rodent species composition in Mbeere district is extremely scanty and is mostly based on isolated collections of materials by naturalists and researchers working on agricultural pests. To date no checklist has been published for the area and any attempt to understand their composition in this area can only be done through inference of studies done in similar environments in Kenya. In light of this, several questions about inter-and intra-specific variation in their abundance in relation to land use types remain unanswered. How does species composition and relative occurrence of rodents vary in different land use sites? How does land use patterns affect rodent species diversity? In this study, I intensively and systematically collected data on rodents in varying land use sites to address these questions.

4.1 METHODS

Traps were set as described in Chapter Three. A record was made of the total number of specimens and the total number of species for each of the sampling plot. Identification of specimens was done by comparing them with preserved rodent collection in National Museums of Kenya, rodent taxonomic literatures (e.g. Delany, 1966, 1974; Kingdon, 1997) and photographs of rodents that were available. The characteristics used in identification included features such as dentition, morphometric measurements, colour and size of the body among others. In addition, a record was made of all the diagnostic characteristics used to identify each species.

The data on trap captures for each species of small mammals were correlated with each of the measured habitat parameter. The assumption underlying this analysis is that the frequency of captures in a particular trap signifies preference for certain microhabitat factors close to that trap. Percentage species composition was calculated by dividing the number of individuals of each species by the total number of individuals of all species collected during the study. This provided the relative proportions of each of the species encountered during the entire study. Since the four sites comprised of different land use types it was necessary to determine whether there was a difference in their rodent species composition (Table 4.1). This was done by counting the total number of the different species in each of the sites and calculating the percentage abundance of each species.

The number of species in each land use type was the overall number of species captured from that particular site (2 replicates pooled together). Similarly the number of specimens per site was an average of all specimens captured from replicates of that site while the number of specimens was the sum of all the specimens for all the replicates in each of the sites. This method has been used by Monadjem (1997), Ferreira (2000).

Ecological factors of rodent was expressed in terms of diversity index, number of species and number of individuals (Ferreira, 2000). Rodent density was calculated by dividing the number of rodents captured by plot size, which was expressed as number of rodents per hectare. The species diversity was calculated from the number of individuals of a species using Shannon – Weiner diversity index (H´) expressed as $H' = - \Sigma Pi \ln Pi$ where Pi is the proportional abundance of the i^{th} species = n / N. Chi – square test was performed to find out how number of specimens and number of species varied within and between the sites.

4.2 RESULTS

4.2.1 Species Composition and Percentage Occurrence of Rodents in Different Land Use Sites

Five species of rodents, *Otomys thomasi* (Swamp rats)*, Leminiscomys barbarus* (Striped grass-mice)*, Arvicanthis nilotica* (unstriped grass-mice)*, Acomys percivalis* (Spiny mice) and *Mastomys natalensis* (Multimammate rat) were captured during this study. Squirrels *Heliosciurus rufobrachium* and common duikers *Sylvicapra grimmia* were also spotted occasionally. Fallow land contained all the species recorded in this study. In contrast, only two species were recorded in cultivated land the least for any land use category. Bushy and grazing sites contained four and three species respectively. Table 4.1 shows the frequency at which all the five rodent species were caught in different land use sites. A total of 213 individuals all belonging to family Muridae were encountered. Of the 5 species, *Lemniscomys barbarus* and *Otomys thomasi* were the best represented with 76 and 75 individuals, comprising 35.6 % and 35.2 % of total respectively. This was followed by *Acomys percivalis* with 16.4 % and *Mastomys natalensis* with 8.5 % respectively. *Arvicanthis nilotica* had the lowest percentage abundance. Low abundance for this species could be attributed to the fact that a small sample was obtained in only two localities within the study area unlike other species which were recorded in at least three of four sites sampled in comparably large numbers.

Acomys sp. was the most widely dispersed species, occurring in all four study sites in relatively low numbers compared to other species. The abundance of *Acomys* increased from cultivated to bushy along a decreasing land use gradient. *Otomys* and *Lemniscomys* sp. were present in three of the four sites. The distribution of *Otomys* was skewed in favour of commonly used sites and missing conspicuously in the relatively natural – bushy site. Among the used sites (i.e. cultivated, grazing and fallow), the occurrence of *Otomys* was highest in fallow and decreased towards cultivated site along an increasing land use gradient. Grazing site was intermediate between fallow and cultivated site in terms of *Otomys* abundance. In contrast, the distribution of *Lemniscomys* sp. was skewed in favour of less used sites and missing conspicuously from cultivated land (most used site). Its numbers decreased progressively from grazing site to bushy, fallow land being the intermediate site. Despite the opposing skew in their distribution both species were well represented in fallow site than any other land use category. In grazing land both species (*Otomys* and *Lemniscomys*) occurred at relatively equal proportion of abundance. Nevertheless, *Lemniscomys* was lowest in cultivated land but appeared significantly more often in grazing land (Table 4.2).

TABLE 4.1 Small mammals caught and their percentage relative abundance (in brackets) at 4 sites in Mbeere district Kenya, between September and December 2001						
	No. Caught at each site					
Species	Cultivated	Grazing	Fallow	Bushy	Total	% Occurrence
Otomys thomasi	9 (4.2)	27 (12.7)	39 (18.3)	0 (0.0)	75	35.2
Lemniscomys barbarus	0 (0.0)	5 (2.3)	27 (12.7)	44 (20.7)	76	35.6
Arvicanthis nilotica	0 (0.0)	0 (0.0)	3 (1.4)	6 (2.8)	9	4.2
Acomys percivalis	3 (1.4)	3 (1.4)	11 (5.2)	18 (8.5)	35	16.4
Mastomys natalensis	0 (0.0)	0 (0)	16 (7.5)	2 (0.9)	18	8.5
Total			12	35	86	50

TABLE 4.2 Comparison of rodent abundance between sites under different land use in Mbeere district Kenya. Figures in the table represent $\chi 2$ values.

Sites	*Otomys*	*Lemniscomys*	*Arvicanthis*	*Acomys*	*Mastomys*
Cultivated vs. grazing	2.504	29***	0	0	0
Fallow	4.904*	20.79***	6.8**	2.037	15.89***
Bushy	11.83***	26.99***	32.08***	48.93***	75.7***
Grazing vs. Fallow	0.429	1.354	6.8*	2.037	15.89***
Bushy	20.88***	0.072	32.08***	48.932***	75.7***
Fallow vs. Bushy	25.33***	0.805	16.437***	35.966***	39.057***

Where * = significance at $p < 0.05$; ** = $p < 0.01$; *** = $p < 0.001$; DF = 1

Marked and recaptured species were never observed to move far from initial trapping points. Maximum distance recorded for all species was 20m, (± 3, n=7).

4.2.2 Diversity of Rodent Species

Diversity index (H) and evenness (J) of rodent species varied between habitats with different land use (Table 4.3). The highest diversity index and evenness was recorded in fallow site. This was followed by bushy site. Grazing and cultivated sites had the lowest diversity indices in the area. Of the two sites, cultivated land recorded the lowest diversity. This site was also one of the most used followed by grazing land.

TABLE 4.3 Diversity indices (H) and evenness (J) of rodent species in different land use sites in Mbeere district Kenya.

Site	Diversity (H)	Evenness (J)
Cultivated	0.201951	0.288926
Grazing	0.328937	0.470602
Fallow	0.669844	0.95833
Bush land	0.509364	0.728735

4.3 DISCUSSION

In this study, five rodent species were recorded. This may not represent all the species present in the study area but it gives an updated account of some of the small mammal species present in the site. Two species, *Arvicanthis* and *Mastomys* were the most site-restricted occurring only in fallow and bushy sites. The distribution of *Arvicanthis* however increased from fallow to bushy - one of the least disturbed site. In contrast, *Mastomys* was more abundant in fallow than bushy. It thus tended to tolerate low or intermediate levels of disturbance or those sites under recovery. Overall, fallow site (perhaps a complex of habitat attributes) was most suitable site and hosted the greatest diversity of small mammal species than any other site.

The data obtained suggests that *Acomys percivalis* has the widest range of habitat preference among the species captured, having been recorded in all land use sites. The species may be highly flexible to both disturbed and undisturbed habitats or has a wide range of tolerance to microhabitat variations such as those prevailing across these sites. Nevertheless, it was affected negatively by human land use and its abundance was lowest in cultivated and grazed (most used sites) compared to bushy and fallow (least used) sites. Despite the divergent differences expected in land use activities between cultivated and bushy sites, both sites had a relatively similar abundance of *Acomys* suggesting that the species tolerate a wide range of disturbance. Land use difference that caused a notable change in its abundance exists between fallow and grazing or fallow and cultivated sites. Another notable difference occurs between bushy and fallow. The observed variation in the distribution and abundance of *Acomys* sp. across different land use sites suggests that it is influenced by changes in microhabitat factors that accompany land use transformations. However, despite the observed low abundance, *Acomys* was the most dispersed species in the study area. Distributional characteristics of this species perhaps make it suitable as indicator of habitat change where the quality and not the specific land use is of interest. The suitability of this species is strengthened by its wide habitat preference and tolerance to change. It is characterized by numerical fluctuation with respect to the habitat quality. It is expected that sites with complete loss of this species may correspond to a severely damaged habitat.

Arvicanthis and *Mastomys*, the other group of species most affected by land use, are restricted in fallow and bushy site as described in the results section. This outcome points to susceptibility of both species to land use change and have a narrow range of tolerance to habitat disturbance. Accordingly, they are the most locally threatened group of small mammal species due to the increasing habitat change in the area. The extent of threat is however not similar for the two species. *Arvicanthis* is notably more susceptible due to its preference for natural sites. *Mastomys* on the other hand prefers recovering sites more than the natural ones. During habitat change such as those occurring in grazing and cultivated sites, *Arvicanthis* is likely to be the first species to be lost and the last one to be recovered during a rehabilitation process of the damaged sites. Both species may be good indicators of habitat change but are severely limited by their high sensitivity to change since they are likely to be missing in intermediate or transient habitat conditions. Potential attractions to bush for these species may have largely been due to greater habitat complexity. Habitat preference for such species in relation to land use has previously not been demonstrated.

Like other species, *Lemniscomys* was also negatively affected by land use. However, data generated in this study suggest that it may be more tolerant and adaptive to changing environment though it has a clear preference for undisturbed sites. In contrast, *Otomys* showed a clear preference for disturbed areas. The result suggests that *Otomys* is highly adaptive to changing habitat and may be highly opportunistic. The observation agrees with that of Ferreira (2000) who reported a similar interspecific variability in abundance of some species of rodents including *Otomys* sp. which he attributed to their varying ability to thrive in disturbed habitats. *Otomys* species is described as granivorous (Field, 1975) which may explain its preference for sites with human induced disturbances owing to a possible increase of cereal crops. Indeed, there was indirect evidence to suggest that the distribution of *Otomys* was related to the occurrence of cereal crops particularly maize which was generally present close to its preferred sites. However, quantitative assessment to ascertain this relationship is recommended for future studies. Overall, both *Otomys* and *Lemniscomys* are unsuitable as indicator species given their high selectivity for altered habitats.

The observed variation in the distribution of species of small mammals reflects responses to changes in the distribution of habitat factors. For instance, the presence of *Lemniscomys* and *Otomys* sp in fallow site may indicate its suitable habitat conditions. Rodent species composition in this site is comparable to that of other areas with similar ecological conditions in the East Africa region. For example, *Lemniscomys barbarus*, *Otomys thomasi* and *Arvicanthis nilotica* have been reported in Kahawa area, 25 km to the North of Nairobi (Martin *et al*, 1985) and in Meru National Park (Neal, 1984). The genus *Acomys* has also been reported in Mt Elgon, Baringo and Kerio Valley areas in Kenya and is considered to be highly adapted to semi arid conditions (Kingdon, 1997). *Otomys, Arvicanthis* and *Mastomys* have been recorded widely in Uganda (Delany, 1974).

The African small mammal populations generally decline during the dry season (Delany and Happold, 1979; Monadjem, 1997). Effects of land use on their distribution can perhaps be best demonstrated during this season since at large population densities additional animals may spill over into less preferred habitats.

CHAPTER FIVE: VARIATION OF HABITAT ATTRIBUTES WITH LAND USE IN THE STUDY SITE

5.0 INTRODUCTION

Understanding the ecological consequences of land use on habitat variability is critical in gaining insight into its effects on animal community and developing an integrated approach to land use management. Studies of the influence of land use patterns on habitat variables assume relationships between the animal and its environment and usually are a compilation of simple correlations between animal and habitat attributes (Hamel *et al.,* 1986; Schamberger & O'neil, 1986). According to some of the studies, stressed or disturbed environments experience a shift from a lognormal pattern of species abundance to an increase in dominance of particular species and a decrease in species richness (Johns, 1986; Skorupa, 1986; Tarara 1986; Struhsaker, 1976; Altmann *et al.,* 1985; Berenstain, 1986). In addition, the dynamics of unexploited areas are predominantly driven by factors arising in the exploited environment (Sauders et al., 1991).

Land use activities, particularly grazing, cultivation and fencing fragment habitats into small isolated patches. This impacts on distribution patterns of plant cover component, species composition as well as the diversity. The variability of microhabitat factors measured in this study (grass percentage cover, composition and diversity of plants, physical characteristics like burrows, mounds, soil depth and hedge fence) was therefore presumed to be consistent with land use. Indeed, only less than 20 % of the natural vegetation cover originally more that 70% in Mbeere district remains relatively undisturbed. Much of it is now almost entirely confined to hill slopes and protected reserve comprising less than 7 % of the land (G. o K., 1997). Bushy vegetation re-growth on fallow farms covers much of the regions that formally supported natural vegetation (personal observation). Little, perhaps nonexistence of vegetation re-growth especially of woody plant species occurs in cultivated sites. The range of plant species composition and diversity in these sites is limited to that chosen by farmers.

Alongside vegetation cover, composition and species diversity, physical habitat parameters were also expected to vary. As a result of encroachment and unsustainable land use, major parts of natural habitats together with prevailing biodiversity are being lost rapidly (Bussmann, 1994). Despite this widespread human land use in Mbeere district, there is little documentation of the use of these habitats by resident animals, particularly small mammals. As such there is need to focus greater attention to understand and document underlying land use factors in habitat variability.

5.1 METHODS

5.1.1 Vegetation Study

To compare the land use types in terms of plant species composition and density, and to estimate vegetation cover in each site, I carried out vegetation surveys using transects running along grid lines used for rodent survey (see section 3.1). A total of six replicate transects were sampled in each site. The transects were spaced at 20m interval, corresponding to the rodent trapping stations as described in Chapter 3 above. The area sampled in each site was $840m^2$ and represented about 15% of the area occupied by the trapping grids.
Analysis of Variance was used to test whether Shannon diversity index (H) varied between sites. This method has been used in previous studies (e.g. Oguge, 1995; Monadjem, 1997; Ferreira, 2000; Newton, 1980; Odhiambo, 2000).

Trees and shrubs (with diameter at breast height (DBH) > 5 cm) were identified to the level of species (Appendix 3). In each transect a quadrant measuring 1m by 1m was taken and sampled for grass species as explained in method section (Appendix 4). Grass samples were identified to species level, and the percentage area covered by grasses estimated. Percentage cover estimates were arcsine transformed before subjecting it to statistical analysis.

5.1.2 Physical Habitat Variables

In order to find out the effect of land use on habitat parameters, four variables, namely soil depth, burrows, mounds, and hedge fences were assessed in each land use type (Appendix 5). A record was made on the number of these variables in each transect as described in section 5.1.1 above. The heterogeneity of habitat was then expressed in terms of abundance, density and diversity indices obtained from these variables.

The relationship between soil depth, burrows, mounds percentage cover and hedge fence was established by performing a correlation analysis on their means (Appendix 6). These means were obtained by taking the average of the samples obtained in each of the 2 replicate plots sampled per site for all the study sites.

5.2 RESULTS

5.2.1 Vegetation Composition and Diversity

5.2.1.1 Vegetation Composition

A total of 20 trees and shrubs species were recorded in the study site (Table 5.1) whereas 14 grass species were recorded (Table 5.2). Thirty two percent of all the plant species were present in all habitats. Nine percent of the grass species were unique in any one habitat. Bushy grassland had more species of grasses (n = 12) and woody plant species (n = 17) than both grazed land (n = 11; n = 13) and cultivated land (n = 6; n = 8) respectively, despite the fact that the area sampled for all locations was equal. Most of the species found only in grazed and fallow land were either planted exotic species such as *Grivellia robusta*, or colonizing and/or invader species *Oxygonum sinuatum, Gnidia subcordata* and *Crotolaria* sp. indicating signs of land degradation in the sites.

TABLE 5.1 Frequency, relative frequency and density of trees and shrubs in sites with varying land use in Gachoka, Mbeere district, Kenya.

	Cultivated			Grazed			Fallow			Bushy grassland		
Species	Freq	Rel. frq	Density trees/shrubs per ha	Freq	Rel. frq	Density trees/shrubs per ha	Freq	Rel. frq	Density trees/shrubs per ha	Freq	Rel. frq	Density trees/shrubs per ha
Terminalia brownii	2	3.08	200	1	0.95	100	14	6.51	1400	30	15.31	3000
Cassia bicapsularis	0	0.00	0	2	1.91	200	16	7.44	1600	16	8.16	1600
C. siamea	1	1.54	100	0	0.00	0	20	9.30	2000	25	12.76	2500
Boswellia neglecta	0	0.00	0	0	0.00	0	2	0.47	200	15	7.65	1500
Combretum sp.	1	1.54	100	8	7.62	800	12	5.58	1200	33	16.84	3300
Acacia tortilis	0	0.00	0	7	6.67	700	21	9.77	2100	18	9.18	1800
A. robusta	0	0.00	0	2	1.91	200	13	6.05	1300	9	4.59	900
A. ataxantha	0	0.00	0	3	2.86	300	5	2.33	500	11	5.61	1100
Polyfera sp.	0	0.00	0	1	0.95	100	4	1.86	400	8	4.08	800
Delnex errata	0	0.00	0	1	0.95	100	0	0.00	0	4	2.04	400
Grevillea robusta	3	4.62	300	2	1.91	200	0	0.00	0	0	0.00	0
Azadirachta indica	0	0.00	0	0	0.00	0	1	0.47	100	0	0.00	0
Lantana camara	4	6.15	400	12	11.43	1200	8	3.72	800	6	3.06	600
Balanoites peridiuraris	1	1.54	100	0	0.00	0	6	2.79	600	2	1.02	200
Rhus natalensis	1	1.54	100	1	0.95	100	5	2.33	500	7	3.57	700
Vitex doniana	0	0.00	0	0	0.00	0	4	1.86	400	6	3.06	600
Mellia vokensii	0	0.00	0	0	0.00	0	3	1.40	300	7	3.57	700
Securigega virosa	0	0.00	0	0	0.00	0	2	0.93	200	6	3.06	600
Gnidia subcordata	0	0.00	0	3	2.86	300	3	1.40	300	0	0.00	0
Aspilia mossambicensis	6	9.23	600	4	3.81	400	7	3.26	700	4	2.04	400
Total			**1900**			**4700**			**14600**			**20700**

TABLE 5.2 Frequency, relative frequency and density of grass species present in sites with different land use in Gachoka, Mbeere district.

	Cultivated			Grazing			Fallow			Bushy grasslands		
Grass species	Freq	Rel frq	Density gr/m2	Freq	Rel frq	Density gr/m2	Freq	Rel frq	Density gr/m2	Freq	Rel frq	Density gr/m2
Dactyloctenium aegyptium	0	0.00	0	3	17.65	48	12	70.59	192	2	11.76	32
Chloris pilosa	18	21.18	288	25	29.41	400	25	29.41	400	17	20.00	272
C. pycnothrix	33	29.46	528	37	33.04	592	28	25.00	448	14	12.50	224
Penisetum ramosum	0	0.00	0	11	26.83	176	13	31.71	208	17	41.46	272
Digitaria milanjiana	22	31.43	352	26	37.14	416	14	20.00	224	8	11.43	128
D. adscendens	8	22.86	128	13	37.14	208	5	14.29	80	9	25.71	144
D. scalarum	4	16.67	64	6	25.00	96	4	16.67	64	10	41.67	160
Brachiaria leucacrantha	7	36.84	112	2	10.53	32	6	31.58	96	4	21.05	64
Sporobolus marginatus	0	0.00	0	0	0.00	0	5	11.11	80	40	88.89	640
Eragrostis superba	0	0.00	0	10	19.61	160	17	33.33	272	24	47.06	384
Eragrostis aspera	0	0.00	0	5	16.67	80	12	40.00	192	13	43.33	208
Panicum makarikariense	0	0.00	0	0	0.00	0	7	100.00	112	0	0.00	0
Vetiver zizamoides	0	0.00	0	0	0.00	0	5	100.00	80	0	0.00	0
Themeda triadra	0	0.00	0	11	25.00	176	16	36.36	256	17	38.64	272
Crotolaria sp.	4	16.67	64	10	41.67	160	6	25.00	96	0	0.00	0
Oxygonum sinuatum	8	22.86	128	26	37.14	416	14	14.29	224	0	0.00	0
Euphorbia heterophyla	4	16.67	64	11	26.83	176	13	31.71	208	0	0.00	0
Total			**1728**			**3136**			**3232**			**2800**

5.2.1.2 Plant Density

The density of woody plants varied significantly between sites ($F = 10.224$, $DF = 3,76$, $p < 0.0001$). Tukey test showed that significant differences occurred between bushy and cultivated ($q = 6.889$, $P < 0.05$) and between woody and grazed sites ($q = 5.863$, $P < 0.05$). There were no differences in woody plant density between cultivated and grazed, cultivated and fallow, bushy and fallow, as well as grazed and fallow sites ($P > 0.05$ in all cases). The density of grasses did not differ between sites ($F = 1.168$, $DF = 3, 64$, $p > 0.05$). Although the plant species with highest density differed in the four sites, 5 out of the top 10 species were common in all four sites.

5.2.1.3 Percentage Grass Cover

Appendix 7 shows the grass cover estimates obtained in during this study. Significant variations in grass cover occurred between land use sites ($F = 38.5$, $DF = 3, 24$, $P < 0.0001$). Cover values in grazing, fallow and bushy sites differed significantly from that of cultivated land ($q = 7.3$; 9.0 and 15.1 respectively, $p < 0.001$ for all cases. Percentage grass cover in bushy varied significantly from that of grazing ($q = 7.8$, $P < 0.05$) and fallow ($q = 6.1$, $P = 0.05$) sites. However, no significant variation was observed between grazing and fallow sites $q = 1.7$, $P > 0.05$.

Although significant difference in grass cover estimates was observed in all pairs of land use sites, with the exception of grazing and fallow sites, the extent of this variability differed. For instance, the difference between cultivated and grazing sites and that of fallow and bushy sites was observed to occur with relatively lower significance level.

5.2.1.4 Plant Species Diversity

Table 5.3 shows diversity indices (H) and their evenness (J) while table 5.4 shows students (t) test comparisons of both woody plants and grass species diversities in different pairs of land use in the Mbeere study site. Diversity index of woody plant and grass species were highest in fallow followed by the bushy site. High evenness indices were also observed in the two sites compared to the rest. Lowest H values were obtained in cultivated and grazing sites. However, the H values for woody and grass species obtained in the two sites did not differ significantly. Similarly, there was no significant difference between grazing and fallow sites, despite the fact that H of woody plant species in fallow varied significantly from that of cultivated site ($t = 2.130$, $DF = 364$, $P < 0.05$). Cultivated and bushy grassland ($t = 2.735$, $DF = 361$) as well as grazing and bushy grassland site ($t = 1.993$, $DF = 361$) $P < 0.05$ were the only other sites showing significant difference between species of woody plants. In the contrary, diversity values for species of grasses did not show any significant variation across the sites.

TABLE 5.3 Indices of diversity (H) and evenness (J), for plant species in four habitats with varying land use, in Gachoka, Mbeere district Kenya.

	Diversity (H)		Evenness (J)	
Habitat	Trees and shrubs	Grasses	Trees and shrubs	Grasses
Cultivated land	0.831944	0.683486	0.610948	0.454353
Grazing land	0.924384	0.832246	0.678832	0.753372
Fallow	1.209816	1.081689	0.888442	0.941398
Bushy grassland	1.197438	0.989834	0.879352	0.888586
Overall	**1.406952**	**3.383835**	**0.765126**	**0.971928**

TABLE 5.4 Comparison of diversity indices (H) between sites in Gachoka, Mbeere district, Kenya.

Sites	Trees and shrubs		Grasses	
	t-statistic	DF	t-statistic	DF
Cultivated vs. grazing	0.758	364	0.283	362
Cultivated vs. fallow	2.130*	364	0.277	361
Cultivated vs. bushy grassland	2.735**	361	0.304	361
Grazing vs. fallow	0.828	360	0.362	362
Grazing vs. bushy grassland	1.993*	361	0.383	362
Fallow vs. bushy grassland	1.132	360	0.850	362

*2 tail t-test p = 0.05; * p< 0.05; ** p < 0.01*

Some species of grass that occurred in all four habitats had very different distribution in each of them. *Chloris* and. *Digitaria sp* were more abundant in cultivated area, while *Sporobolus, Eragrostis* and *Themeda sp* were common in fallow and bushy grassland. All sample replicates were homogeneous for plant species composition and percentage vegetation cover (Appendix 8).

5.2.2 Physical Habitat Variables

5.2.2.1 Burrows, Mounds and Soil depth

Appendix 5 shows the physical habitat variables measured across the study site, while table 5.5 shows differences in habitat variables across and between land use sites. Frequency distribution of all the habitat factors measured varied with land use. Abundance of burrows in fallow and bushy grassland sites differed significantly from that of cultivated site ($q = 5.0$ and 5.6, $p < 0.05$ respectively). However, barrows in grazing and fallow sites did not vary from those in the bushy site. Similarly, there was no significant difference between both the fallow and the cultivated site from the grazing ones. The occurrence of mounds also varied between numerous pairs of land use sites. Barrows in the bushy site differed from that of cultivated and grazing sites while barrows in cultivated sites varied from those in fallow and the grazing sites. However, no significant difference existed between fallow sites and both the bushy and the grazing sites. On the other hand, differences in soil depths between sites related to the respective land use practices there. Significant differences in soil depth occurred between cultivated and grazing sites as well as in fallow and bushy sites. No significant difference existed between grazing site and both fallow and the bushy sites. In addition, soil depths in fallow sites were not significantly different from those of bushy sites.

Although distribution of burrows was not even across sites, it correlated positively to most plant species except *Azadirachta indica* ($r = 0.372, p > 0.05$, n = 1), *Baranoites peridiuraris* ($r = 0.403, p > 0.05$, n = 9) and *Aspilia mossambicensis* ($r = -0.286, p > 0.05$, n = 21). However, successful captures did not relate to distribution of burrows ($r = 0.416, p > 0.05$, n = 12) for all sites.

5.2.2.2 Trees, Shrubs and Hedge Fences

The abundance of trees and shrubs in cultivated, grazing and fallow sites differed significantly from that of bushy site. However, there was no significant difference between fallow and the grazing sites when both were compared to cultivated sites. In addition, the occurrence of trees and shrubs was not different between fallow and grazing sites. The occurrence of hedge fences did not vary significantly across the entire study sites ($F = 1.1, P > 0.05$).

TABLE 5.5 Variation in physical habitat variables across the Mbeere study site. Figures in the table re

	Soil depth	Barrow	Mound	Trees/Shrubs	Fence
F	15.7***	6.4**	28.0***	9.0***	1.1
Tukey test multiple comparisons					
	q	*q*	*q*	*q*	
4 versus 1	9.5*	5.6*	12.4*	6.5*	
4 vs. 2	3.5	2.7	7.7*	6.3*	
4 vs. 3	3.0	0.7	3.8	4.3*	
3 vs. 1	6.5*	5.0*	8.5*	2.2	
3 vs. 2	0.5	2.0	3.8	1.9	
2 vs. 1	5.9*	3.0	4.7*	0.2	

5.3 DISCUSSION

Although grass density did not vary across different land use categories, some grass species did not occur in all the four sites. *Chloris* and *Digitaria* sp. were more abundant in cultivated area, while *Sporobolus, Eragrostis* and *Themeda* sp. were common in fallow and bushy grassland. Most of the woody plant species found only in grazed and fallow land were either planted exotic species such as *Grevillia robusta*, or colonizing/invader species *Oxygonum sinuatum, Gnidia subcordata* and *Crotolaria* sp. indicating signs of land degradation in the sites (Maathai pers com.). Low prevalence of invader species in cultivated site may suggest high frequency of tillage and weeding expected in subsistent plots as evidenced by absence of natural vegetation cover and soil erosion. Degradation of habitat (based on plant species diversity, density and percentage cover estimates) occurred with greater incidence in cultivated and grazing lands, than in fallow and bushy grassland. Cultivated, grazing and fallow lands experienced the highest degree of human influence, with cultivated land ranking highest. Therefore there were distinct differences between habitats where species richness of natural sites (bushy grassland) was reduced to about 40% by grazing and further by less than 20% by cultivation.

Land use differences prevailing in bushy land, compared to grazing and/or cultivated sites result in density differences of woody plants but not for grass species. Cultivated and grazing sites are the most intensively used, which also represent the lowest densities of woody plants. No significant variation in woody plant density was observed in some sites (section 5.2.1.2). This outcome suggests that activities across pairs of these land use categories result in more or less similar vegetation variability. Overall, land use activities across sites have greater impacts on density of woody plants compared to that of grass species. This may be associated with the different growth patterns of the two species. i.e. woody plants are perennials while grass species are mostly annuals. Both group of plants must have different habitat requirements and are likely to respond differently to similar land use activities. For instance, the regeneration and/or recruitment of saplings of woody plants is disrupted by fire and intensive grazing. In general perennials are more susceptible to land clearing and/or burning, associated with land use transformations into cultivated or grazing pastures as has occurred in these sites.

Data on grass cover estimates obtained in this study indicate that cultivated site contrasted greatly with the rest of the sites. This site was observed to have the lowest cover values. Accordingly, the site is under regular but intense tillage and cropping which maybe directly related to the observed low cover estimates. Cover values obtained in grazing and fallow sites did not vary significantly. Both sites contained the highest cover values obtained during this study. Greater vegetation diversity as well as density of plant species in these categories may be associated with the cover values. This observation perhaps point to the nature of use that exist between them. Both have been left with relatively little disturbance. Of the two, the bushy site could be considered to present a relatively undisturbed site. Significant differences observed between grazing and bushy as well as fallow and bushy sites may indicate divergent land use practices that exist between them. For instance bushy site has limited accessibility and very little activity goes on compared to the rest of the sites. Overall, the bushy site contained the highest grass cover estimates than any other sites.

Diversity indices obtained for woody plant species indicates significant variations between cultivated and fallow and/or bushy sites. Likewise, significant difference exists between grazing and bushy grassland. Causes for this observation may be related to those attributable to cover described in this section. No significant variations were observed between grass species across different land use types. Variability in diversity indices for these sites is a direct result of disturbance related to the land use patterns.

Results in this study compares with that of Norton-Griffiths (1979), Dublin (1995) and Salvatori and others (2001) that land use pressure from both cultivation and grazing activities impact on the vegetation and limit the natural regeneration of woody plants. This indirectly affects the small mammal community, which limits its long-term establishment. Keesing (1998) also found that ungulates could have a strong impact on small mammals abundance and diversity in East African savanna. The land use practices proceeding in some section of this study area may not allow proper establishment of conditions suitable for the small mammals to inhabit them. If the observed decline in habitat quality with respect to land use intensity is not controlled, it may affect adversely the population size of medium-sized predators (both mammals and birds) in this area and perhaps disrupt the normal functioning of the ecosystem.

CHAPTER SIX: EFFECTS OF LAND USE ON RODENT DIVERSITY

6.0 INTRODUCTION

The common application of biological diversity is in conservation of nature, monitoring of environment and a source of genetic diversity. Biodiversity of species is used to indicate ecological quality and its measure is used extensively to assess the adverse effects of environmental disturbances (Magurran, 1988)

Diversity is assessed by recording the number of species, describing their relative abundance or using measures which combined the two (Magurran, 1988). There are three basic types of diversity (Whittaker, 1975); alpha (α) diversity (the number of species coexisting within a single uniform type of habitat), Beta (β) diversity (diversity between habitats) and gamma (γ) diversity (diversity of landscape that result from both α and β diversities of communities). The three types of diversity measures related to this study in varying degree. The presence and/or absence of particular species of rodent in a given area result from its specific interaction with the prevailing environmental factors. Rich differentiation in the sites that result in broad overlapping of ecological factors could result from intermediate level of disturbance and perhaps the inter- and intra-specific competition between species (Ferreira *et al*., 2000). Congeneric species show different patterns of adaptive coexistence. For example some can share the same general habitat by differing in affinities for microhabitat types (Wilson et al., 1993). Others show no obvious difference in microhabitat type but differ dramatically in affinities for physical factors and / or vegetation types and appear to avoid intrageneric interaction (e.g. Competition) by avoiding co-occurrence. An animal will choose their habitat within which they can maximize its fitness, food quality and quantity and will rarely choose or totally avoid habitats that do not meet these requirements (Rogers, 1980; Kiringe, 1993). In general factors found to have an effect on rodents species diversity include physical and chemical composition of soil, level of habitat disturbance, vegetation parameters and elevation (Ajayi, 1977; Wareborn, 1992). Soil minerals may have an indirect effect on diversity of rodents. For instance Ajayi & Tewe (1977) found that concentration of sodium potassium and magnesium were significantly lower in locations without burrows than with burrows, while phosphorus content was significantly higher in former burrows. Similarly increased nitrogen deposition may raise its contents in plants and insects foods, which possibly increases the abundance of rodents. Indeed soil particles have actually been found in the stomach of the giant rat and may have been intentionally swallowed to supplement their diets (Ajayi, 1977). However, the effect is difficult to evaluate because nitrogen content is possibly correlated with base saturation and soil moisture (Wareborn, 1992).

The land use patterns and the associated destruction of natural vegetation in Kianjiru can be considered as a continuous disturbance of high intensity resulting in considerable habitat degradation. Subsequently, the species diversity, composition and distribution of rodent species in this study may correlate to the diverse land use management practices in the area. The aim of this chapter is to correlate the habitat conditions observed in various land use types to the ecology of rodents in the respective sites.

6.1 METHODS

Four sites with common land use types were identified and sampled for habitat variables and rodent species as outlined in Chapter Three and Four. The means of diversity measures and habitat variable for different land use types were calculated by taking the average of all the plots sampled per site in the particular unit. Each site had 2 sampling plots while the whole study included four sites. Data on percentage vegetation cover were first arc sine transformed before subjecting it to statistical test. The relationship between rodents and land use parameters was assessed by correlating the environmental variables measured in different land use sites with rodent diversity indices and measures of rodent abundance in those sites. Significance values of *r*, are shown in table 6.3.

6.2 RESULTS

6.2.1 Correlation Analysis

Table 6.1 shows the mean density of grass and woody plant species, percentage grass cover, soil depth, burrows, mounds and hedge fence while table 6.2 shows the means of number of species, number of specimens and diversity index of rodent species that were obtained in all the sampling sites.

TABLE 6.1 Number of plant specie, density, diversity and physical variables measured in Mbeere study site.

	Plant sp.		Density		Diversity (H)		Physical habitat variables			
Habitat	Gr	Wo	gr	Wo	gr	wo	Sd	Bar	Mo	H fence
Cultivated land	9	7	101.647	95	0.683	0.832	18.021	8	12	10
Grazing land	14	13	184.471	235	0.832	0.924	14.548	26	21	18
Fallow	17	18	190.118	730	1.082	1.21	14.206	29	28	20
Bushy grassland	12	17	164.706	1035	0.99	1.197	4.365	30	40	7

Where gr = grasses; wo = woody plants; Sd = soil depth; Bar = burrows; Mo = mounds; H fence = hedge fence.

TABLE 6.2 Number of species, number of specimen and diversity index for rodent species recorded in Mbeere district

Site	no. species	no. specimen	Diversity (H)
Cultivated	2	12	0.201951
Grazing	3	35	0.328937
Fallow	5	96	0.669844
Bushy	4	70	0.509364

Result in table 6.3 shows that the abundance of *Lemniscomys barbarus, Acomys percivalis* and *Arvicanthis nilotica* increased with percentage grass cover (positive correlation) but decreased with increase in soil depth (negative correlation). Total number of specimens increased with increase in heterogeneity of habitats, exemplified by fallow and bushy sites. *Lemniscomys* and *Acomys* sp. were positively correlated to mounds though both were negatively correlated to soil depth.

TABLE 6.3 Correlations coefficients (*r*) of five species of rodents and habitat variables. P = 0.05; n = 2

Rodent species	% Gr cov	No. gr sp.	Soil depth	Burrows	Wo sp.	Mound	H fence
Otomys thomasi	-0.420	0.174	0.532	0.251	-0.163	-0.305	0.990**
Lemniscomys barbarus	0.987*	0.809	-0.989*	0.765	0.945*	0.954*	-0.375
Acomys percivalis	0.987*	0.519	-0.969*	0.509	0.815	0.888*	-0.651
Mastomys natalensis	0.307	0.222	-0.168	0.549	0.457	0.459	0.453
Arvicanthis nilotica	0.905*	0.493	-0.955*	0.437	0.758	0.832	-0.721

Where * *Implies significance at $p < 0.05$; ** = $p < 0.01$*; % Gr cov = percentage grass cover; No. gr sp. = number of grass species; Wo sp. = woody plant species; H fence = hedge fence

In general, vegetation cover had a greater influence on the distribution of most rodent species with exception of *O. thomasi* ($r = -4.20$, $p > 0.05$) and *M. natalensis* ($r = 0.307$, $p > 0.05$) both common in cultivated areas. More species were found to occur in areas with greater percentage grass cover and wood plant density, while very few were found not to occur in such areas. The *Lemniscomys, Arvicanthis* and *Acomys* species were more abundant in areas of higher plant species diversity, percentage grass cover, whereas *Otomys* species were found in low vegetation cover and plants species diversity. *Acomys* was found in areas with more barrow and mounds. However, this species was not limited to this site and occurred at a lower frequency in site with fewer burrows. Appendices 8 & 9 show the variation in numbers of individual rodent species in response to patterns of land use. *Mastomys* did not correlate to distribution of burrows and/or mounds.

6.3 DISCUSSION

Results show that small mammals may be strongly affected by the specific environmental conditions at various land use types. It seems probable that vegetation cover was used for predator avoidance and shelter from direct radiation. For these animals predator includes cats, snakes, eagles and other raptors (Tuner & Watson, 1965; Jones, 1978). Snakes were notably common. On one occasion unidentified species of bird was observed preying on *Otomys* sp. Elsewhere, Kundaeli (1978) suggested that climate and availability of shelter were important factors limiting the population of small mammals.

Cultivation could have resulted in the destruction of mounds and elimination of subterranean and herbaceous plants species some of which comprise food sources for rodent species. These changes may have both direct and indirect effects on rodents as disturbance removes vegetation, destroys nest sites and is also associated with alteration of soil environment and leads to exposure to predators. In this regard qualitative changes in the rodent communities occur when land is cleared and cultivated. For instance species such as *Lemniscomys barbarus* and *Arvicanthis nilotica*, which are associated with burrowing, were largely absent in cultivated sites. Thus the consequence of land use that leads to the removal of trees and herbaceous vegetation cover affects the survival of small mammal species. Sites with dense plant cover supported a higher diversity of rodent species. In desert habitats, small mammals diversity tend to increase with increase in plant cover up to a certain level above which diversity decreases (Abramsky & Rosenzweig, 1984, Kerley 1992). Similarly, Monadjem (1997) and Ferreira (2000) found that species diversity tended to be highest at intermediate values of plant cover. The observed rodent species diversity in this study corroborates the findings of previous studies.

Four of the five species exhibited significant correlations between their abundances and at least one of the measured environmental features. The low correlation coefficient suggests that other undetected feature were also influencing the distribution and abundance of rodents. This study was conducted partly during the dry season and therefore the effect of temperature and rainfall could not be assessed. Rodent populations exhibit great seasonal (Leirs *et al*., 1989) and year to year variation (David & Jarris, 1985). Food supply is another factor that influences small mammals biomasses (Soonan & Slade, 1995). In this study the highest small mammals biomass was recorded on fallow site, which appeared to attract all the five species or rodents captured. Perhaps in this site, food supply and shelter were favourable for the species.

Mastomys natalensis is highly adaptable (Meester Lloyd & Rowe–Rowe, 1979) a feature allowing it to inhabit a wide range of environmental conditions. This observation was not supported by the results of this study. *Mus minatoides* is reported to occur in almost any habitat (De graaff 1981, Rowe–Rowe & Meester, 1982). The association between species and cover in also documented (Bond *et al.,* 1980) as is that of *Otomys irroratus* and *Otomys* sp. with dense grass cover (De graaff 1981; Bond *et al.,* 1980). *Otomys* were the least affected by vegetation clearing, a phenomenon also observed by (De graaff, 1981; Bond *et al.,* 1980). This could be due partly to their ability to utilize a variety of food sources. *Arvicanthis nilotica* seemed restricted only to grassy habitats while in contrast, *Acomys percivalis* appeared to have the most diverse habitat range.

The ability for *Otomys* to survive land clearing may also be attributable to their nest building behaviour. Most species build nest below ground level in burrows. Consequently they may suffer lower nest damage and are sheltered from the effect of environmental change experienced by the surface nesting species after clearing. Nevertheless, species that construct burrows may also have a narrow microclimatic range.

Variability in percentage vegetation cover associated with different land use types was one of the most important factors affecting distribution of small mammal species. *Lemniscomys barbarus, Acomys percivalis* and *Arvicanthis nilotica,* were significantly correlated with percentage plant cover. However, vegetation cover was of lesser importance compared to the presence of hedge fences for *Otomys thomasi,* which predominated cultivated sites. Burrows occurred in association with hedge fences more than expected although none of the rodent species correlated with their prevalence. Barrow-hedge fence connection may arise from rampant damages to them (burrows), within the cropland during tilling as opposed to the edges where hedge fences are mostly located. Unlike burrows however, the distribution of *Lemniscomys barbarus* and *Acomys percivalis* correlated significantly to prevalence of mounds. Since the two species were common in sites lower in human use, it is perhaps possible that those sites used for cultivation and grazing experienced frequent disturbance of burrows and mounds thereby limiting their availability. Rodents in cultivated sites are also commonly predated upon and killed by domestic pets and farmers respectively. In addition, termites form a significant number of burrows present in these sites. This perhaps explains the observed disparity between distributions of burrows/mounds and species of rodents.

Some particular plant species like *Combretum* sp*,* correlated with greater number of rodents even though this could not be linked to aspects like diet since knowledge regarding the available plant species as food component for study organism is lacking (Blake *et al.,* 1990). A similar study in a bushed grassland site in Uganda, Neal (1970) found that the distribution of small mammals species was associated with the distribution of plant species other than those observed in this study. However, unlike Neal (1970), abundance of burrows did not correlate to rodent species diversity.

Results obtained in this study suggest that the ecological response of small mammals is significantly determined by microhabitat component. Inter-site variation in distribution of *Lemniscomys barbarus* and *Otomys thomasi* is due to the differences in habitat types arising from diverse land uses, which in turn determine distribution and availability of resources. These results are consistent with the hypothesis that land use pattern has impacted on the distribution of small mammals in Mbeere district. Areas without extensive crop production correlated with high quality habitat. Agricultural expansion onto marginally productive soils in LM5 has reduced native vegetation cover and consequently the diversity of small mammals. The ecological response of small mammals to changes in the environment is a potentially useful indicator of alteration in local environmental conditions such as habitat modifications caused by man (Kuhnelt *et al.,* 1976). With the increase in cropping replacing bush and pasture, it would be expect that diversity of small mammals species would decrease while the population size of *Otomys thomasi* may increase considerably over time. Therefore, a brief regular survey of the diversity and distribution of the small mammals (as indicator species) in this site would help one to detect whether the ecosystem is stable or not (Seddon & Tattersfield, 1996). The separation of species with apparently similar environment requirements can largely be explained in terms of current land use practices and biology of species (Neal, 1984).

CHAPTER 7

7.0 CONCLUSION AND RECOMMENDATIONS

7.1 CONCLUSION

Rodents play an important role in ecosystems. Their importance in carbon and energy fluxes in the trophic structure is widely accepted (Soul'e, 1991). For example rodents constitute a major food resource to a number of bird species. An in-depth study on the proportion of food contributed by rodents to these and other species of bird is necessary. Similarly, the importance of rodent behaviour in enhancing decomposition of plant matter in natural ecosystem is needed. Elsewhere, Noss and others (1994) documented the role of rodents in facilitating decomposition of plant matter. Their findings suggests that a reduction in rodent diversity and abundance would have a negative impact on ecosystems in terms of energy flow and nutrient cycling though short term agricultural productivity is likely to be enhanced. However further research is required to assess this interaction fully in view of long term ecosystem structure and function. This study showed that species diversity of rodents decline when natural vegetation is cleared and the land cultivated. Vegetation clearing in cultivated site resulted in drastic reduction in the number of species to about 40% of what existed in natural (Bushy) sites. Reduction in small mammals diversity alter ecological processes and perhaps may result in diminishing ecosystem balance with time.

Anthropogenic activities that foster fragmentation and modification of natural habitats continue to pose serious threat to biological diversity. In this study, indices of habitat diversity over locations varying in land use, related to diversity of both plant and rodents species. Distributional surveys at the four sites and detailed line transects suggests that patterns of population changes associated with disturbance is complex. Several factors have been found to influence diversity and distribution of small mammals as discussed in the preceding chapters. If these factors indeed influence the study species in different ways, then the observed variability in diversity and distribution would be clearly explained. Since the study species were in the same locality, it is possible they experienced similar ecological factors like interspecific competition, predation and weather conditions and therefore the observed demographic variation was solely as a result of land use patterns.

A major problem in effective conservation of biodiversity in East Africa is the lack of knowledge of the impact of anthropogenic transformation of natural habitats outside protected areas and the influence of these changes on various ecosystems (Macdonald, 1989). The well being of these populations is dependent on the quality of the habitats (Maclean, 1993). Mammals and particularly small mammals, being highly dependent on natural habitat as demonstrated in this study, are threatened with reduction of their diversity, if not with extinction, due to the rapid and irreversible degradation of habitats occurring throughout most of the sites. Particularly vulnerable are those species with low numerical abundance for example *Acomys percivalis* or those restricted to one or a few habitats e.g. *Arvicanthis niloticus*. These results are consistent with the hypothesis that land use pattern has impacted on the distribution of small mammals in Mbeere district. Areas without extensive crop production correlated with high quality habitat. Agricultural expansion onto marginally productive soils in LM5 has reduced native vegetation cover and consequently the diversity of small mammal. This contradicts the common belief that distribution of rodents follows that of humans. However, typical pest species like *Otomys* appeared to prefer sites under cultivation and grazing. Given that most of these habitats are being fragmented into small-disturbed patches, the ability of mammals to survive in such areas is of great importance in formulating conservation strategies. For a number of species e.g. *Otomys*, the ability to persist following habitat disturbance may be correlated with their biology and the emerging modified habitat factors.

7.2 RECOMMENDATIONS

Integrative management and sustainable exploitation of unprotected areas can increase substantially the size of populations that can be conserved over the long term. One fundamental goal of managing ecosystems is to maintain or restore their natural structure and function (Noss and Cooperrider, 1994). Outside reserves we may accept some compromise in reaching this goal. Human land use for subsistence leads to degradation and is generally incompatible with the maintenance of high levels of biological diversity (Vasant-Saber Wal, 1996). Nevertheless land use practices need not lead to degradation or to a decline in biological diversity but should lead to more inclusive conservation policies outside and beyond protected area boundaries. Implementing restrictive policies is further associated with difficulties and should be discouraged.

Harnessing traditional knowledge on local biodiversity, as a conservation tool and integrating land use with conservation management practices is likely to yield better results than is currently experienced. Some of the current aspects, as well as new approaches to land use can be exploited to enhance conservation of biodiversity. This can be achieved through creation of programmes that continuously tap indigenous knowledge, monitor, research and educate as well as formulate an integrated sustainable land use approach that foster local wildlife management and community development. The benefits maybe enhanced by better biological information for management, greater local participation in the programme operations and dispensation, as well as the promotion of ecological and ethical standards for land use. A local system of certification and recognition could foster this improvement.

In addition, it is vital to build individual and institutional capacity for better understanding and management of biodiversity at local, national and regional levels. For example creating ethno-botanical / zoological projects that targets and harnesses the links between the local people and the local plants / animals as a means of conserving both biological and cultural diversity, while at the same time improving the well-being of people through the sustainable use of local resources. Emphasis should be laid on capacity building through action – oriented problem solving research and formal/informal training for university students, professional and local community members using practical activities directed at reinforcing peoples ability to analyze and solve local problems while at the same time exposing trainees to the realities of conservation and related development issues.

The results of investigations covering different aspects are returned to the community enabling them to use local biodiversity sustainably and maximize the benefits. Awareness through media, film shows and slide lecture presentations at formal / informal workshops for local people and authorities is required. The community should be left to reap direct benefits from fauna / flora conservation, which will enhance peoples perceptions. In order to succeed, strong local support should be marshaled, which means listening to concerns and working cooperatively with residents to ensure conservation proposals that truly benefit affected communities. Otherwise this may create resentment and lack of grassroot commitments. Another approach may be to encourage locally adapted crops, e.g. cow peas and activities such as bee keeping, curio-shops and ethno-botanical gardens which do not require intensive tillage, while enhancing greater market access and supplementing crop prices as a means to sustain production without the need to over cultivate.

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APPENDICES

APPENDIX 1. Checklist of mammals found in Gachoka area and its environs

Common name	**Scientific name**
African elephant	*Loxodonta africana*
Rothschild giraffe	*Camelopardis reticulata*
Zebra	*Equus burchelii*
Hippopotamus	*Hippopotamus Amphibius*
Sykes monkeys	*Cercopithecus mitis*
Vervet monkeys	*Cercopithecus mitis*
Olive baboons	*Papio anubis*
Common duiker	*Sylvicapra grimmia*
Red legged sun squirrel	*Heliosciurus rufobrachium*
Slender mongoose	*Hapestes sanguineus*
Rock hyrax	*Procavida johnstonii*
Swamp rats	*Otomys thomasi*
Striped grass-mice	*Leminiscomys barbarus*
Unstriped grass-mice	*Arvicanthis nilotica*
Spiny mice	*Acomys percivalis*
Multimammate rat	*Mastomys natalensis*

APPENDIX 2. Checklist, body mass (g) and frequency distribution of species of rodents caught at 4 sites in Mbeere district between the month of September and December 2001

	Number of rodents caught at each study site					
Species	Cultivated	Grazing	Fallow	Bushy	Mass (g)	SE
Otomys thomasi	9	27	39	0	107.1	12.1
Lemniscomys barbarus	0	5	27	44	34.8	6.2
Arvicanthis nilotica	0	0	3	6	83.9	5.8
Acomys percivalis	3	3	11	18	24.9	1.4
Mastomys natalensis	0	0	16	2	63.5	8.5
Total	12	35	86	50		

RAW DATA ON VEGETATION VARIABLES IN THE SITE

APPENDIX 3. Data on Frequency distribution of trees and shrubs in sites with varying land use

Species	***Cultivated***	Grazed	Fallow	Bush
Terminalia brownii	2	1	14	30
Cassia bicapsularis	0	2	16	16
C. siamea	1	0	20	25
Boswellia neglecta	0	0	2	15
Combretum sp.	1	8	12	33
Acacia tortilis	0	7	21	18
A. robusta	0	2	13	9
A. ataxantha	0	3	5	11
Polyfera sp.	0	1	4	8
Delnex errata	0	1	0	4
Grevillea robusta	3	2	0	0
Azadirachta indica	0	0	1	0
Lantana camara	4	12	8	6
Baranoites peridiuraris	1	0	6	2
Rhus natalensis	1	1	5	7
Vitex doniana	0	0	4	6
Mellia vokensii	0	0	3	7
Securigega virosa	0	0	2	6
Gnidia subcordata	0	3	3	0
Aspilia mossambicensis	6	4	7	4

APPENDIX 4. Frequency distribution of grass species present in sites with different land use

Grass species	Cultivated	Grazed	Fallow	Bushy grassland
Dactyloctenium aegyptium	0	3	12	2
Chloris pilosa	18	25	25	17
C. pycnothrix	33	37	28	14
Penisetum ramosum	0	11	13	17
Digitaria milanjiana	22	26	14	8
D. adscendens	8	13	5	9
D. scalarum	4	6	4	10
Brachiaria leucacrantha	7	2	6	4
Sporobolus marginatus	0	0	5	40
Eragrostis superba	0	10	17	24
Eragrostis aspera	0	5	12	13
Panicum makarikariense	0	0	7	0
Vetiver zizamoides	0	0	5	0
Themeda triadra	0	11	16	17
Crotolaria sp.	4	10	6	0
Oxygonum sinuatum	8	26	14	0
Euphorbia heterophyla	4	11	13	0

APPENDIX 5. Raw data on physical habitat variables obtained in varying land use sites in Mbeere.

Variables	CULTIVATED							GRAZING						FALLOW						BUSHY								
Barrow	1	1	1	1	1	0	1	5	2	0	2	4	5	3	4	3	3	4	2	5	2	3	3	2	2	2	1	2
Mound	0	0	1	1	0	0	0	3	1	1	0	3	2	3	3	3	3	3	3	5	2	4	4	5	5	5	5	3
Soil depth	22.5	20.8	20	15.8	31.7	15	15.8	27.5	13	16.7	15	9.3	12.5	10.8	17.5	11.7	11.7	14.2	20.8	10.8	11.4	2.5	3.3	4.2	4.2	4.2	5	2.1
Tree/Shrub	4	3	3	4	3	0	0	2	0	1	4	4	3	4	2	3	5	5	4	7	1	5	8	8	7	7	8	4
Fence	1	2	2	1	1	0	3	4	1	0	0	2	2	2	4	2	2	2	3	3	1	6	1	0	0	0	0	0
Percentage cover	0	2	0	2	2	0	6	13.3	1.2	22.5	17.7	18.5	22.7	19.2	15.8	17.5	23.3	34.2	35.7	7.7	15.1	53.3	48.3	40.8	43.3	45	32.5	42.5
Cover arcsines	0	8.13	0	8.13	8.13	0	14.2	21.1	6.29	28.3	24.9	25.5	28.5	26	23.4	24.7	28.9	35.8	36.7	16.1	22.9	46.9	44	39.7	41.2	42.1	35.4	40.7

RAW PHYSICAL HABITAT VARIABLES

APPENDIX 6. Correlation coefficient (r) for habitat variables recorded in the Mbeere study sites.

Cultivated Site				
Variables	Mound	Fence	% Cover	Depth
Mound	+			
Fence	+	+		
%Cover	-	-	+	
Depth	-	-	+	+
Barrow	+	+	-	-
Grazing Site				
X	Mound	Fence	% Cover	Depth
Mound				
Fence		+		
%Cover		+	+	
Depth		-	-	+
Barrow		-	-	+
Fallow Site				
X	Mound	Fence	% Cover	Depth
Mound	+			
Fence	+	+		
%Cover	-	-	+	
Depth	-	-	+	+
Barrow	+	+	-	-
Bushy Site				
X	Mound	Fence	% Cover	Depth
Mound	+			
Fence				
%Cover	+		+	
Depth	-		-	+
Barrow	+		+	-

Where: + refers to positive correlation & - refers to negative correlation at $p < 0.05$

RAW DATA ON PERCENTAGE GRASS COVER ESTIMATES

APPENDIX 7. Percentage grass cover estimates and their arcsines (in brackets) recorded in four Mbeere study sites

Cultivated	Grazing	Fallow	Bushy
0.0(0.00)	13.3(21.13)	15.8(23.42)	53.3(46.89)
2.0(8.13)	1.2(6.29)	17.5(24.73)	48.3(44.03)
0.0(0.00)	22.5(28.32)	23.3(28.86)	40.8(39.7)
2.0(8.13)	17.7(24.88)	34.2(35.79)	43.3(41.15)
2.0(8.13)	18.5(25.47)	35.7(36.69)	45.0(42.13)
0.0(0.00)	22.7(28.45)	7.7(16.11)	32.5(35.37)
6.0(14.18)	19.2(25.99)	15.1(22.87)	42.5(40.69)

APPENDIX 8. Arcsine transformation of percentage abundance of rodent species in each site.

Species	Cultivated	Grazing	Fallow	Bushy
Otomys	60	61.41	42.3	0
Lemniscomys	0	22.22	34.08	69.73
Arvicanthis	0	0	10.78	20.27
Acomys	30	67.78	20.96	36.87
Mastomys	0	0	25.55	11.54

APPENDIX 9. Arcsine transformation of percentage abundance of rodent species in the entire study site

Species	Cultivated	Grazing	Fallow	Bushy
Otomys	11.83	20.88	25.33	0
Lemniscomys	0	29	20.79	26.99
Arvicanthis	0	0	6.8	32.08
Acomys	6.8	6.8	13.18	66.82
Mastomys	0	0	15.89	75.7