THE INFLUENCE OF LAND USE PATTERNS ON DIVERSITY AND ABUNDANCE OF RODENTS IN GACHOKA DIVISION OF MBEERE DISTRICT, KENYA

BY

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2004

DECLARATION

I hereby declare that this is my original work and has not been presented for award of a degree in any other university.

………………………………………… 18/11/04 …………………………………

SIMON MBUGUA MUGATHA **DATE**

I56/7093/99

This thesis has been submitted for examination with my approval as university supervisor

………………………………………… 18/11/2004 …………………………………

Dr. P. N. NDEGWA **DATE**

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DEDICATION

To my father, Stephen Mugatha, my mother Jecinta Wangui, brothers, Joseph Ngugi, Peter Karanja, Peter Munge and Jesse Mwangi, and to my sisters, Agnes Nyambura, Agnes Murugi, Alice Wanjiku and Ann Njeri, to my dear wife Josephine Mumbi, to Mbugua Gikonyo and to the memory of the late Joel Mwangi Gathua, without whom this work would have never been.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

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ABSTRACT

This study was conducted in Gachoka division of Mbeere district Kenya, between the months of September and December 2001. The aim of the study was to establish how patterns of land use influences the diversity, distribution and abundance of small mammals in various habitats types under varying human influence and assess which of the measured habitat parameters strongly influence diversity of rodents, information which is hitherto not well documented in Gachoka division of Mbeere district. The study also sought to determine how land use practice influences habitat conditions with a view of identifying possible indicator species for the site. Various habitat factors, such as plant species composition, percentage vegetation cover, plant density and diversity, burrows, and mounds, all of which influence diversity, distribution and abundance of small mammals were determined in various land use types in the semi-arid region of 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 in four land use types, namely cultivated, grazing, fallow and bushy sites. All rodents sampled were identified to species level. Data on vegetation parameters was obtained through a habitat survey conducted using transects. The number and composition of woody plant species, number of burrows and mounds 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 the transect line. The area sampled for habitat parameters corresponded with trapping points of small mammals.

A total of 213 specimens comprising of five species of Murids were recorded. Three species, *Lemniscomys barbarus* (Linnaeus), *Otomys thomasi* (Thomas) and *Acomys percivali* (Dollman) were the most abundant with percentage abundance values of 35.6%, 35.2% and 16.4% of total captures. Burrows were found to occur with greater incidence near the edges of cultivated areas while in uncultivated (fallow and bushy grassland) sites burrows were situated under trees and shrubs alongside mounds. Mounds distribution was associated with distribution of woody plants. However, no relationship between mounds or burrows to particular plant species was observed although both tended to occur less frequently under trees than shrubs. Unlike burrows, vegetation cover was correlated with abundance of rodent species.

Bushy grassland and fallow sites provided greater diversity of plant (H' = 1.20; 1.21) and small mammal species (H' = 0.5; 0.7) respectively, compared to cultivated and grazed lands. Abundance of *Lemniscomys barbarus* and *Acomys percivali* was found to be greatest in uncultivated (bushy and fallow) sites, while *Otomys thomasi* was dominant in cultivated and grazing sites. The fallow land, which is considered intermediate between cultivated and bushy sites (based on the measured habitat parameters), had the highest diversity of trees/shrubs (H' = 1.21), grass (H' = 1.08) and small mammal species (H' = 0.7). This site hosted all of the five species of rodents in varying proportions.

This study demonstrates that non-opportunistic small mammal species like *Arvicanthis niloticus* was restricted to natural bushy environment, and therefore requires persistence such habitats to survive. Bush clearing in this area therefore jeopardizes the future survival of the species. The rodent species composition in Mbeere was nevertheless 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.

CHAPTER ONE: INTRODUCTION AND LITERATURE REVIEW

1.0 INTRODUCTION

The term land use refers to immediate activities that change habitat conditions, which has ecological consequences on both fauna and flora. For plants and animals, aspects of land use can be measured. A typical example of land use activity is agriculture. With the rapid increase in human population, large tracts of existing wild arable lands are being degraded continually after being converted to agricultural fields. It is commonly assumed that opportunistic species particularly pests, increases with increased agricultural activities and deteriorating habitat conditions, while specialized non-pest species decrease (Primack, 1993). Some studies have however reported contradictory findings on the role of land use on the distribution of opportunistic small mammal species (Gilpin & Diamond, 1986). Although there is a general consensus that diversity of species decrease in exploited 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 (Hartenberger, 1985). 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 major threats of maintaining biological diversity (Harris, 1984; Wilcox & Murphy, 1985). Isolation and diminishing size of remaining habitats increases the probability of extinction through demographic, environmental or genetic stochastic processes (Wiens, 1976; Harris, 1984; Wilcove *et al.*1986; Goodman, 1987; Soulé, 1991;

Adren, 1994; 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 (Soulé, 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 (Fiedler, 1994).

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, 1993), birds (Wiens & Rotenberry, 1985; Hill *et al.*, 1991), and mammals (MacArthur & Pianka, 1966; Struhsaker 1975; Charnov, 1976; Clutton-Brock & Harvey, 1977; Wrangham, 1980; Crompton, 1984; Harcourt, 1986; Boinski, 1987; Chapman & 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 factors. Food (Bennett, 1986), location of burrows (Ajayi, & Tewe, 1978; Davies, 1994), interaction between conspecifics, 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), 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 in 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 the 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 information on specific requirements of most species has not been collected 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 and distributions. 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 drier 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. This study therefore aims at assessing the ecological consequences of land use patterns on the distribution and abundance of small mammals in Mbeere district, Kenya.

1.1 LITERATURE REVIEW

1.1.1 Influence of habitat alteration on ecology of small mammals

Habitat factors have pervasive effects on behaviour and spatial organization of organisms (Altmann & Altmann, 1970; Wrangham, *et al.* 1993), and are believed to be key factors determining the richness of small mammal communities and the abundance of particular species (Bourliere, 1975; Davies, 1994). 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 or of poor nutritional quality (Radolph & Cameron, *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 & Dickson (1985) observed seasonal variation in numbers of small mammal species and that species distribution correlated with different microhabitat parameters. Other investigators (Delany & Neal, 1966; Taylor & Green, 1976; Neal, 1970; Cheeseman & Delany, 1979 and Chidumayo, 1980) reported similar observations while Ajayi (1977) noted a correlation between location of burrows with physical and chemical characteristics of soil. However, Martin & Dickson (1985) argue 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 consequence of 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 (Pickett & Thomson, 1978), windfall (Foster, 1980), flood and volcanicity (Mentis & Ellerry, 1994). However, the most important and large-scale cause of habitat modification is the expansion and intensification of human land use (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 & Murphy, 1985; Wilcox, 1990; 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 (MacArthur & Pianka, 1966; Struhsaker 1975; Charnov, 1976; Clutton-Brock & Harvey, 1977; Wrangham, 1980; Crompton, 1984; Harcourt, 1986; Boinski, 1987; Chapman & Chapman, 1990; Spencer *et al.*, 1990; Remis, 1997). Other works demonstrate that habitat structure determines dispersion amongst small mammals (Neal, 1984), primates (Harrison, 1983), birds (MacArthur & MacArthur, 1961; Pianka, 1967) and desert lizards (Abramsky & Rosenzweig, 1984).

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 (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. A measure of habitat diversity reflects the degree of habitat suitability to numerous species of rodents. A major form of habitat alteration 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.*, 1980). 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 between managed remnant fragments.

1.1.2 Taxonomy and diversity of rodents

Rodents range in size from the crested porcupine (*Hystrix cristate*) which weighs an average of 20 kg, to the small African pigmy mouse (*Mus minutoides*), weighing an average of 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 & Reader 1993; Fiedler 1994). Wilson & Reader (1993) put the number of rodent species to be 2,015, which is more than twice the 925 species described for the next largest order, Chiroptera, which has 17 families and 177 genera. 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 numerous parts of the world with 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.

The genus *Apodemus, Clethrionomys* and *Microtus* are widespread and common in Europe while the genus *Dipodomys, Microdipodops* and *Cynomys* are found in North America. The genus *Muscardinus* and *Typhlomys* are well represented in Europe and Asia. *Praomys* is one of the commonest and most widespread genus of rodent 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 & Dickson, 1985; Ajayi, 1977). Africa has about 89 genera and 290 species of rodents belonging to 14 families. A number of rodent species are known to be endemic to different areas. For instance, Odhiambo (2000) describes *Praomys taitae* as an endemic species in the Taita hills, 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 rodents' distribution in different continents is difficult due to the fact that many tropical areas are not adequately sampled (Soulé, 1991). The most critical factors that have been found to influence their distribution are food and shelter (Cooney *et al.,* 1982). However, though some species are opportunistic and others appear to have specialized diets, food 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 grasslands (Kingdon, 1974; Delany, 1975; Delany & Happold, 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 (Meserve, 1981). According to the marginal value theorem, a species will leave a given habitat when critical resources drop below the average for that habitat (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, 1982). Deaths and low density of some small mammal population are reported to coincide with severe habitat conditions (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 & Dickson, 1985; Spencer *et al.*, 1990; Monadjem, 1997). For instance, removal of vegetation cover through agricultural cultivation reduces the species diversity of small mammals (Ajayi, 1977).

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 use of habitat. Many studies have investigated the diversity and distribution of small mammals (Delany, 1964; Delany & Neal, 1966; Neal, 1970; Cheeseman, 1977; Martin & Dickson, 1985; Monadjem, 1997) but none of them has investigated the influence of land use. More over, no such studies have been conducted in Mbeere district, Kenya. 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.

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 (Christian, 1980). 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 & Reeder, 1993).

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. Leishmaniasis is by far the most important rodent associated disease in east Africa, where rodents serve as reservoirs and / or vectors. Other diseases affecting humans or livestock and involving rodents in 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 the African pigmy mouse and possibly the black rat have been reported to host 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 of antibodies to Lassa virus have also been found in *Praomys* and *Arvicanthis niloticus*

(Desmarest) in Tanzania and antibodies were found in 12 to 13% of human sera from western Sudan (Grazt, 1998). 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 (Van der-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 not well understood or has not been confirmed.

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 amphibians, reptiles, birds of prey and some medium mammals of the cat family. 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. Nevertheless, the importance of rodents as facultative agricultural and domestic pests perhaps arises from encroachment on their natural habitat by humans.

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 in the area.

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 does habitat factors influencing small mammals vary with land use practice on the site of study? 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 Gachoka division of 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.

CHAPTER TWO: MATERIALS AND METHODS

2.0 INTRODUCTION

Measurement of habitat parameters is based on estimating the frequency of their occurrence in the study site. Parameters measured here are those reported elsewhere as having important influence on the diversity and distribution of small mammals (Cheeseman, 1977; Ajayi & Tewe, 1978; Spencer *et al.*, 1990; Oguge, 1995 *unpub*; 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 under field conditions except by inference. Even deciding which reactions result from which environmental stimulus is sometimes difficult (Gathua, 2000). For example Martin & Dickson (1985) 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 (Primack, 1993); and the habitat type (Oguge, 1995 *Unpub*; Monadjem, 1997) are known to influence the choice of rodent sampling method. An example of how size and 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 rodent 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 & Happold, 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 burrowing 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. As such an attempt to sample rodents in all these places would require the use of a carefully designed sampling technique.

In this study, data on rodent species composition and abundance, occurrence of burrows and mounds, soil depth, vegetation species composition, percentage cover and growth forms were collected in four sites selected from the four most common land use practices in the study area. Methods were chosen if they allowed sampling of a fairly adequate area within a short time without jeopardizing the results of the study objectives, and had a 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) All rodents responded in the same way to the baited traps and to the handling of specimens.

(ii) All individual rodents irrespective of species had equal chances of being trapped.

2.1 STUDY AREA

2.1.1 Location, Climate and Agro-Ecological zones

This study was conducted in Gachoka division, Mbeere district, Kenya (Figure 1, 2 & 3.). 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 administrative divisions forming Mbeere district which is located in the Eastern province of Kenya. 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^{0}C and 32^{0}C. August is usually the coldest month whereas March is the hottest month (GOK, 1997).

The study area falls under eco-climatic zones IV and V of Pratt & Gywnne (1965) classification, and corresponds respectively to two main agro-ecological zones - the marginal cotton zone (LM4) and the lower midland livestock millet zone (LM5). The marginal cotton zone corresponds to the transitional zone from semi humid to semi arid

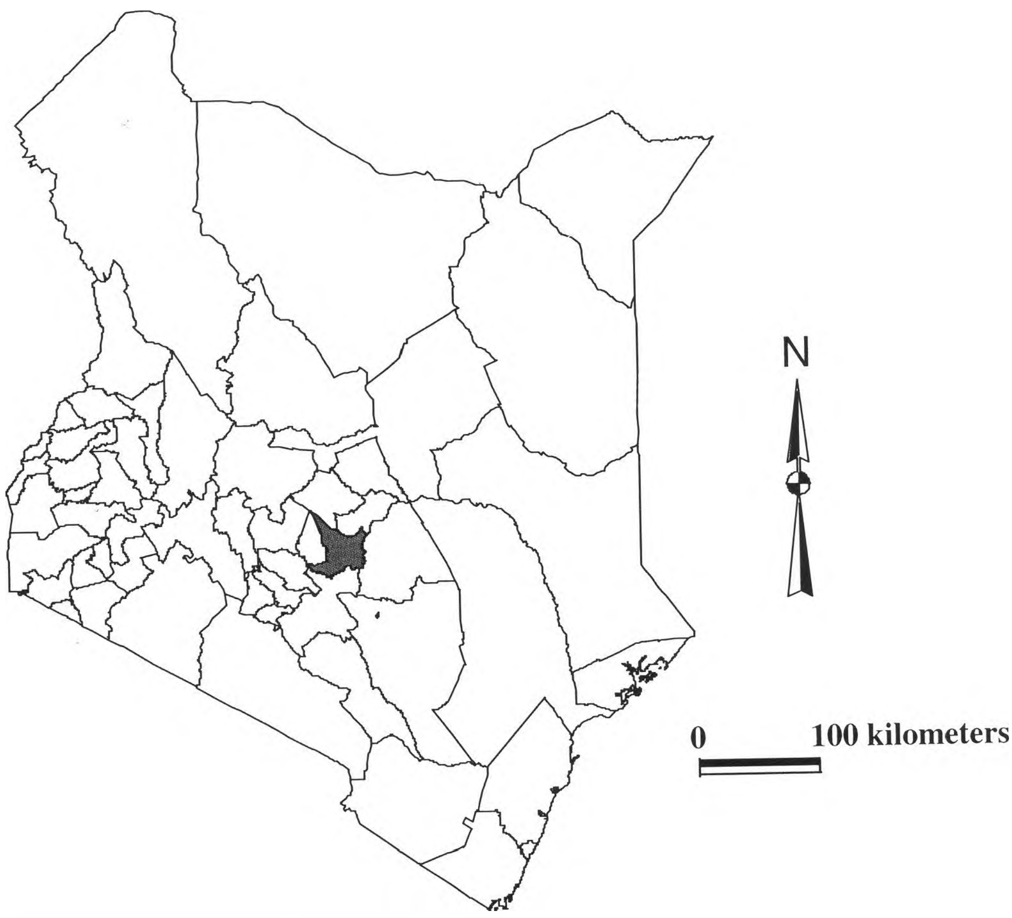

FIGURE 1 Mbeere district in the national context.

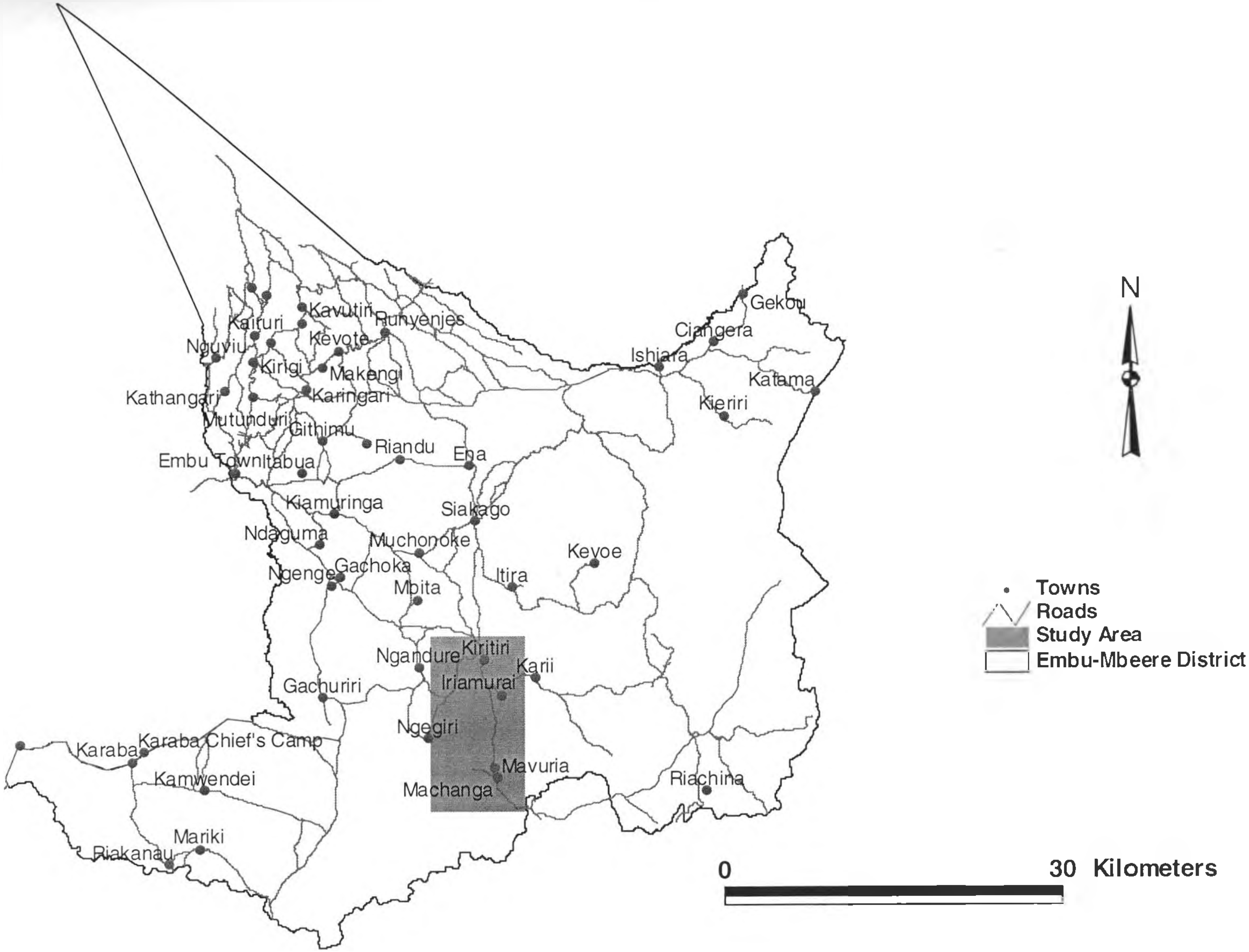

FIGURE 2.2 Study area and its environs: Administrative and regional settings.

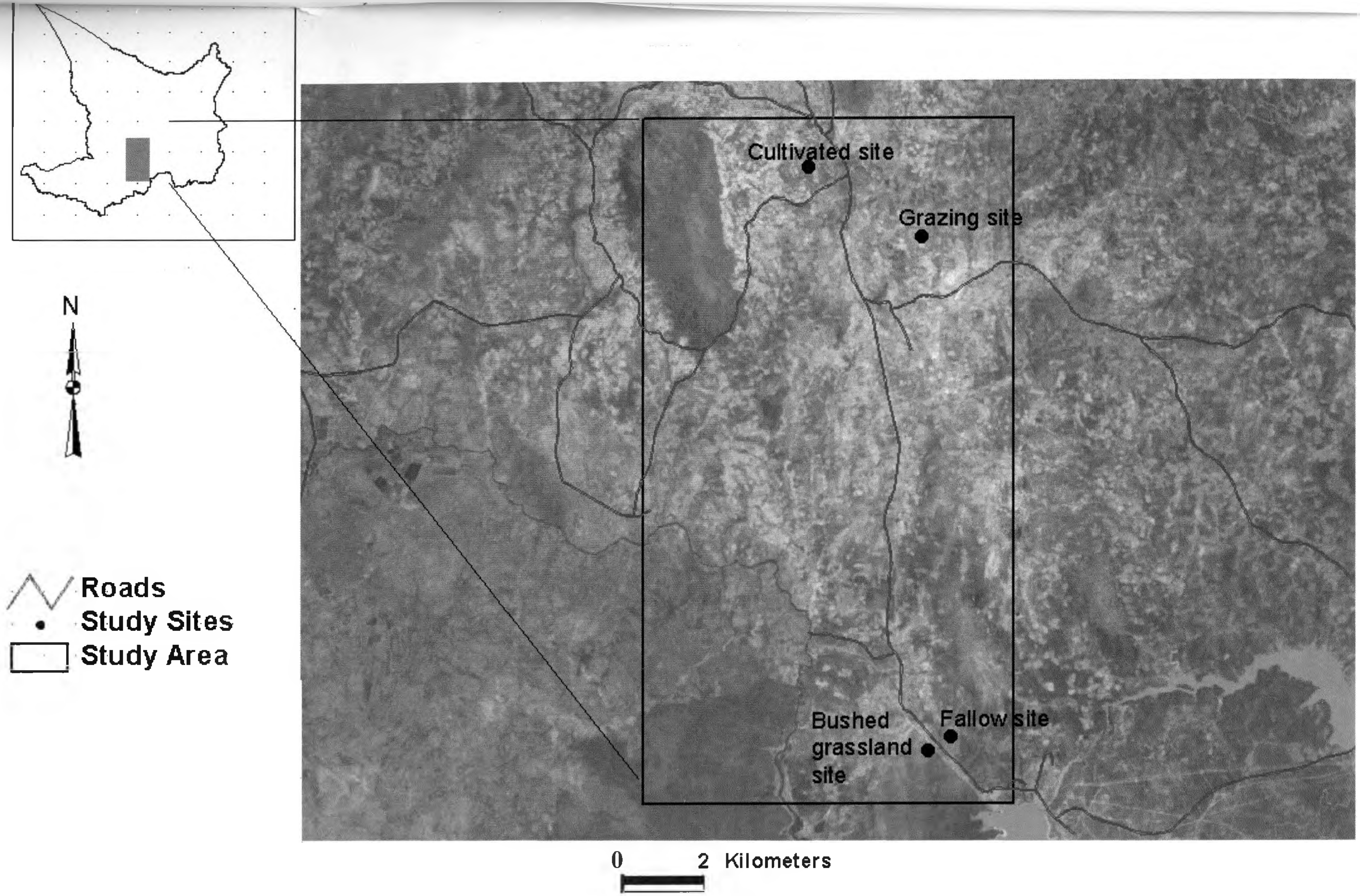

FIGURE 2.3 Satellite image showing the location and the vegetation cover surrounding the different land use sites in the Mbeere study area.

zone. It rises 980-1130 meters above sea level and rainfall ranges between 800-900 millimeters per annum. The lower midland livestock millet zone represents the semi arid area. The zone rises 830-1130 meters above sea level. Rainfall ranges between 700-800 millimeters per annum.

2.1.2 Topography, Drainage and Soils

The area slopes in a northwest to the southeast direction. The slope is however broken by the Kianjiru and Kiambere hills, at 1560 and 1525 meters above sea level, respectively. The lowest part is the Tana valley that falls to 600 meters, reaching its lowest point at the confluence of Tana and Mutonga Rivers at approximately 570 meters above sea level. The area is characterized by a rugged topography. Gullies, resistant rocks and soil outcrops are a common feature in the region (Njeru, 1978).

Numerous seasonal streams drain into Tana, Thiba and Rupingazi, which are perennial rivers. This includes Itabua, Nguu and Thura. A number of springs along the foothills of Kianjiru and Kiambere hills also occur.

The influence of altitude and climate on the underlying geology has given rise to varying soil types, 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.

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 activity also occur. The rock types are mostly Mount Kenya phonolites, kenytes and tracytes. The Precambrian series are characterized by a series of intrusive 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 (GOK, 1997).

2.1.3 Plant and Animal Communities

The natural vegetation is savannah type with *Comiphora, Acacia, Combretum* and numerous grass species. Mwea National Reserve is one of the gazetted forests in 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) (GOK, 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 Gachoka division in 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*), plains zebra (*Equs burchalii*), hippopotamus (*Hippopotamus amphibius*); primates such as Sykes (*Cercopithecus mitis*), vervet monkeys (*Cercopithecus aethiops)*, Olive baboons (*Papio anubis.*) and antelopes like Common duiker (*Sylvicapra grimmia*). Similarly, the avifauna is remarkably diverse and perhaps hosts a rich assemblage of dry land species of birds.

2.1.4 General Land Use and Conservation Needs

Gachoka division 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 area. The division 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 division is marginally suitable for livestock activities. Of this, 56% 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*), cowpeas (*Vigna unguiculata*), mangoes (*Mangifera indica*), cassava (*Manihot esculenta*) and pawpaws (*Carica papaya*). Cotton (*Gossypium* sp.) and tobacco (*Nicotina tabacum*) have for a long time been 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 area, 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 uncleared since adjudication particularly on the lower eastern zones of the division due to 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.

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 latter 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. Gachoka division 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 SMALL MAMMAL SAMPLING

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.

Four sites were selected within the study area (Fig. 2.3). Each of the sites represented a distinct land use category namely Cultivated, Grazing, Fallow and Bushy. Land was considered to be cultivated if it was cropped and tilled regularly while grazing land was one which was primarily used for grazing free ranging and/or tethered livestock. Land was considered to be fallow if cultivation on it was abandoned at least five years ago and was not put into any other productive use particularly the grazing of domestic animals. Bushy site is one, which has never been cultivated and/or grazed before. This site served as the control for this study. In each site, a square grid of 64 live wire gauge 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) to capture rodents. Each trap was set and inspected twice a day, for 3 consecutive days per month for three months. All specimens captured were identified to species level. 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 abundance of rodents was estimated by using small mammals' wire gauge traps, measuring 26 x 18 x 31 cm, and positioned at 10m intervals. The type of traps ensured that only mammals smaller than 10cm wide and/or high were caught (Odhiambo, 2000). The traps were sufficiently numerous to ensure that no animal was ever excluded due to prior occupancy. Captures above 80% of the set traps 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 (Oguge, 1995 *Unpub*; Monadjem, 1997 and Ferreira & Van Aarde, 2000). 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 photographs and preserved rodent collection in National Museums of Kenya, and rodent taxonomic literature (e.g. Delany, 1964, 1974; Kingdon, 1997). 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.

Previous studies on microclimatic factors have shown that altitude is an important factor in determining the type of microhabitat (Trapnell & Brunt, 1987; Bussmann, 1994). For this study, altitude was determined using a topographical map (1:50,000) and a geographical positioning system (GPS). All plots and their replicates were selected from a homogenous vegetation type.

2.3 VEGETATION SAMPLING

To compare the land use types in terms of plant species composition, density, and herbage cover, a survey was conducted within the grids set for the capture of rodents, using line transects (Figure 4). In each grid, a set of three parallel transects, 20m apart, were sampled for the number and composition of woody plant species. Trees and shrubs (with diameter at breast height (DBH) > 5 cm) were identified to species level and enumerated in 10x10m quadrat, placed at 10m intervals on each of the three transects. The measurement of grass and herbaceous species composition and its percentage cover was carried out in 1m x 1m quadrats, also placed at 10m intervals on the transects. Species were identified and enumerated in each quadrat and the percentage of the area covered by this layer estimated.

A total of six replicate transects, spaced at 20m interval were sampled in each site corresponding to the rodent trapping stations.

2.4 PHYSICAL HABITAT VARIABLES

In order to find out the effect of land use on habitat parameters, three variables, namely soil depth, burrows, and mounds, were assessed in each land use type. Soil depth was estimated using a pin of 0.25mm in diameter and calibrated along its length to the nearest 5cm. The pin was pressed gently into the ground until it stopped or the 50cm mark was attained. The reading of soil depth was made on the pin at the ground surface. Three replicates were taken in each 1m x 1m quadrant making a total of 36 samples. On the other hand, burrows and / or mounds were counted in 5m x 5m quadrats placed at 5m intervals along the transects. A total of seven quadrats were sampled on each transect. The heterogeneity of habitat was then expressed in terms of abundance and density indices obtained from these variables. The area sampled for habitat parameters corresponded with trapping points of small mammals.

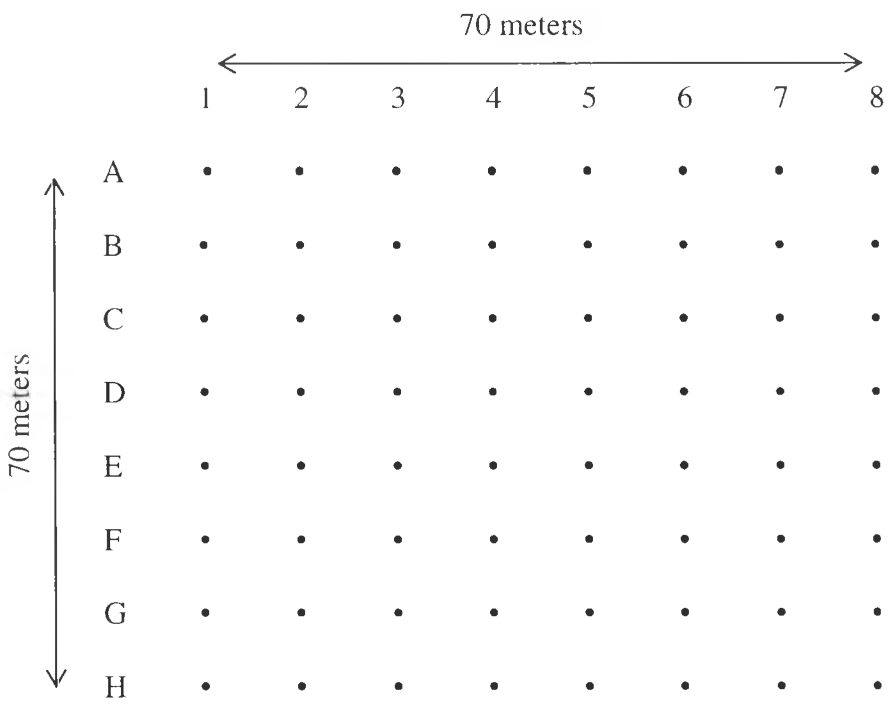

FIGURE 4. Schematic presentation of a trapping matrix. Each dot represents a trapping station, whose position was identified by letters and figures combined.

2.5 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 were 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.

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. 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.

At each site the total number of individuals of each species caught was used as a relative measure of abundance. The number of species in each land use type was the overall number of species captured from that particular site (two 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 & Van Aarde (2000). Rodent density was calculated by dividing the number of rodents captured by plot size, which was expressed as number of rodents per hectare.

Species diversity of plants and small mammals was calculated using the Shannon index of diversity, $H' = -\Sigma pi \ln pi$, where pi is the proportion of the i^{th} species in the habitat (Shannon & Weaver, 1949; Pielou, 1975; Ludwig & Reynolds, 1988). H' is influenced both by the number of categories (species) as well as by the evenness with which rodents and / or plants are distributed within those categories. Equal H' values may thus be obtained if one habitat contains fewer and evenly distributed species of rodents and /or plants. The evenness of species was calculated as, $J' = H'/H'_{max}$ where $H'_{max} = \ln(s)$, s being the number of species. This measure varies between 1 (complete evenness) and 0 (complete unevenness).

Analysis of variance was performed to detect differences in habitat variables and abundance of rodent and plant species between land use sites whereas correlation coefficient (r) was used to find out whether rodent species were affected by land use patterns, by relating the habitat factors (listed above) to abundance of rodents across sites. Rodent abundance was expressed as proportion of captures relative to the number of traps set over a given period (Telford, 1989).

Percentage cover estimates were arcsine transformed before subjecting them to statistical analysis. Analysis of Variance (ANOVA) was used to test whether vegetation density, percentage herbage cover estimates and soil depth varied between various land use sites. Tukey test was used to distinguish the means that differed significantly between the land use sites. Student's t-test was also used to find out whether Shannon-Wiener diversity index (H') for both woody and herbage layer species varied between sites. This method has been used in previous studies (e.g. Oguge, 1995 *Unpub*; Monadjem, 1997; Ferreira & Van Aarde, 2000; Newton, 1980; Odhiambo, 2000).

The density of burrows and mounds was obtained by dividing the mean count of each by the total area in which they were observed. Frequency counts of burrows and mounds were square root transformed in order to assume normality prior to their analysis. Analysis of variance was used to test for variation in the physical habitat factors observed in various land use categories and Tukey test used to separate the means.

All tests are 2-tailed with significance level of 0.05. Statistical analyses are based on Zar (1984).

CHAPTER THREE: RESULTS

3.0 SPECIES COMPOSITION, DIVERSITY AND ABUNDANCE OF RODENTS IN GACHOKA DIVISION, MBEERE DISTRICT, KENYA

3.0.1 Species Composition, Percentage Occurrence and Diversity of Rodents in Different Land Use Sites

Five species of rodents, *Otomys thomasi* (Swamp rats), *Lemniscomys barbarus* (Striped grass-mice), *Arvicanthis niloticus* (unstriped grass-mice), *Acomys percivali* (Spiny mice) and *Mastomys natalensis* (Smith) (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 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,

TABLE 1 The number of rodents caught, their relative abundance (in brackets), diversity index (H') and evenness (J') at 4 sites in Mbeere district Kenya, between the months of September and December 2001

Species	No. Caught at each site				Percent of total
	Cultivated	Grazing	Fallow	Bushy	
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 niloticus	0 (0.0)	0 (0.0)	3 (1.4)	6 (2.8)	9 (4.2)
Acomys percivali	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)
Number captured in 1536 trap days	12	35	96	70	213
Diversity index H'	0.2	0.3	0.7	0.5	
Evenness J'	0.2	0.4	0.9	0.7	

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 percivali* with 16.4 % and *Mastomys natalensis* with 8.5 % respectively. *Arvicanthis niloticus* had the lowest percentage abundance. Low abundance for *Arvicanthis niloticus* could be attributed to the fact that a small number of animals were captured in two localities within the study area, unlike the rest of the species which were captured in at least three of the four sites in fairly large numbers.

Acomys percivali was the most widely dispersed species, occurring in all four study sites in relatively low numbers compared to other species. The abundance of *Acomys percivali* increased significantly from cultivated and grazing lands, to bushy site (table 2), along a decreasing land use. *Otomys thomasi* and *Lemniscomys barbarus* were present in three of the four sites. The *Otomys thomasi* were common in sites with high anthropogenic influence and missed conspicuously in the relatively natural – bushy site. Among the used sites (i.e. cultivated, grazing and fallow), *Otomys thomasi* were significantly more in fallow than cultivated land and decreased along an intensifying land use. Grazing site was intermediate between fallow and cultivated and therefore did not vary from either site in terms of *Otomys thomasi* abundance. In contrast, *Lemniscomys barbarus* was common in the less used sites and missed conspicuously in cultivated land (most used site). Its numbers increased progressively from grazing to the bushy site. The cultivated and the grazing sites, therefore, showed significant variation from both the fallow and the bushy sites. However, variation in abundance for this species was not significant between cultivated and the grazing sites, as was the case for fallow and the bushy sites. Despite the difference in their distribution, both species were well represented in fallow site than in any other land use category. The abundance of *Otomys thomasi* in grazing land and of *Lemniscomys barbarus* in fallow site was relatively similar. Nevertheless, the abundance of *Lemniscomys barbarus* was lowest in cultivated land whereas that of *Otomys thomasi* was lowest in the bushy site (Table 2). *Arvicanthis niloticus*, and *Mastomys natalensis*, were found in the sites that had low anthropogenic influence, and clearly avoided highly disturbed areas. *Arvicanthis niloticus* was observed to have the lowest abundance compared to other species.

TABLE 2 Variation of rodent abundance in different land-use categories in Mbeere district, between September and December 2001.

Sites	*O. thomasi*	*L. barbarus*	*A. niloticus*	*A.percivali*	*M. natalensis*
Cultivated N=4; F=14.98; DF=3,12	4.5	0.0	0.0	1.5	0.0
Grazing N=4; F=16.95; DF=3,12	13.5^{e}	2.5	0.0	1.5	0.0
Fallow N=4; F=4.71; DF=3,12	19.5^{b,f}	13.5^{b,d}	1.5	5.5	8.0^{b,d,f}
Bushy N=4; F=9.65; DF=3,12	0.0	22.0^{c,e}	3.0^{c,e}	9.0^{c,e}	1.0

Means in the same column followed by different letters are significantly different; Tukey test P<0.05.; Letters are: b, Fallow vs Cultivated site; c, Bushy vs Cultivated site; d, Fallow vs Grazing site; e, Bushy vs Grazing site; f, Fallow vs Bushy site.
Abbreviations: DF., Degrees of feedom;

Diversity index (H') and evenness (J') of rodent species varied between habitats with different land use (Table 1). 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.

3.1 VARIATION OF HABITAT ATTRIBUTES WITH LAND USE IN THE STUDY SITE

3.1.1 Vegetation Composition and Diversity

3.1.1.1 Vegetation Composition

A total of 20 trees and shrubs species were recorded in the study site (Table 3) whereas 14 species of grasses and herbs were recorded (Table 4). Thirty two percent of all the plant species were present in all habitats. Nine percent of the herb species were present in only one habitat. Bushy grassland had more species of grasses (n = 12) and woody plant species (n = 17) than both the 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 3 The abundance and density of trees and shrubs in sites with varying land use in Kiritiri, Mbeere district, Kenya.

		Cultivated			Grazed			Fallow			Bushy grassland		
Species	Family	Frq	Rel. frq	Density trees/shrubs per ha	Frq	Rel. frq	Density trees/shrubs per ha	Frq	Rel. frq	Density trees/shrubs per ha	Frq	Rel. frq	Density trees/shı per ha
Terminalia brownii	Combretaceae	2	3.1	200	1	1.0	100	14	6.5	1400	30	15.3	3000
Cassia bicapsularis	Leguminosae	0	0.0	0	2	1.9	200	16	7.4	1600	16	8.2	1600
C. siamea	Leguminosae	1	1.5	100	0	0.0	0	20	9.3	2000	25	12.8	2500
Boswellia neglecta	Burseraceae	0	0.0	0	0	0.0	0	2	0.5	200	15	7.7	1500
Combretum sp.	Combretaceae	1	1.5	100	8	7.6	800	12	5.6	1200	33	16.8	3300
Acacia tortilis	Leguminosae	0	0.0	0	7	6.7	700	21	9.8	2100	18	9.2	1800
A. robusta	Leguminosae	0	0.0	0	2	1.9	200	13	6.1	1300	9	4.6	900
A. ataxantha	Leguminosae	0	0.0	0	3	2.9	300	5	2.3	500	11	5.6	1100
Polyfera sp.	Rubiaceae	0	0.0	0	1	1.0	100	4	1.9	400	8	4.1	800
Delonix errata	Leguminosae	0	0.0	0	1	1.0	100	0	0.0	0	4	2.0	400
Grevillea robusta	Proteaceae	3	4.6	300	2	1.9	200	0	0.0	0	0	0.0	0
Azadirachta indica	Meliaceae	0	0.0	0	0	0.0	0	1	0.5	100	0	0.0	0
Lantana camara	Verbenaceae	4	6.2	400	12	11.4	1200	8	3.7	800	6	3.1	600
Balanites aegyptiaca	Balanoitaceae	1	1.5	100	0	0.0	0	6	2.8	600	2	1.0	200
Rhus natalensis	Anarcadiaceae	1	1.5	100	1	1.0	100	5	2.3	500	7	3.6	700
Vitex doniana	Verbenaceae	0	0.0	0	0	0.0	0	4	1.9	400	6	3.1	600
Mellia vokensii	Meliaceae	0	0.0	0	0	0.0	0	3	1.4	300	7	3.6	700
Securinega virosa	Euphorbiaceae	0	0.0	0	0	0.0	0	2	0.9	200	6	3.1	600
Gnidia subcordata	Verbenaceae	0	0.0	0	3	2.9	300	3	1.4	300	0	0.0	0
Aspilia mossambicensis	Compositae	6	9.2	600	4	3.8	400	7	3.3	700	4	2.0	400

Where: Frq = Frequency; Rel frq = Relative frequency
Total: 20 species 11 families

TABLE 4 The abundance and density of grass and herb species present in sites with different land use in Kiritiri, Mbeere district.

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

Where: Frq = Frequency; Rel frq = Relative frequency; g/h = Grass/Herbs
Total: 17 species 4 families

3.1.1.2 Plant Density

The density of woody plants varied significantly between sites ($F_{3,76,} = 10.224$, $P < 0.01$). Tukey test showed that significant differences occurred between bushy and cultivated ($q = 6.889$, $P < 0.05$) and between bushy 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. The density of grasses and herbs did not differ between sites ($F_{3,64,} = 1.168$, $P > 0.05$). Although the plant species with the highest density differed in the four sites, five of the top 10 species were common in all the four sites.

3.1.2 Percentage herbage Cover

Significant variations in cover occurred between land use sites ($F_{3,24,} = 38.5$, $P < 0.01$). Percentage herbage cover in grazing, fallow and bushy sites differed significantly from that of cultivated land ($q = 7.3$; 9.0 and 15.1 respectively, $p < 0.01$ for all cases). Percentage herbage 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 herbage 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.

3.1.3 Plant Species Diversity

Table 5 shows diversity indices (H') and their evenness (J') while table 6 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

TABLE 5 Indices of diversity (H') and evenness (J'), for plant species in four habitats with varying land use, in Kiritiri, Mbeere district Kenya.

	Diversity (H')		**Evenness (J')**	
Habitat	Trees / shrubs	Grasses	Trees / shrubs	Grasses
Cultivated land	0.83	0.68	0.61	0.45
Grazing land	0.92	0.83	0.68	0.75
Fallow	1.21	1.08	0.89	0.94
Bushy grassland	1.20	0.99	0.88	0.89
Overall	**1.41**	**3.38**	**0.77**	**0.97**

TABLE 6 Comparisons of diversity indices (H') between sites in Kiritiri, Mbeere district, Kenya. Figures indicate t-test statistics

	Trees and shrubs		Grass and herbs	
Sites	t-statistic	DF	t-statistic	DF
Cultivated vs. grazing	0.76	364	0.28	362
Cultivated vs. fallow	2.13*	364	0.28	361
Cultivated vs. bushy grassland	2.74**	361	0.30	361
Grazing vs. fallow	0.83	360	0.36	362
Grazing vs. bushy grassland	1.99*	361	0.38	362
Fallow vs. bushy grassland	1.13	360	0.85	362

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

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. Cultivated and bushy grassland as well as grazing and bushy grassland were the only other sites showing significant difference between species of woody plants (Table 6). Nevertheless, diversity values for species of grasses and herbs did not show any significant variation across the entire study site. Some species of grass that occurred in all four habitats had very different distribution in each of them. *Chloris pycnothrix* and. *Digitaria milanjiana* were more abundant in cultivated area, while *Sporobolus marginatus, Eragrostis superba, E. aspera* and *Themeda triadra* were common in fallow and bushy grassland.

3.1.4 Physical Habitat Variables

Significant difference was observed in the distribution of soil depth (F = 15.7; N=288; $P < 0.05$), frequency of burrows (F = 6.4; N=320; $P < 0.05$) and mounds (F =28.0; N=320; $P < 0.05$) in all habitats. Specific inter-site variation in soil depth occurred when land under cultivation was compared to bushy, grazing and fallow sites (Table 7). Similarly, the 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, burrows 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 four pairs of land use sites. Burrows 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.

TABLE 7 Variation in physical habitat variables in different land use categories in Mbeere district between September and December 2001.

Comparison	Soil depth	Burrows	Mounds
Bushy versus Cultivated	9.5*	5.6*	12.4*
Bushy versus Grazing	3.5	2.7	7.7*
Bushy versus Fallow	3.0	0.7	3.8
Fallow versus Cultivated	6.5*	5.0*	8.5*
Fallow versus Grazing	0.5	2.0	3.8
Grazing versus Cultivated	5.9*	3.0	4.7*

Where * represents means that are significantly different; Tukey test $P < 0.05$

Although soil depth 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, captures did not relate to soil depth factor (r = -0.416, p > 0.05, n = 12) for all sites.

The abundance of *Lemniscomys barbarus, Acomys percivali* and *Arvicanthis niloticus* 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 (Figure 5 and Table 8).

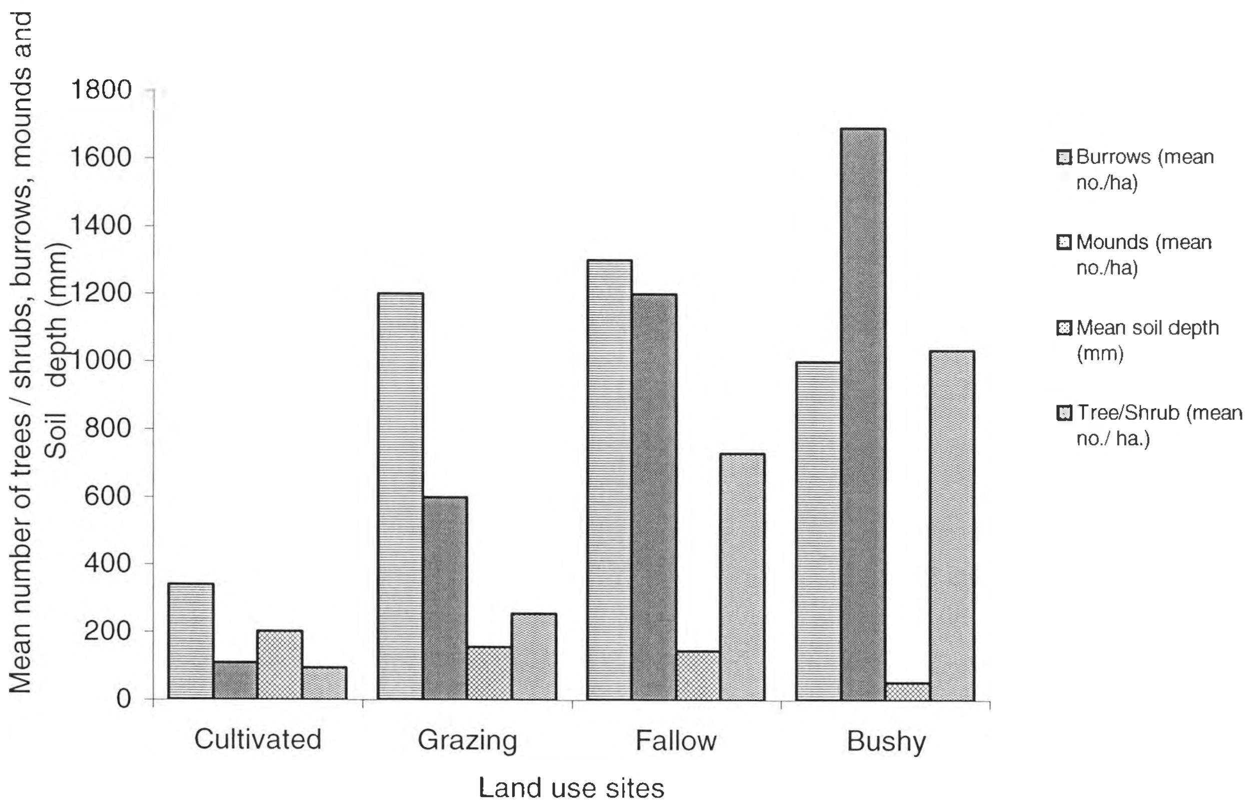

Figure 5 Habitat variables in different land use sites in the Mbeere study site, between the month of September and December, 2001

TABLE 8 The relationship between rodent abundance and habitat variable in Mbeere district, Kenya. Figures in the table are Pearson Correlations coefficients.

Rodent species	% Gr cov[a]	No. gr sp.[b]	Soil depth	Burrows[b]	Wo sp.[b]	Mound[b]
Otomys thomasi	-0.420	0.174	0.532	0.251	-0.163	-0.305
Lemniscomys barbarus	0.987*	0.809	-0.989*	0.765	0.945*	0.954*
Acomys percivali	0.987*	0.519	-0.969*	0.509	0.815	0.888*
Mastomys natalensis	0.307	0.222	-0.168	0.549	0.457	0.459
Arvicanthis niloticus	0.905*	0.493	-0.955*	0.437	0.758	0.832

Where: * Implies significance at $P < 0.05$; ** = $p < 0.01$;

a = Variables that were arc sine transformed before performing correlation analysis.

b = Variables that were square root transformed before performing correlation analysis.

% Gr cov = percentage herbage cover; No. gr sp. = number of grass and herb species; Wo sp. = No. of woody plant species.

Lemniscomys barbarus and *Acomys percivali* were positively correlated to mounds though both were negatively correlated to soil depth.

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 herbage cover and higher woody plant density, while very few were found not to occur in such areas. The *Lemniscomys barbarus, Arvicanthis niloticus* and *Acomys percivali* species were more abundant in areas with greater plant species diversity, percentage grass cover, whereas *Otomys thomasi* were found in low vegetation cover and plants species diversity. *Acomys percivali* was found in areas with more barrow and mounds. However, the species was not limited to this site and occurred at a lower frequency in site with fewer burrows. *Mastomys natalensis* did not correlate to distribution of burrows and/or mounds.

3.2 DISCUSSION

In this study, five rodent species were recorded. Two species, *Arvicanthis niloticus* and *Mastomys natalensis* were the most site-restricted occurring only in fallow and bushy sites. The distribution of *Arvicanthis niloticus* however increased from fallow to bushy - one of the least disturbed sites. In contrast, *Mastomys natalensis* 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 was the most suitable site and hosted the greatest diversity of small mammal species than any other site.

The data obtained suggests that *Acomys percivali* has the widest range of habitat preference among the species captured, having been recorded in all land use sites. The species may be highly adaptable 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 the cultivated and grazed sites (most used sites) compared to the bushy and fallow (least used) ones. Despite the divergent differences expected in land use activities between cultivated and bushy sites, both sites had a relatively similar abundance of *Acomys percivali* 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 percivali* 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 percivali* 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 niloticus and *Mastomys natalensis*, the other species most affected by land use, were restricted to the fallow and bushy sites. This suggests that the two species are susceptible to land use change and have a narrow range of tolerance to habitat disturbance.

Accordingly, they are therefore the most locally threatened small mammal species by the increasing habitat change in the area. The extent of threat is however not similar for the two species. *Arvicanthis niloticus* is notably more susceptible due to its preference for natural sites. *Mastomys natalensis*, on the other hand, prefers recovering sites more than the natural ones. During habitat changes such as those occurring in grazing and cultivated sites, *Arvicanthis niloticus* 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 barbarus* was also negatively affected by land use. However, data generated in this study suggest that it may be more tolerant and adaptive to a changing environment though it has a clear preference for undisturbed sites. In contrast, *Otomys thomasi* showed a clear preference for disturbed areas. The result suggests that *Otomys thomasi* is highly adaptive to changing habitat and may be highly opportunistic. The observation agrees with that of Ferreira & Van Aarde (2000) who reported a similar interspecific variability in abundance of some species of rodents including *Otomys thomasi* which he attributed to their varying ability to thrive in disturbed habitats. *Otomys thomasi* 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 thomasi* 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 thomasi* and *Lemniscomys barbarus* are perhaps suitable indicator species for disturbed areas 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 barbarus* and *Otomys thomasi* in fallow site may indicate its suitable habitat conditions. Rodent species composition in this site is comparable to that of other dry areas 15^0N and S of the equator. In the East Africa region for example, *Lemniscomys barbarus*, *Otomys thomasi* and *Arvicanthis niloticus* have been reported in Kahawa, 25 km to the North of Nairobi (Martin & Dickson, 1985) and in Meru National Park (Neal, 1984). The genus *Acomys percivali* has also been reported in Baringo and Kerio Valley areas in Kenya and is considered to be highly adapted to semi arid conditions (Kingdon, 1997). *Otomys thomasi, Arvicanthis niloticus* and *Mastomys natalensis* have been recorded widely in Uganda (Delany, 1974).

The African small mammal populations generally decline during the dry season (Delany & Happold, 1979; Monadjem, 1997) suggesting, like this study found out, that the effects of land use on their distribution is best demonstrated during this season since at large population densities additional animals spill over into less preferred habitats.

Bushy site contained a higher density of woody plant species than all other sites. Although grass and herb 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, whereas *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 increased 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 were the most intensively used and had the lowest densities of woody plants. No significant variation in woody plant density was observed in some sites (section 3.1.1.2) suggesting that land use types in these sites resulted in more or less similar vegetation variability. Overall, land use activities across sites had 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 may be 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 existed between grazing and bushy grassland. The causes for these variations may be related to those attributable to vegetation 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 of this study supports the findings of Norton-Griffiths (1978), Tilman *et al.* (1994) and Nupp & Swihart, (2001) that land use pressure from both cultivation and grazing activities impact on the vegetation and limit the natural regeneration of woody plants. Keesing (1998) found that ungulates could have a strong impact on small mammal abundance and diversity in the East African savanna. The intensive cultivation, and grazing by large herbivores in some of the study sites did not allow the establishment of suitable conditions for the small mammals to inhabit them successfully. The decline in habitat quality as a result of land use intensity may have severe consequences on the abundance and diversity of small mammals and subsequently on the structure and function of the ecosystem as a whole by reducing the population of medium-sized predators that depend on the small mammals for food.

Results show that small mammals may be strongly affected by the specific environmental conditions in various land use types. It seems probable that vegetation cover was used for predator avoidance and shelter from direct radiation. The predators includes cats, snakes, eagles and other raptors (Oguge pers com.). Snakes were notably common. On one occasion an unidentified species of snake, and a bird were independently observed attempting to prey on a trapped *Lemniscomys barbarus* and *Otomys thomasi* respectively. Elsewhere, Bond *et al.* (1980) 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 niloticus*, 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 & Van Aarde (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 factors were also influencing the distribution and abundance of rodents. 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 (Bourliere, 1975; Oguge, 1995 *Unpub*). In this study the highest small mammals biomass was recorded on fallow site, which appeared to attract all the five species of rodents captured. Perhaps in this site, food supply and shelter were favourable for the species.

Mastomys natalensis is highly adaptable (Meester Lloyd *et al*, 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 small mammal species and vegetation cover is also documented (Bond *et al.*, 1980) as is that of *Otomys irroratus* and *Otomys thomasi* with dense grass cover De graaff (1981) and Bond *et al.*, (1980). *Otomys thomasi* 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 niloticus* seemed restricted only to grassy habitats while in contrast, *Acomys percivali* appeared to have the most diverse habitat range.

The ability for *Otomys thomasi* 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 percivali* and *Arvicanthis niloticus,* were significantly correlated with percentage plant cover. However, vegetation cover was of lesser importance compared to the presence of peripheral hedges for *Otomys thomasi,* which predominated cultivated sites. Hedges may have provided shelter that was otherwise lacking in cultivated sites. Indeed, burrows were common in the edges of cultivated sites more than expected although none of the rodent species correlated with their prevalence. Burrows-hedge correlation may have occurred due to damages on burrows that may persist inside the cropland during the frequent tilling. Unlike burrows however, the distribution of *Lemniscomys barbarus* and *Acomys percivali* correlated significantly to prevalence of mounds. Since the two species were common in sites with little anthropogenic activity, 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 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 most of rodents species. 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 & Loiselle, 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* was mainly 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 into the 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 (Spencer *et al.,* 1990). As the increase in cropping replaces bush and pasture, the diversity of small mammal species would be expected to decrease. Conversely, 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 FOUR: GENERAL DISCUSSION, CONCLUSION AND RECOMMENDATIONS

4.0 GENERAL DISCUSSION

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 alpha and beta diversity measures related directly to this study while the gamma diversity was largely as a result of the two. The diversity observed in each land use type represented the alpha diversity whereas variations between land use types represented the beta diversity.

The presence and/or absence of particular species of rodent in a given area result from its specific interaction with the prevailing environmental factors. Variation 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 & Van Aarde, 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 & Reeder, 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. Animals 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 (1978) 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 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 relationship between habitat conditions observed in various land use types and the diversity of rodents in the respective sites is a key finding for this study.

4.1 CONCLUSION

This study provides information on some of the ecological aspects affecting composition and diversity of rodents in Kiritiri area of Mbeere district. During the study five species of rodents were obtained. Some of the reasons for the small number of species observed may have been due to the small size of the area sampled relative to the entire Kianjiru, Mavuria and Kithunthiri sublocations of Gachoka division, the methods used and the duration of study. The study was only restricted to major land use types and did not include households or building structures which may host numerous species of rodents since the method used may have been inadequate in sampling them; moreover, specific selection of houses or structures could have led to an element of bias in the sample. Although households were not present in the specific areas where the trap grid was laid, the sampling grid was less than 10m (inter-trap) intervals away from households in some areas, and the baited traps were left overnight. It may therefore be sufficient to assume that the close vicinity of the households in such areas probably introduced domestic factors in the sample. Although mammals that were near-medium in size like the squirrels and the duikers were found to exist in the area, their sizes ranged outside the scope envisaged in this study for the study species. Food baited traps on the ground may have been unlikely to attract fed specimens, arboreal species and those moving in underground burrows, in accordance with the assumptions postulated. This study was therefore not exhaustive and may have led to underestimating the number of species in some of the areas.

Variability in the distribution of both plants and animals on the land use gradient varied depending on whether they benefited or were harmed by the prevailing human activity in each area. This study showed that species diversity of rodents decline when natural vegetation is cleared and the land cultivated. Vegetation clearing in cultivated sites resulted in drastic reduction in the number of species to about 40% of what existed in natural (bushy) sites. In this study, indices of habitat diversity over locations varying in land use, related to diversity of both plant and rodents species. A number of species respond to environmental change by migration while others exploit finer environmental heterogeneity with more localised movements. This was the case with the small mammals. However, most medium to large mammals that existed here have been entirely lost due to habitat modifications and degradation except for a small population of common duikers (*Sylvicapra grimmia*) that were observed. This too is under severe stress from habitat loss and hunting pressure. The potential change in the diversity of small mammal species was not only dependent on the attributes of the resultant plant community, but also on the land use aspects that made them susceptible to change. The emerging state of disturbance and herbage cover regimes are important land use factors that determine successful or unsuccessful establishment of small mammal population in this area. For instance, most pest species considered to have prolific reproductive output and capacity to establish or persist following disturbance, were observed to be dominant in highly disturbed cropland. A major attraction to these sites may have been the abundance of grains that were in cultivation.

Vegetation cover was found to be an important ecological component associated with greater diversity of small mammal species. Its loss due to crop and livestock farming appeared to benefit some invasive weed and pest species, while resident plant and animal communities were harmed leading to general decline in biodiversity of flora and fauna on these sites. The importance of plant cover may be related to habitat complexity and perhaps function through modifying microclimatic conditions e.g. humidity, temperature, refuge/shelter and availability of food favourable to the establishment of small mammal species. Conditions that allow coexistence of diverse plant and animal species also provide a natural mechanism by which ecological equilibrium is attained. The dominance of particular species is controlled through competition and predation, while loss of species is mitigated by resource partitioning in the heterogeneous habitat leading to more stable populations (Adren, 1994). Therefore, management of vegetation cover was found to be a critical strategy to obtaining high small mammals' species diversity. Apart from small mammals, vegetation cover may also favour reptiles, medium and large mammalian species, among others.

Diversity of flora is associated with diversity of small mammal fauna (Christian 1980). Areas that hosted a high floral diversity also contained a high number of small mammal species. The direction of causality may not be clear from this study, although small mammals are likely to select sites with diverse plant species, owing to the potential of a wide range of food resources, shelter and breeding sites. Small mammals are known seed dispersal agents and floral abundance and diversity may in fact benefit from their dispersal roles. In addition, effects of herbivory have been reported to facilitate increased biodiversity by removing dominance of a few plant species (Sinclair, 1977). The high diversity of small mammal species in fallow site may have contributed to the high floral diversity observed in the same site through folivory, although the extent to which this happens require further study.

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 (Verner *et al.*, 2000). The well being of these populations is dependent on the quality of the habitats (Newton, 1980). 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 extinction, due to the rapid and irreversible degradation of their habitats. Particularly vulnerable are those species with low numerical abundance, for example *Acomys percivali*, 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 positively with high quality habitat for the small mammals. Agricultural expansion into the 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 follow that of humans. However, typical pest species like *Otomys thomasi* 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 thomasi*, the ability to persist following habitat disturbance may be related to their biology and the emerging modified habitat factors.

One fundamental goal of managing ecosystems is to maintain or restore their natural structure and function (Noss & Cooperrider, 1994). However, we may accept some compromise in reaching this goal outside protected areas. Human land use for subsistence leads to degradation and is generally incompatible with the maintenance of high levels of biological diversity (Christian, 1980). 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 protected areas.

This study as discussed in the preceding chapters has found several land use factors to influence diversity and distribution of small mammals. If such 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 perhaps possible that the ecological conditions in which they existed did not vary widely and that the observed demographic variation may have largely been as a result of land use patterns.

4.2 RECOMMENDATIONS

Since small mammals are highly dependent on natural habitat, the rapid and irreversible degradation of habitats occurring throughout most of the sites is exerting severe pressure on their survival. Land use policies that integrate intermittent mosaics of cultivated and natural vegetation patches may provide sufficient number of habitats both temporal and spatial to buffer and protect widespread loss of species and maintain ecological equilibrium.

Hoeing, mechanical and draught tillage are primary methods of cultivation that lead to loss of vegetation cover in this area. These methods are associated with high frequency of intense tillage with extensive loss of herbaceous cover, exposure of soil in vast areas and general degradation of habitats. In order to protect the cultivated patches, this study recommends minimum tillage operations. Incorporation of minimum tillage means that the soil is less disturbed, which in turn become less vulnerable to erosion and evaporation processes, conserving soil, vegetation and water reserves all of which are important to the habitat. This may also promote accumulation of plant residues at the soil surface thereby facilitating, through nutrient recycling, further vegetation growth and subsequently diversity of small mammal species.

Introduction of cover crops in the cultivated patches is also recommended. Cover crops produce sufficient biomass thereby providing a layer of plant canopy near the soil surface that will enhance conditions favourable to the establishment of small mammals. Cover crops may however have added cost of seed, time and labour for planting and may compete with the crop of interest by depleting nutrients and soil moisture reserves. Leguminous types of cover crops may provide soil nitrogen while inhibiting weed growth and serving to provide suitable conditions for establishment of wildlife, particularly small mammals. However, further study is required to determine and justify the application of cover crops as a conservation method in cultivated patches in view of their increased management cost. In addition, rotational farming both in cultivated and grazing lands may facilitate vegetation growth and hence increased cover. Rotation will allow time for establishment of diverse plants and small mammal species. It may also remove dominance of a few species that may be detrimental to the long-term management of the area.

Maize, sorghum, millet, cotton and beans are common in this area and are grown in rows wider than 50cm. Planting them in rows less 25cm wide is an option for some of these crops and can be integrated into conservational cover management. Canopy or cover closure in narrow rows can be achieved much faster, and may provide protection against erosion from raindrops and loss of moisture while increasing habitats for small mammals. Rapid canopy development may discourage weed germination, growth and establishment by shading, thereby minimising the need for tillage. Further, the type of crop, timing of planting and tillage is critical in determining which plant species may predominate during the growing season. The type of crop for instance may influence the habitat conditions depending on its growth form and rate and may be integrated into habitat management. In addition, the type of crops that are not the preferred food by pest species may discourage their dominance in the cultivated patches. Nevertheless, as a means of rehabilitating some of the degraded sites, the abundance of a few pest species observed may be controlled biologically using medium to small mammalian carnivores and birds of prey, which are presumably common in the natural or unaltered habitats. Determination of protein potential and palatability by humans of the dominant small mammal species may provide an economical biological control and this requires to be explored.

In conclusion, viable populations and high level of species diversity can be maintained by a land use system that does not reduce the amount of vegetation cover occurring in natural sites. A system that incorporates fallowing and minimum tillage as well as grazing or pasture and canopy cover management is highly suitable in ecological terms to perpetuate existence of a wider range of small mammal species.

Further, this study recommends a long-term study to investigate whether the low number of species observed in this area was as a result of methodological, temporal and / or climatic factors, which were outside the scope of this study.

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APPENDIX

APPENDIX 1. Raw data on physical habitat variables obtained in varying land use sites in Mbeere.

Variables (Quadrat in M)	CULTIVATED							GRAZING						FALLOW						BUSHY								
Burrow (5x5)	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 (5X5)	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 (1X1)	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 (10X10)	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
Percentage Cover (1X1)	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
Percentage 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