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SPECIES COMPOSITION, DISTRIBUTION, ABUNDANCE AND HABITAT ASSOCIATION OF RODENTS IN FOREST AND FARMLANDS AROUND TEPI, SOUTHWEST ETHIOPIA

A Thesis Presented to the School of Graduate Studies of the Addis Ababa University in Partial Fulfillment of the Requirements for the Degree of Master of Science in Dryland Biodiversity

By

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ABSTRACT

A comparative study on species composition, distribution and habitat association of rodents in forest and farmlands was carried out around Tepi, from August, 2009 to March, 2010. Five different types of habitats were randomly selected comprising natural forest, bushland, sugarcane plantation, coffee plantation and maize-sorghum farmland. In each habitat type, a representative trapping grid was randomly selected for live-trapping. In addition, rodents were trapped from each habitat by snap-trapping. The following nine species of small mammals were trapped from the area: *Stenocephalemys albipes* (37.38%), *Mastomys natalensis* (20.56%), *Arvicanthis dembeensis* (11.99%), *Lophuromys flavopunctatus* (9.34%), *Lemniscomys striatus* (8.43), *Mus musculus* (6.59%), *Mastomys erythroleucus* (4.36%), *Crocidura fumosa* (0.93%) and *Crocidura niobe* (0.31%). The distribution of rodent species varied from habitat to habitat. *S. albipes*, *M. natalensis* and *A. dembeensis* were widely distributed in all habitat types. *L. flavopunctatus* was the least distributed rodent species. There was statistically significant variation in the abundance of rodents among the different habitat types and between seasons. There was significant variation in trap success among different habitat types. All age groups from all species were represented. Breeding of rodents was seasonal during the study period. There was high population of rodents in the first trapping session of wet season and least in the second trapping session of dry season. The population density of rodents was high in the bushland and least in the coffee plantation**.** The highest population density (422/ha) was contributed by *S. albipes,* followed by *M. natalensis* (216/ha). The biomass of rodents in the present study area varied among the habitats and trapping sessions. The stomach content of rodents was mostly plant matters and few animal matters. The three rodent species (*M. natalensis*, *A. dembeensis* and *M. musculus*) were identified as pests of maize. *S. albipes*, *M. natalensis* and *A. dembeenis* were identified as pests of sugarcane plantation. Vegetation cover, rainfall and human interference were the major factors affecting the abundance and distribution of rodents in the study area.

Key words: Pest management, species diversity, rodent.

1. INTRODUCTION

Ethiopia is characterized by diverse climatic conditions and habitats. As Ethiopia is located in the tropical latitudes, its area of lower elevation experiences climatic conditions typical of tropical savanna. However, relief plays a significant role in moderating temperature, and hence higher elevations experience weather typical of temperate zones. Thus, average annual temperature in the highlands is about 16^{o}C, while in the lowlands it is about 28^{o}C (Safra and Yashua, 2002). Ethiopia is distinguished from other African countries by the extent of its highlands. Approximately, 15% of the country lies above 2000 m asl and 2% lies above 3000 m (Yalden, 1983). Altitudinal variations along with other physical factors have contributed for a very diverse set of ecosystems ranging from humid forest and extensive wetland to the desert of the Afar depression (Agboola and Hodder, 1979) in Ethiopia. The latitudinal variations in Ethiopia produce wide range of climate (temperature, rainfall and humidity), which affect the faunal and floral distribution as well as their diversity (Yalden and Largen, 1992).

Ethiopia is known for its rich variety of wildlife. The Rift Valley, the Omo River Valley and the western lowlands of Ethiopia contain large game animals. Midium sized carnivores such as foxes, jackals, wild dogs and hyaenas are found abundantly throughout the country. In order to protect the wildlife of the country, national parks, game reserves and sanctuaries are established covering a total area of 55,195 km^2, which is about 5 % of the total area of the country (Safra and Yashua, 2002). The flora and fauna of Ethiopia are very heterogeneous with high endemic elements (Yalden and Largen, 1992). An estimated number of 7,000 species of higher plants, 284 species of mammals, 926 species of birds, 201 species of reptiles, 63 species of amphibians, 324 species of butterflies and 145 species of fresh water fish are known from Ethiopia (Yalden and Largen, 1992; Hillman, 1993; Yalden *et al.*, 1996; Lepage, 2006).

Among the 284 species of mammals of Ethiopia, 31 are endemic to the country. Of these, five are larger mammals. Others are smaller mammals including bats (2 species), insectivores (9 species) and rodents (15 species) (Yalden and Largen, 1992; Hillman, 1993; Yalden *et al.*, 1996). Among the mammalian fauna, rodents are the dominant order having over 2700 species (Davis, 1963; Kingdon, 1997; Nowak, 1999). This forms about 42% of all the mammal species (Nowak, 1999; Hickman *et al*., 2006). The East African rodents are grouped into 64 genera and 161 species (Nowak, 1999). Among them, over 70 species are found in Ethiopia (Yalden and Largen, 1992; Hillman, 1993; Yalden *et al.*, 1996).

1.1. Literature review

Rodents are the most diverse order of mammals, due to an extraordinary proliferation of rats and mice within the last 10 million years (Davis, 1963; Kingdon, 1997; Futuyma, 2005). About two-third of the living rodent species belongs to Murid. Most of the rodents that occur in Asia, also belong to this family (Singleton *et al.*, 2003). The genus *Rattus* accounts for most of the species (Proctor, 1994). Rodents have adapted to a wide range of environments (Davis, 1963; Wicander and Monroe, 1980). Following their appearance during the Paleocene, they rapidly diversified and occupied many of the microhabitats unavailable to many of the larger animals (Wicander and Monroe, 1980). They occur in every habitat, from the highest Arctic tundra (e.g. lemmings), to the hottest and driest deserts (e.g. gerbils) (Stoddart, 1984; Kingdon, 1997; Nowak, 1999). Others glide from tree to tree (e.g. flying squirrels), which seldom come down to the ground. Still some others have different living habitats, where they spent their entire lives in an underground network of burrows (e.g. mole rats) (Nowak, 1999). Ecologically heterogeneous areas may be expected to exert different influences on resident rodent species leading to varying levels of population fluctuations (Makundi *et al.*, 2005). Population dynamics of rodents in different habitats is an important aspect of ecological studies.

Rodents are opportunists (Delany, 1986). The success of rodents is partly attributable to their recent evolutionary history (between 26 and 38 million years), and populations retaining large and untapped stock of genetic variability. This variability is exposed to the selective force of rapid evolution, as rodents produce many litters each year. A second facet of their success is that rodents have very wide range of diet. Most rodents consume all sorts of plant materials, primarily seeds, leaves, stems, flowers and roots (Futuyma, 2005). They also consume small invertebrates such as insects, spiders and worms. A few are specialized carnivores; for example, the Australian water rat feeds on small fish, frogs and mollusks and seldom eats plant materials (Macdonald, 1984). Insectivorous rodents tend to have sharp cusped molars and slender muzzle. True herbivores have broad incisors, mill-like grinding teeth and a stout skull, while omnivorous rodents tend to be intermediate (Kingdon, 1997). The digestive system of rodents is very efficient, which assimilates 80% of the ingested food (Nowak, 1999). Food habit is one of the most important dimensions of ecological niche and, therefore, information on diets of animals is virtually a prerequisite for ecological research.

Rodents show less overall variation in their body plan than do members of other mammalian orders. The body build of most rodents is that of conventional quadrupeds, but evolution of burrowing, bounding, climbing and gliding has given rise to more specialized body forms in a number of groups (Macdonald, 1984; Kingdon, 1997). According to Delany (1986), small rodents are recognized as those with a mass of up to 150 g. Most rodents are small, weighing 100 g or less. There are only a few larger species, of which the largest (Capybara) weighs up to 105 kg. All rodents have characteristic teeth, including single pair of sharp incisors. With these teeth, they can gnaw even hard materials. Constant gnawing is essential for them to control the size of the ever growing incisors. The name “rodent” comes from the Latin word “rodere”, which means “to gnaw”. Gnawing is facilitated by the sizable gap, diastema, immediately behind the incisors. Rodents have no canine teeth, but they possess molar teeth by which they can grind all their food matters. Most rodents have 22 teeth, though one exception is the silvery mole-rat with 28 teeth (Macdonald, 1984).

Rodents show a wide range of life style ranging from solitary to highly social, but frequently living in aggregation (Meehan, 1984). A group of prairie dog may contain more than 5,000 individuals. Solitary life appears to be restricted to those species that live in arid grasslands; for example, desert hamsters and desert mice. Most rodents are nocturnal or crepuscular while squirrels are diurnal. There are two peaks of activities among the nocturnal rodents, the major peak occurring just after sunset and a minor peak just before sunrise (Proctor, 1994). In general, rodents have well developed sense of smell and touch but, poorly developed eye sight. They have excellent light sensitivity, but poor acuity. They are colour blind. Rodents are intelligent, and can master simple tasks for obtaining food. They can be readily conditioned, and easily learn to avoid fast acting poisoned baits, a factor that makes them difficult pests to control (Macdonald, 1984).

Rodents have short life span and are prolific breeders (Taylor and Green, 1976; Meehan, 1984). They multiply rapidly under favorable conditions. A female rat may give birth up to five litters. *Rattus norvegicus* and *R. rattus* produce 7-8 young in each litter. The multimammate rat (*Mastomy natalensis*) can have up to 20 young in a litter, the average being about 11 (Proctor, 1994). Seasonal distribution of food and quantity of rainfall are considered as the major variables determining population dynamics of rodents in East Africa (Delany and Monro, 1986; Leirs, 1994; Quy *et al*., 2003). Extended rainy seasons result in longer periods of breeding and higher litter size, which in turn lead to high population (Taylor and Green, 1976; Leirs *et al*., 1994). Studies in grassland and maize field in central Ethiopia also revealed that breeding in rodents is seasonal and is related to rainfall (Afework Bekele and Liers, 1997). For management purposes, it is important to study the factors that influence the starting and cessation of breeding, and changes in abundance, so that management actions can be taken at an appropriate time (Leirs, 1996; Makundi *et al*., 1999).

1.1.1. Economic Importance of rodents

Rodents have ecological, economical, social and cultural values (Davies, 2002; Singleton *et al*., 2003). They play an important structural role in ecosystem, for example by pruning or eliminating vegetation types, spreading seeds and pollen, competing with other animals and spreading disease (Kingdon, 1997; Davies, 2002). They are also important environmental engineers, responsible for aerating the soil through their digging and burrowing activities, and in extreme cases (e.g. beavers) changing the whole nature of the landscape through the dams they make (Singleton *et al.,* 2003). They influence nutrient cycling in the ecosystem; being pervasive seed predators, they serve as model organisms to identify the effects of seed predation on the dynamics and distribution of plant populations (Lambert *et al.*, 2003; Singleton *et al*., 2003). Furthermore, rodents have served as model organisms for studying the effects of tropical forest fragmentation (Adler, 1994). Rodents are also useful in the study of environmental gradient; they are good indicators of habitat change. They are also useful in detecting environmental impacts, because they occur in densities adequate for statistical analysis (Heaney, 2001; Singleton *et al*., 2003). Generally, they play a great role towards conservation and management of the entire ecosystems as they occur in every habitat and exploit a variety of food items.

In natural communities, rodents play an important role in the food web, both as consumers of plants and as a food resource for many of the larger predator mammals, birds and reptiles (Kingdon, 1997; Linzey and Kesner, 1997; Davies, 2002; Hickman *et al*., 2006). Furthermore, they comprise a substantial portion of wild game consumed by humans in many areas (Lynwood, 1990). Species such as guinea pigs and dormice are deliberately bred for food (Macdonald, 1984). In tropical Africa, rodents are a significant source of animal protein for humans. For instance, in Benin, rodents ensure the food security of the population (Assogbadjo *et al*., 2005). In Ethiopia, sixteen rodent and one insectivore species are important components of the diets of Gumuz indigenous people (Tadesse Habtamu and Afework Bekele, 2008). In addition to this, rodents are important laboratory animals, and a great deal of progress in biomedical research can be attributed to the use of rodents as experimental models (Gorbunova *et al*., 2008).

Some rodents are major agricultural and urban pests across much of the developed and developing world (Proctor, 1994; Dickman *et al*., 1999). They have found human civilization to be ideal environments for sources of food, shelter, and for transportation to new territories, and even to continents. This has been responsible for rodent outbreaks in different environments throughout the world (Gratz, 1997). They are vectors of pathogens and diseases such as hanta-viruses, lungworms, rat typhus, leptospirosis, salmonellosis, fowl cholera, Weil's disease and bubonic plague (Meehan, 1984; Gratz, 1994; Mills, 1999). In addition to this, they destroy human property by gnawing not only to get food items, but also to keep their rapidly growing incisors short and sharp enough for regular use (Young, 1992). In this process, they destroy merchandise both stored and in transit, cause enormous damage to buildings by gnawing wood, pipes, walls and foundation, make holes in mail sacks and consume mail, ignite fires by gnawing insulation on electrical conductors, and cause tremendous harm by consuming or spoiling grain, fruits and vegetables, both in farms and in stores. Their capacity for almost unlimited destruction and transmission of diseases introduces an applied aspect of rodent ecology (Odhiambo and Oguge, 2003).

Globally, some rodents are major agricultural pests. They damage and destroy 30% of the crops during pre-harvest periods (Singleton, 2001). Most damage occurs during the sensitive young seedling stage and just before harvest (Singleton *et al.*, 2003). However, the actual pattern and levels of rodent infestation, and the extent of damage vary in crop variety, geographical location, the species involved, length and method of storage and climate (Taylor and Green, 1976; Macdonald, 1984). In the Asia–Pacific region, rodents are one of the most important constraints to agricultural production (Singleton *et al.*, 2003). Rats in general are serious pests of rice in Asia, causing 5–10% of annual pre-harvest losses. The exact post-harvest losses are difficult to assess (Proctor, 1994). After harvest, the crop attains its highest value, taking into account all the cost of producing, processing, packaging, storage and distribution prior to consumption. Generally, rodents cause considerable losses to stored grains. In Asia, 20% of post-harvest grain losses from rats are not unusual (Singleton 2001). Rodents, particularly the house mouse and Norway rat are responsible for the loss on stored grains, amounting to at least 5-10 %, most from farm and village stores (Macdonald, 1984).

Tropical crops damaged by rodents include coconuts, maize, coffee, beans, citrus melons, tubers and cocoa (Macdonald, 1984; Makundi *et al*., 1999). In Africa, rodents are the most important pre-harvest pests in economic terms. For instance, in Tanzania rodents cause damage to crops such as maize, sorghum, millet, cassava and pulses in the field (Odhiamba and Oguge 2003; Makundi *et al*., 2005). In Tanzania and Ethiopia, the frequency of occurrence of rodent outbreaks was reported to be high (Makundi *et al.*, 2005). In terms of magnitude, an estimated annual yield loss of 5-15% of maize was reported in Tanzania (Leirs, 2003). In Ethiopia, an estimated rodent damage of 20-26% cereal crops was recorded (Afework Bekele *et al*., 2003). For developing countries like Ethiopia with high population growth rate, periodically affected by drought and famine, such crop loss is paramount, which demands extensive ecological investigations with emphasis on rodent population control.

Among East African rodents, the one with the most economic importance is the multimammate mouse, *M. natalensis* (Fidler, 1994; Leirs *et al*., 1996). *Mastomys* as a pest in Ethiopia was documented in maize fields from Ziway (Afework Bekele and Leirs; 2003). Workneh Gebresilassie *et al*. (2004) observed *M. natalensis* acting as pest attacking different types of crops. In the higher and more temperate areas of East Africa, it is replaced by the grass rat, *Arvicanthus niloticus*. As a pest, under favourable condtions, it is as bad as the multimammate mouse; *A. dembeensis* was also documented as the most noxious Muridae pest in eastern Africa (Fidler, 1994; Leirs *et al*., 1996; Afework Bekele and Leirs, 1997). The other pest rodents, which can cause localized damage to crops are *R. rattus*, *R. norvegicus* and *Mus musculus* (Smythe, 1986). There are 11 species of rodents in Ethiopia that are classified as pests (Afework Bekele and Leirs, 1997).

1.1.2. Ecologically-based Management of rodents

High emphasis on ecologically-based rodent management (EBRM) has emerged in recent years both in developed and developing countries (Belmain *et al*., 2003). In agricultural areas where rodents cause significant impacts, control activities over the past 25 years tended to focus on choice of rodenticides and its carrier, structure and placement of bait stations, and genetic and behavioural resistance to rodenticides (Quy *et al*., 2003; Inglis *et al*., 1996). The concept of EBRM was developed as a formal description of the sound ecological basis required for developing management strategies for rodent pests (Singleton *et al*., 1999). The concept aims to combine basic and applied research on rodents through focusing on the population ecology of rodents and developing management directed at the agro-ecosystem level. The process of developing effective EBRM is a learning cycle that involves phases of observation, formulation and testing of hypotheses, and further observations or experimentation, with each round of activities leading to a better understanding (Belmain *et al*., 2003).

The review from the studies in southeast Asia highlighted that EBRM provides increased yields, lowers rodent population, reduces use of toxic rodenticides, decreases rodent control costs, improves health conditions of the rural poor and provides an impetus for a more cohesive interaction among community members (Singlton *et al*., 2003; Palis *et al*., 2004). In recent years, applied research on EBRM has taken place in many countries throughout Asia and Africa, involving a number of research and extension institutions working together in collaboration with farming communities to develop effective, sustainable, environmentally safe and cost-effective rodent management strategies (Belmain, 2007). Various studies have also been carried out in East Africa to establish the relationship between ecological parameters and rodent population dynamics (Taylor, 1968; Leirs *et al.*, 1989; Leirs, 1994; Mwanjabe, 1993; Makundi, 1995; Afework Bekele and Leirs, 1997).

Good understanding of the basic ecology of individual species is dependent on access to field methodologies that enable us to understand the population dynamics and ecology of rodents (Quy *et al*., 2003). Despite this fact, management of rodents in eastern Africa relies mostly on use of chemical rodenticides (Makundi *et al*., 1999). Even though, rodents are major agricultural problems, only some rodents (less than 5%) are pests (Dickman *et al*., 1999; Singleton *et al*., 2003). Thus, the non-pests contribute positive ecological roles in different ecosystems, and hence, require conservation. Owing to the high number of species, poorly known taxonomy and lack of detailed information on population status, the assessment of threat status is considered arbitrary in some cases (Amori and Gippoliti, 2003). In addition to this, the high number of rodent species and the high rate of endemism of rodents emphasize the priority for research on these animals (Singleton *et al*., 2003).

Only limited areas of Ethiopia are extensively surveyed for small mammals, especially rodents (Yalden *et al.*, 1976; Yalden and Largen, 1992). At the same time, limited studies on rodent ecology and their interaction with farmlands have been made in the country (Afework Bekele and Leirs, 1997; Afework Bekele *et al*., 2003; Workneh Gebresilassie *et al*., 2004; Makundi *et al*., 2005; Manyingerew Shenkut *et al*., 2006; Demeke Datiko *et al.*, 2007). This indicates that detailed studies on rodents are lacking for many regions of the country. Hence, the present ecological study was designed to collect information on the interaction of rodents with the vegetation, species composition, distribution, abundance and their association in forests and farmlands in Tepi area, southwest Ethiopia.

2. OBJECTIVES

2.1. General Objective

The general objective of the present study is to study the species composition, distribution, abundance and habitat association of rodents in farmland and forest habitats around Tepi, southwest Ethiopia.

2.2. Specific Objectives

- To determine the species composition of rodents in the study area.
- To study the distribution pattern and habitat association of rodents in Tepi.
- To study seasonal variation in the abundance of rodents in the study area.
- To study the population dynamics of rodents in the study area.
- To determine biomass of rodents in different habitats in the study area.
- To compare pre-harvest and post-harvest rodent populations in farmlands.
- To study the food habits of rodents based on stomach content analysis.
- To identify rodent pests associated with maize, sorghum and sugarcane in the study area.

3. THE STUDY AREA

3.1. Location and Area

Tepi is located in the southwestern part of Ethiopia. It occurs in the Yeki Woreda, which is one of the three Woredas of Shaka Zone, in Southern Nations Nationality and People Regional State (SNNPRS). The study area is geographically located at latitude 7^{o}10’6.064’’ - 7^{o}12’59.744’’ and longitude 35^{o}23’58.993” - 35^{o}26’14.285”. The grid reference indicates that Tepi is located near the tropic of Cancer, close to the equatorial region, around 30 km from Mizan Teferi (southern), 105.3 km from Gore (northern) and 620 km from Addis Ababa, the capital of Ethiopia (Fig.1).

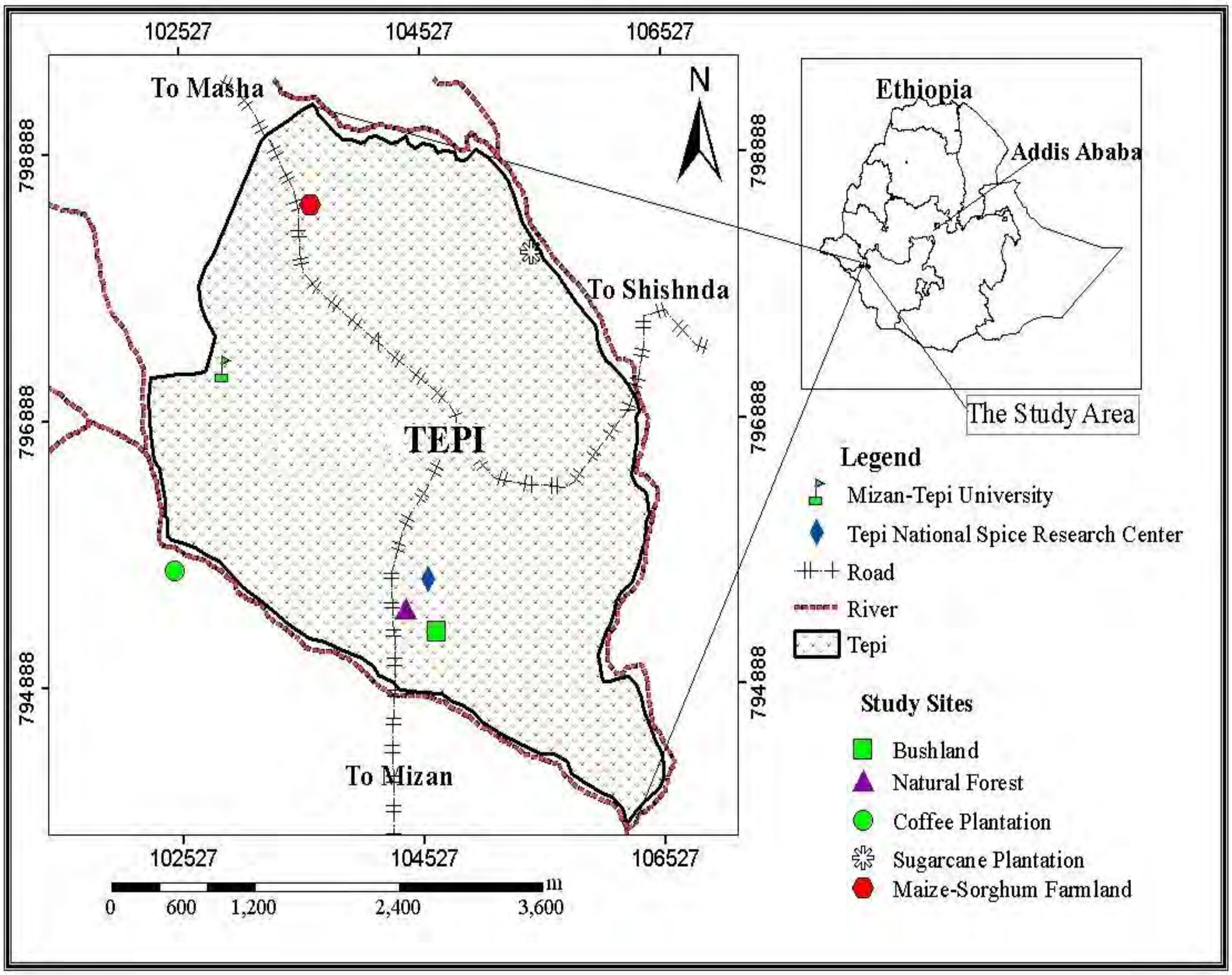

Figure 1. Location of the study area showing the study sites.

3.2. Topography and Geology

The physical features of the study area are characterized by a topography dominated by gentle slopes and localized steep slopes. There is also a large area of land in the study area under farming activities including coffee plantation and residence. The altitude of the study area lies between 1175-1250 m asl.

The rocks in the study area consist of Precambrian, in the lower complex granite gneiss basement (EMA, 1988). The soils of the area are red or brownish ferrisols derived from volcanic parent material. The prevalence of high rainfall has masked other soil forming-factors and hence, very similar soils have developed on a variety of parent materials. According to the information from Tepi National Spice Research Centre, the soils are porous and have good potential for agriculture, good physical properties, stable structure, deep rooting volume, and high moisture storage volume. The chemical feature of the soils shows low base saturation.

3.3. Climate

Generally, southwestern part of Ethiopia is the wettest region with rains extending up to eight months a year (Friis, 1992). The climate of the study area is characterized by hot climatic condition with higher and nearly evenly distributed rainfall pattern among eight rainy months that extend from March to October. The annual rainfall follows unimodal regime characterized by one distinct rainfall peak (August - September), while the driest season is November - February. Data for the years 2001-2010 show that the study area had an average annual rainfall of 1500 mm. The average minimum and maximum temperatures are 14.7^{o}C and 29.9^{o}C, respectively. The mean monthly rainfall, mean minimum and maximum monthly temperature record in the study area are shown in Figure 2.

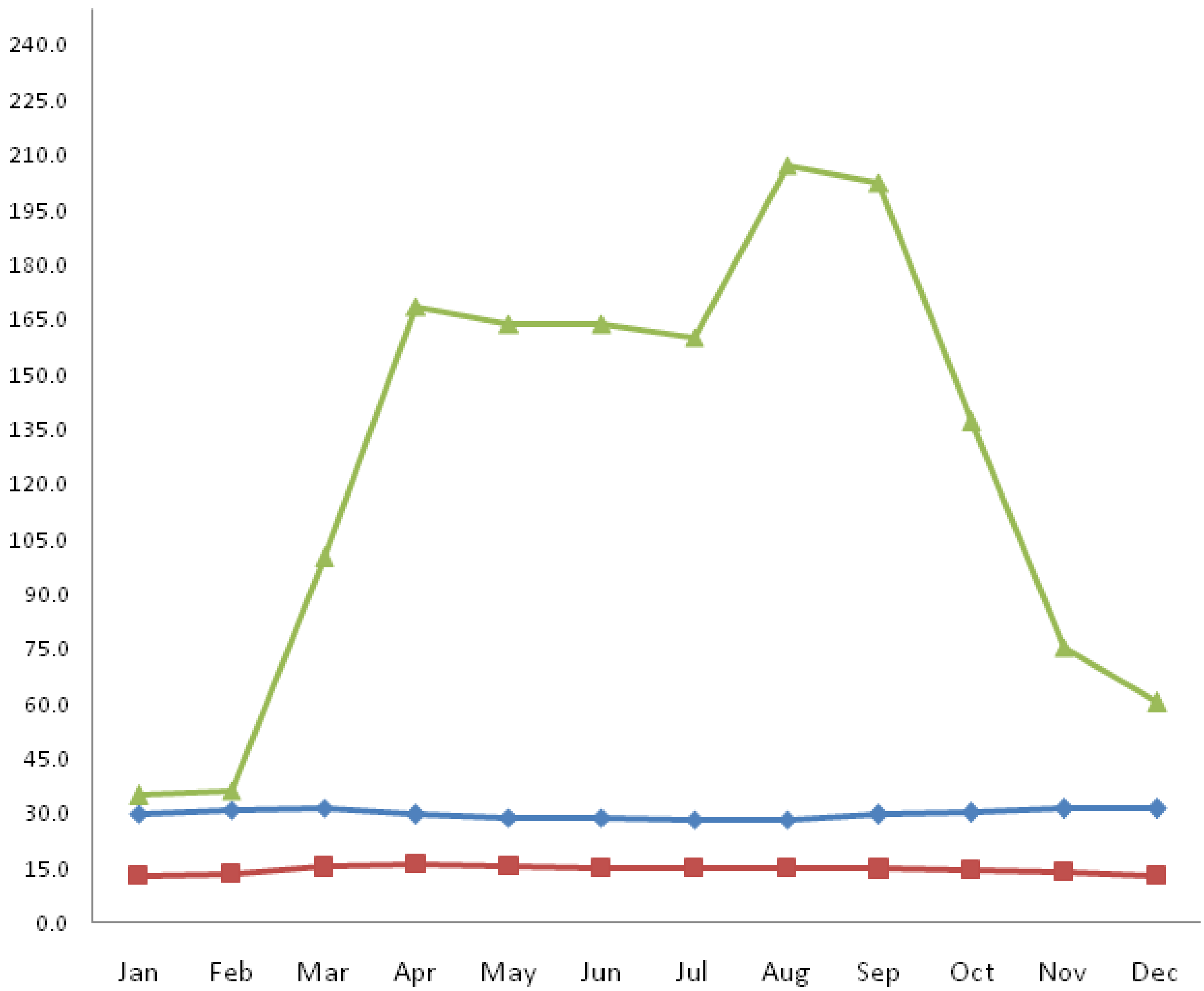

Figure 2. Monthly rainfall, monthly mean minimum and maximum temperatures of Tepi during 2001 - 2010. (= Monthly rainfall, = Maximum temperature, = Minimum temperature)

(Source: Ethiopian Meteorology Agency)

3.4. Land-Use Patterns and Vegetation

Agricultural practices are the sole livelihood of the majority of the inhabitants in the study area. Enset and maize are the major staple crops, and mainly used for household subsistence. Coffee and honey are the major income earning products of the study area. A wide range of fruits and vegetables are also cultivated both for subsistence and for sale. The study area was characterized by its high natural forest resources. However, large extent of the forest is being cleared every year for agricultural expansion and private investment ventures. The total area of the Woreda is 489.413 km^2. According to Yeki District Information Center (2008/2009), the estimated proportion of land under various uses of the Woreda is as follows: covered by annual plants (31%), forest and bushland (24%), suitable and used for production of crops (16%), open land (29%) and covered by different social activities.

3.4.1. Habitat Description

3.4.1.1. Natural Forest

Friis (1992) classified the forest of southwestern Ethiopia as lowland dry peripheral semi-evergreen Guineo-Congolean forest at altitudes 450 – 600 m asl, Afromontane rainforest (1500 to 2600 m asl) and transitional Afromontane rainforest (500 to 1500 m asl). One of the habitats identified for this study is natural forest, locally named as Accha Forest, which is found under the protection of Tepi National Spice Research Center, covering an area of 3.06 km^2. This forest is categorized under transitional Afromontane rainforest type (Friis, 1992). This habitat is located at an altitude of 1190 m asl. The dominant tree species in this habitat are indigenous trees such as *Albezia. gummifera*, *Cordia africana*, *Ficus vasta, F. exasperata, Croton macrostachyus, Pouteria frebirici, Allophyllus abyssinicus, Aningeria altissima, Anthocleista schweinfurthii, Campylospermum bukobense, Celtis philippensis, C. zenkeri, Elaeodendron buchananii, Eugenia bukobensis, Garcinia huillensis, Manlikara butugi, Morus mesozygia, Strychnos mitis, Trichilia dregeana* and *Trilepisium madagascarensis.* The forest generally forms a good canopy cover with a number of undergrowth plant species including some wild coffee plants (*Coffea arabica*), grasses and herbs (Fig. 3). The habitat harbours different species of arboreal animals (monkeys), other small mammals and reptiles.

Figure 3. Vegetation of natural forest habitat in the study area.

(Photo: Daniel B., August, 2010)

3.4.1.2. Bushland

This habitat is located at 350 m away from the forest habitat at an altitude of 1185 m asl. This habitat has a dense and dominant shrub stratum of plants 2.5 -5 m tall, and trees project out of this shrub layer. Below the shrub layer, herbs and perennial grasses are present (Fig. 4). The dominant herbs are *Acalypha racemosa, Brillantaisia grotanellii, Desmodium repandum, Isoglossa punctata*, *Phaulopsis imbricata*, *Pilea bambuseti*, *Piper capense* and *Setaria megaphylla*. Ferns are also found throughout. Shrubs that occur in this vegetation type include *Carissa edulis, Myrsine africana, Rhamnus staddo, Acokanthera schimperi, Euclea schimperi, Jasminum abyssinicum, Dodonaea angustifolia, Calpurnia aurea, Osyris quartipartita, Ximenia Americana* and *Protea gaguedi.*

Figure 4.Vegetation of bushland habitat in the study area.

(Photo: Daniel B., December, 2010)

3.4.1.3. Coffee Plantation

This habitat is at the western part of the town, adjacent to Shi River, which flow from northwest down to south of the town. It is at an altitude of 1235 m asl. The habitat had good canopy cover, while the ground cover was poor during all the trapping sessions (Fig. 5). The coffee plantation (*Coffee arabica*) was owned by private investor and it covers an area of 2.5 km^2.

Figure 5. Coffee plantation in the study area.

(Photo: Daniel B., August, 2010)

3.4.1.4. Sugarcane Plantation

Sugarcane plantation is one of the five habitats identified, and is located adjacent to Beko River, which flow from north to northwest and down to the south of the town. The plantation is located at about 80-100 m away from the river and the riparian habitat. This habitat covers an area of 1.8 km^2. It is at an altitude of 1220 m asl. The sugarcane plantation is owned by local Cooperative Farmers Association. During the first wet session (August, 2009), sugarcane was grown to an old stage with the maximum height of 4 m, and hence the habitat had a high ground cover. The second wet session (October, 2009), was post-harvest time with minimal cover made by some leftover sugarcane plants. During the first dry session (December, 2009), the vegetation cover of this habitat was made by immature sugarcane plants. The growth of the sugarcane plants during the second dry session (February, 2009) reached to young stage, intermingled and surrounded with weeds, grasses and fallen foliages (Fig. 6a and b).

Figure 6a. The vegetation of sugarcane habitat in the study area.

(Photo: Daniel B., February, 2010)

Figure 6b. A rodent (*Stenocephalemys albipes*) climbing to the shoot of sugarcane plant.

(Photo: Daniel B., February, 2010).

3.4.1.5. Maize-Sorghum Farmland

Maize-Sorghum farmland is the other habitat identified for this study. It is at an altitude of 1210 m asl. The system of cultivation of maize and sorghum in the study site is a type of inter-cropping. Maize was sown during mid-March, 2009 and grown to its maturity during late August, 2009, which was the season of first data collection. Sorghum was sown in the maize field during the beginning of August, 2009. So, the appearance of this habitat at the time of the first wet data collection session was of a matured maize farmland in which sorghum was emerging. During the second wet session, maize was harvested. Hence, the farmland was cover with growing sorghum plants. During the first dry session, the habitat was covered with mature sorghum plants ready to harvest. During the second dry session, the ground was covered with harvested sorghum field composed of falling sorghum plants and dried sorghum leaves (Fig. 7). The ground cover of the habitat was poor. Furthermore, the surrounding area of this habitat was fallow land covered with grassy patches.

Figure 7. Post-harvest sorghum farmland habitat in the study area.

(Photo: Daniel B., February, 2010).

4. MATERIALS AND METHODS

4.1. Materials

Materials used during the present study were Sherman live-traps, snap-traps, bait (pea nut better), GPS, dissecting kit, camera, spring balance, 70% alcohol, compound light microscope, 0.2 mm sieve and Paint.

4.2. Methods

4.2.1. Preliminary Survey

Reconnaissance survey of the study area was conducted early August, 2009. The survey was conducted in forests and farmlands around the town. During the survey, information about the different vegetation types, the approximate size and distance of each of the vegetation types from each other and from the town were collected. In addition to this, all available and necessary information about the study area such as climate, topography, farming system and timing of different farming activities were gathered.

4.2.2. Data Collection

Data collection was based on capture-mark-recapture (CMR) method. Trapping was made in four trapping sessions covering both wet and dry seasons. The wet and dry seasons for the data collection were selected based on the previous metreological data of Tepi town, accessed from Tepi National Spice Research Center. The selection of data collection sessions was also based on the timing of different farming activities in the study area. Accordingly, the first two trapping sessions were in the wet season (August and October), and the last two trapping sessions were in the dry season (December and February).

4.2.3. Grid Design and Sampling

Selection of the different habitats was based on vegetation composition of the study area. Based on this, random selection of habitats from the different vegetation types and farmlands was made. The five selected habitats were natural forest, bushland, coffee plantation, sugarcane plantation and maize-sorghum inter-cropping farmland in which maize and sorghum were grown during different data collection sessions. Five grids, each 70x70 m (4900 m^2) in the five habitat types were established to gather information on live-trapped specimens; the grids comprised of 7 parallel lines 10 m apart, with a trapping station in each line, resulting in 49 trapping stations (Fig. 8).

Sampling grids were selected randomly based on the representation of the habitats. The same grids were used during both seasons. In each of the sampling grids, permanent sampling stations at 10 m interval were placed. To explore the remaing habitat, 25 snap-traps at an interval of 20 m were used at a minimum of 300 m away from the live-trapping grids. Snap-trapping was also done in the maize and sorghum store house, 20-25 m away from the maize-sorghum field. In the store house, Six snap-traps were set, one each in the four corners and two in the middle of the store during the second wet session and the two dry trapping sessions, when there where storage in the store house. Traps were set for three consecutive days per session.

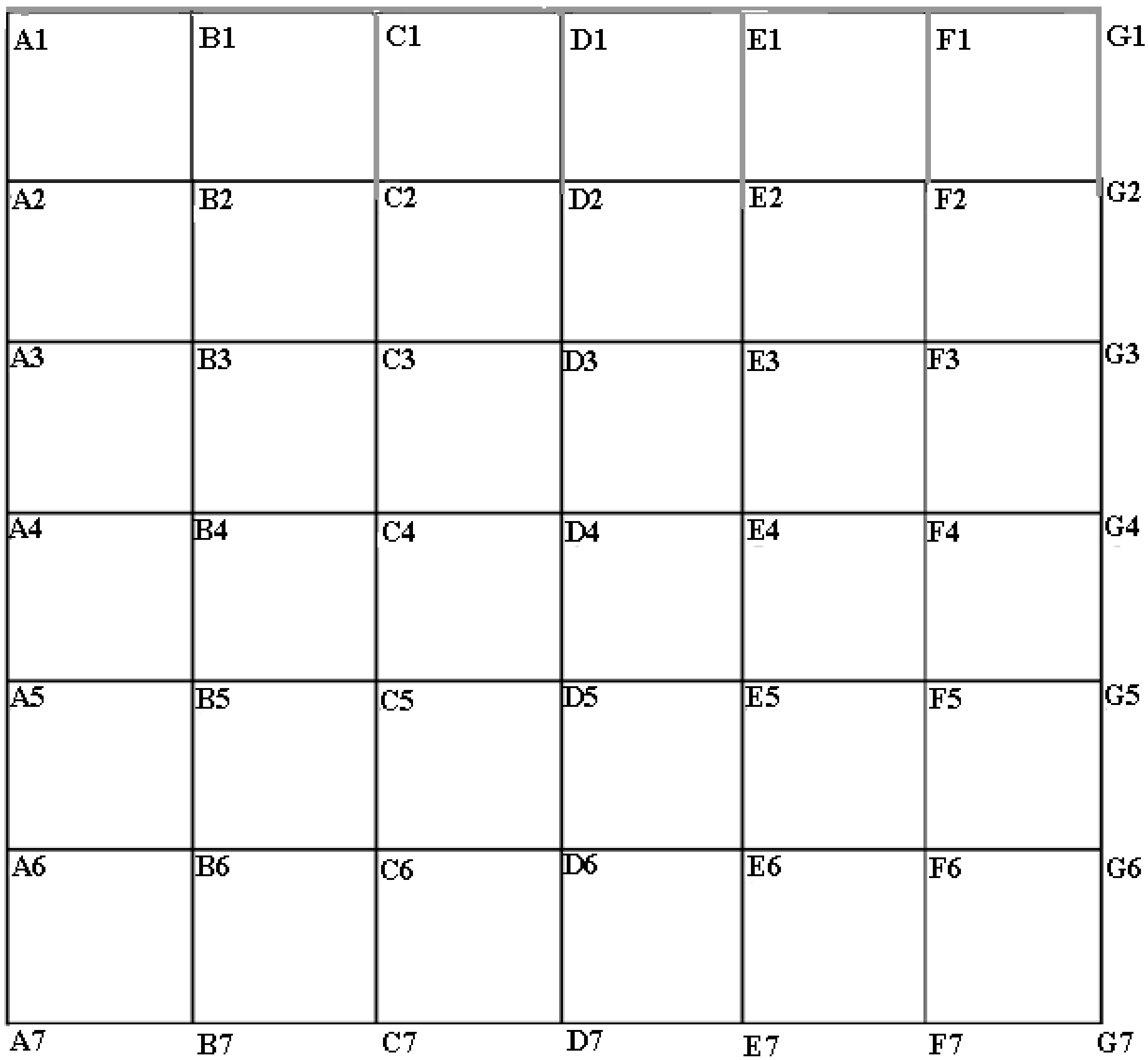

Figure 8. Diagrammatic representation of a live-trapping grid with trap locations.

4.2.4. Trapping

Sherman live-traps and snap-traps were used to trap rodents in the natural forest, bushland and farmland habitats. Each trap was baited with peanut butter and was checked twice a day, morning hours (07:00 - 08:00 h) and late afternoon hours (17:00 - 18:00 h). Trapped specimens were removed from the trap and kept in polyethylene bag. They were marked by toe clipping. For each individual trapped, grid and trap-station number, toe clipping code, body mass, and sexual condition were recorded prior to release. In addition, body measurements were taken from the snap trapped animals for species identification. Sexual conditions in males were detected by the colour and position of testicles (scrotal or abdominal) following Ghobrial and Hodieb (1982). The relative size of testicles was also used. For females, conditions of the vagina, size of the nipples and body weight were noted. Age structure was assessed as juvenile, sub-adult or adult based on their weight and peladge colour (Afework Bekele, 1996a). The taxonomic characteristics listed by Yalden *et al*. (1976) and Afework Bekele (1996a) were used for species identification. The prepared voucher skins and skulls were compared with the specimens available in the Zoological Natural History Museum of Addis Ababa University.

Dissection of 40 snap-trapped animals was carried out for stomach content analysis. The stomach contents were removed and preserved in 70% alcohol. The contents were put on a glass slide and observed under a compound light microscope to identify the type as well as proportion of the diet following Leirs (1994).

2.2.5 Data Analysis

The relative abundance of rodents in each habitat and season was assessed as the percentage of trap success between seasons and habitat types. Trap success was calculated by using the number of caught individuals and trapping nights. The population of rodents in each of the trapping sessions and grids was estimated by minimum number alive (MNA) estimation method (Krebs, 1998). SPSS (15.0) computer program was used to analyze the data. Shannon-Weaver Index (H') and Simpson's Similarity Index (SI) were used to compute rodent species diversity and similarity in different habitats, respectively. Population density of rodents was estimated for each trapping session by dividing the number of rodents alive per hectare. Biomass was calculated using the mean weight of each species and the population per hectare. In the agricultural habitats data on variation in the abundance of rodents before and after harvest was recorded. Pest status in the store was estimated by dividing the damaged amount by the total stored product and converted to percentile.

5. RESULTS

5.1. Species Composition and Relative Abundance of Small Mammals

A total of 11 species of small mammals were recorded during this investigation. Out of these, nine species were trapped and two species were sighted, but not captured. Altogether, 642 individuals of small mammals belonging to the orders Rodentia and Insectivora were trapped in 4440 trap nights (including Sherman-live traps and snap-traps), during both dry and wet seasons. Out of the total trapped small mammals, 634 (98.8%) individuals represented 7 species of rodents and 8 (1.2%) individuals represented 2 species of shrews (Table 1).

The seven captured rodent species were *Stenocephalemys albipes, Mastomys natalensis, Arvicanthis dembeensis*, *Lophuromys flavopunctatus*, *Lemniscomys striatus*, *Mus musculus* and *Mastomys erythroleucus*. The insectivore species were *Crocidura fumosa* and *Crocidura niobe*. The two sighted but not trapped rodent species were *Hystrix cristata* and *Paraxerus cooperi*. *H. cristata* and *P. cooperi* occur in the forest, bushland and other low level vegetation area in the compound of Tepi National Spice Research Centre.

Table 1. Species composition and relative abundance of small mammals captured.

Species	Numbers trapped	Relative abundance (%)
S. albipes Rüppell, 1842	207 (53)	38.05
M. natalensis Smith, 1834	106 (38)	19.48
A. dembeensis Rüppell, 1845	66 (25)	12.14
L. flavopunctatus Thomas, 1888	51 (17)	9.37
L. striatus Linnaeus, 1758	48 (10)	8.82
M. musculus Linnaeus, 1758	30 (12)	5.52
M. erythroleucus Temminck, 1853	28 (6)	5.14
C. fumosa Thomas, 1904	6	1.12
C. niobe Thomas, 1906	2	0.36
H. cristata Linnaeus, 1758	*	*
P cooperi Hayman, 1950	*	*
Total	544 (161)	100

* = non-trapped, but sighted; figures in parentheses are recaptured individuals

5.1.1. Species Composition and Abundance using Sherman-live trap

A total of 697 (87.7%) capture of rodents were made by Sherman live-traps in 2940 trap nights. Among the total live-trapped rodents, 536 individuals were recorded as new capture and the remaining 161 were recaptures. The relative abundance of live-trapped rodents varied from species to species. The variation in abundance of the different species in the study area was statistically significant ($\chi^2 = 58.31$, df = 6, $p < 0.01$). *S. albipes* was the most abundant species in the study area, followed by *M. natalensis, A. dembeensis, L. flavopunctatus, L. striatus* and *M. musculus.* The least abundant species was *M. erythroleucus*.

Among the seven species of rodents trapped, *S. albipes*, *M. natalensis* and *A. dembeensis* were trapped from all the five habitats. *L. striatus* was trapped from four habitats. *M. erythroleucus* and *M. musculus* were trapped from three habitats. *L. flavopuctatus* was trapped only from bushland and natural forest. The distribution of each of the rodent species among the different habitats is given in Table 2. The two non-trapped rodents were observed in the bushland and natural forest.

Table 2. Distribution of rodent species in the five habitat types.

Species	Presence/Absence in various habitat types				
	SCP	CP	MSF	BL	NF
S. albipes	*	*	*	*	*
M. natalensis	*	*	*	*	*
M. erythroleucus	–	–	*	*	*
A. denbeensis	*	*	*	*	*
L. flavopunctatus	–	–	–	*	*
L. striatus	*	–	*	*	*
M. musculus	*	–	*	*	–
H. criststa	−	−	−	x	x
P. cooperi	−	−	−	x	x
Total species/habitat	5	3	6	9	8

SCP = Sugarcane plantation, CP = Coffee plantation, MSF = Maize-sorghum farmland, BL = Bushland, NF = Natural forest. (* = indicates captured species, x = sighted, − = absence)

Species diversity indices of rodents was relatively high in natural forest and less in coffee plantation. The result of Shannon-Weaver Index (H') for the species diversity was 1.551, 1.007, 1.489, 1.221 and 1.557 for sugarcane plantation, coffee plantation, maize-sorghum farmland, bushland and natural forest, respectively. The variation in species diversity among different habitat types was statistically insignificant ($p > 0.05$). The overall Simpson's similarity index (SI) among the five habitat types during the entire trapping session was 0.234.

The highest number of rodents was captured from bushland 174 (32.5%), followed by maize-sorghum farmland 122 (22.8%), whereas coffee plantation was the least both in terms of species and the number of individuals 15 (2.8%). Sugarcane plantation 118 (22%) and natural forest 107 (19.9%) were intermediate in the number of captured individuals. *S. albipes* was highly associated with bushland (53.6%). *M. natalensis* was the second abundant species with the highest trapping from maize-sorghum farmland (53.8%). The highest proportion (57.1%) of *M. erythroleucus* was also trapped from this habitat (Table 3). The highest trapping of *A. dembeensis* was made from sugarcane plantation (34.8%) and maize-sorghum farmland (20.3%). *L. flavopuctatus* had a complete preference to the non-agricultural habitats (natural forest and bushland). The highest proportion (70%) of *M. musculus* was trapped from sugarcane plantation. The percentile occurrence in different habitats of *L. striatus* was in the order of natural forest (31.3%), sugarcane plantation (25%) and maize-sorghum farmland (22.9%) and bushland (20.8%).

The result of variations in abundance of *S. albipes* ($\chi^2 = 78.86$, df = 4, $p < 0.001$), *M. natalensis* ($\chi^2 = 87.24$, df = 4, $p < 0.001$), *A. dembeensis* ($\chi^2 = 30.86$, df = 4, $p < 0.001$) and *M. musculus* ($\chi^2 = 60.72$, df = 2, $p < 0.001$) among the different habitats were significant. The overall difference in the abundance of rodents among the different habitats was also statistically significant ($\chi^2 = 24.99$, $p < 0.01$). However, the abundance of *L. flavopunctatus*, *L. striatus*, and *M. erythroleucus* among the different habitats were statistically insignificant ($p > 0.05$).

Table 3. Abundance and percentage occurrence of each species in the five habitats.

Species	Habitat types					Total capture
	SCP	CP	MSF	BL	NF	
S. albipes	36(17.4)	8(3.8)	14(6.7)	111(53.6)	38(18.5)	207
M. natalensis	26(24.5)	4(3.8)	57(53.8)	3(2.8)	16(15.1)	106
A. dembeensis	23(34.8)	3(4.6)	20(20.3)	15(22.7)	5(7.6)	66
L. flavopunctatus	-	-	-	23(45.1)	28(54.9)	51
L. striatus	12(25)	-	11(22.9)	10(20.8)	15(31.3)	48
M. musculus	21(70)	-	4(13.3)	5(16.7)	-	30
M. erythroleucus	-	-	16(57.1)	7 (25)	5(17.9)	28
Total	118(22)	15(2.8)	122 (22.8)	174(32.5)	107(19.9)	536(100%)

SCP = Sugarcane plantation, MSF = Maize-sorghum farmland, CP = Coffee plantation, BL = Bushland, NF= Natural forest. Dash shows absence of trapped individuals. (figures in parentheses indicate percentage of occurrence per habitat)

All the seven rodent species were recorded in both seasons and in all the four trapping sessions. Two species (*L. striatus* and *M. musculus*) showed increase in their number during the dry season, whereas the other five species showed decease in captured individuals during the dry season (Fig. 9). The total captured individuals during the wet and dry seasons were 299 (55.8%) and 237(44.2%), respectively. The difference in the abundance of individual rodents between wet and dry seasons showed statistically significant difference ($\chi^2 = 7.17$, $p < 0.05$).

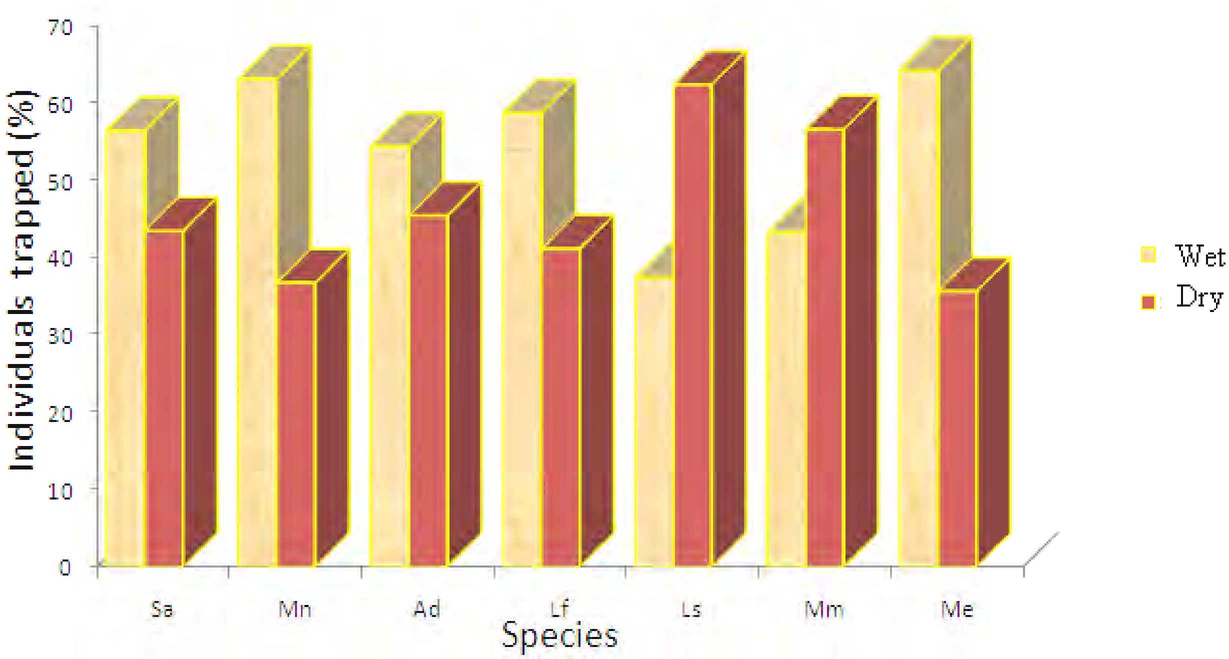

Figure 9. Seasonal variation in abundance of rodents (Sa = *S. albipes*, Mn = *M. natalensis*, Ad = *A. dembeensis*, Lf = *L. flavopunctatus*, Ls = *L. striatus*, Mm= *M. musculus and* Me= *M. erythroleucus*)

The average trap success in the study sites in 2940 trap nights was 18.23% (Table 4). The highest trap success (32.3%) was recorded in the bushland habitat during the wet season. The least trap success (1.4%) was recorded in the coffee plantation during the dry season. Variation in trap success among the habitat types was statistically significant ($\chi^2 = 20.68$, df= 4, $p < 0.01$).

Table 4.Trap nights and trap success of rodents during wet and dry seasons in the five habitats (each294 trap nights).

Habitat type	Season	Captures	Trap Success (%)
SCP	Wet	42	14.3
	Dry	76	25.9
CP	Wet	11	3.7
	Dry	4	1.4
MSF	Wet	75	25.5
	Dry	47	15.9
BL	Wet	95	32.3
	Dry	79	26.9
NF	Wet	76	25.9
	Dry	31	10.5
Total		536	18.2

SCP = Sugarcane plantation, MSF = Maize-sorghum farmland, CP = Coffee plantation, BL = Bushland, NF = Natural forest

Out of the 536 individuals of rodents captured, females comprised 169 (31.5 %) and males 367 (68.5 %). In all rodent species, the sex ratio of males was higher than females. The difference in the rate of capture of females and males was statistically significant ($\chi^2 = 73.14$, $p < 0.001$). The sex ratio of trapped rodents from different habitats is given in Table 5.

Table 5. Sex ratio of rodents captured in the five habitats (M = Male, F = Female).

Grid	Sa		Mn		Ad		Lf		Ls		Mm		Me		Total	
	Number of individuals of different species															
	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F
SCP	29	7	19	7	15	8	-	-	8	4	8	13	-	-	79	39
CP	6	2	2	2	3	-	-	-	-	-	-	-	-	-	11	4
MSF	11	3	34	23	14	6	-	-	8	3	1	3	11	5	79	43
BL	81	30	1	2	12	3	17	6	6	4	2	3	5	2	124	50
NF	26	12	7	9	5	-	20	8	12	3	-	-	4	1	74	33
Total	153	54	63	43	49	17	37	14	34	14	11	19	20	8	367	169
Ratio	1.48:0.52		1.18:0.82		1.48:0.52		1.46:0.54		1.42:0.58		0.74:1.26		1.42:0.58		1.37 :0.63	

SCP = Sugarcane plantation, CP = Coffee plantation, MSF = Maize-sorghum farmland, BL = Bushland, NF = Natural forest (Sa = *S. albipes,* Mn = *M. natalensis,* Ad = *A. dembeensis,* Lf = *L. flavopunctatus,* Ls = *L. striatus,* Mm= *M. musculus and* Me= *M. erythroleucus*)

All age groups of all species were trapped. Out of the total, juveniles accounted for 74 (13.8%), sub-adult 180 (33.6%) and adult 282 (52.6%). Majority (27) of the juveniles were captured during the second wet session, followed by the first wet session (23). The number of juveniles captured during both dry sessions was less (Table 6). The difference in the total capture of juveniles during wet and dry seasons was statistically significant ($\chi^2 = 9.135$, $p < 0.01$). Sub-adults were captured more (55) during the first wet session and the least (31) during the second dry session. The proportion of adult was maximum during the first wet session and minimum during the second wet session. The difference in age groups of rodents in the study area showed significant statistical difference **(**$\chi^2 = 121.08$, $p < 0.001$).

Table 6. Comparison of different age groups of live–trapped rodents during different trapping sessions.

Trapping Session	Age group			Total
	Juvenile	Sub-adult	Adult	
Wet-I	23	55	95	173
Wet-II	27	53	46	126
Dry-I	14	41	66	121
Dry-II	10	31	75	116
Total (Percent)	74 (13.8 %)	180 (33.6 %)	282 (52.6 %)	536 (100 %)

Out of the total females trapped, 147 (86.7%) were perforated. Among the perforated ones, 55 (37.4%) were sub-adults, 41 (27.8%) were non-pregnant adults, 28 (19.0%) were pregnant and 23 (15.7%) were lactating. The abundance of breeding females during wet and dry seasons was 37 (72.5%) and 14 (27.5%), respectively. There was significant variation in the abundance between seasons ($\chi^2 = 20.25$, $p < 0.01$). Relatively more breeding females of *M. natalensis* and *S. albipes* were captured during both dry and wet seasons. There were no breeding females of *L. striatus* captured during any of the seasons. Among other species, breeding females were less during the dry season than during the wet season (Table 7). Among the adult males, 106 (55.7%) were scrotal and 84 (44.3%) were abdominal (Table 8). Among the 106 scrotal males, 67(63.2 %) were captured during the wet season and 39 (36.8%) during the dry season. The difference was statistically significant ($\chi^2 = 7.4$, $p < 0.05$).

Table 7. Reproductive status of females trapped during the wet and dry seasons.

Species	Season	Young	Sub-adult	Non - breeding Adult	Pregnant	Lactating	Total
		Number of trapped female rodents					
Mn	Wet	3	8	2	6	5	24
	Dry	2	6	6	2	3	19
Sa	Wet	5	9	-	6	8	28
	Dry	3	8	9	4	2	26
Ad	Wet	2	4	-	2	-	8
	Dry	1	3	4	1	-	9
Mm	Wet	1	3	1	2	2	9
	Dry	1	3	5	-	1	10
Ls	Wet	2	2	1	-	-	5
	Dry	-	4	5	-	-	9
Lf	Wet	1	1	2	4	-	8
	Dry	-	2	4	-	-	6
Me	Wet	1	2	1	-	2	6
	Dry	-	-	1	1	-	2
Total		22	55	41	28	23	169
%		13.0	32.5	24.3	16.6	13.6	100

Mn = *M. natalensis*, Sa = *S. albipes, Ad = A. dembeensis,* Lf = *L. flavopunctatus*, Ls=*L. striatus,* Mm= *M. musculus and* Me= *M. erythroleucus*

Table 8. Reproductive status of males trapped during the wet and dry seasons.

		Number of trapped male rodents				
Species	Season	Young	Sub-adult	Abdominal	Scrotal	Total
Mn	Wet	8	11	4	13	36
	Dry	4	9	4	10	27
Sa	Wet	7	37	16	24	84
	Dry	6	27	21	15	69
Ad	Wet	3	11	4	11	29
	Dry	2	4	9	5	20
Mm	Wet	3	1	–	2	6
	Dry	2	–	2	1	5
Ls	Wet	4	7	3	7	21
	Dry	–	8	3	2	13
Lf	Wet	4	2	2	6	14
	Dry	–	5	13	5	23
Me	Wet	6	3	1	4	14
	Dry	3	–	2	1	6
Total		52	125	84	106	367

Mn = *M. natalensis,* Sa = *S. albipes, Ad* = *A. dembeensis,* Lf = *L. flavopunctatus,* Ls =*L. striatus,* Mm= *M. musculus and* Me= *M. erythroleucus*

The population size of rodents from the live-trapping grid showed a continuous decrease from the first wet trapping session to the second dry trapping session. The population size of rodents in the first wet trapping session was the highest of all trapping sessions. The rodent population tended to decline in all grids except sugarcane plantation during the second dry trapping session. The minimum number of rodents known to be alive (MNA) in different trapping sessions is given in Figure 10. The present study showed that there is statistically significant difference in the population size between seasons ($p < 0.05$).

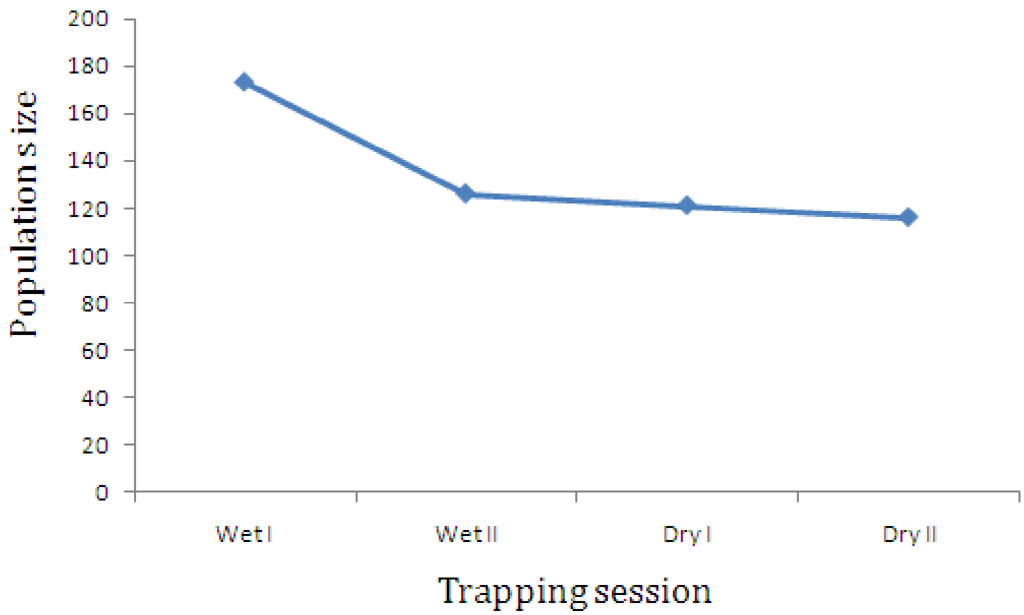

Figure 10. Population size of trapped rodents during different trapping sessions

The overall population density of rodents in the study area was 1087/ha. The highest population density (422/ha) was contributed by *S. albipes*, followed by *M. natalensis* (216/ha). *A. dembeensis* had a density of 133/ha in the study area. The density of *S. albipes* ranged from 16/ha in coffee plantation to 226/ha in the bushland habitat. The density of *M. natalensis* was from 6/ha in the bushland to 117/ha in maize-sorghum farmland and that of *A. dembeensis* was 6/ha in coffee plantation, whereas 47/ha in sugarcane plantation. The density of *M. musculus*, *L. striatus* and *L.flavopunctatus* in different habitats ranged between 0-42/ha, 0-30/ha and 0-56/ha, respectively. The density of *M. natalensis* was 0/ha during the third and fourth trapping sessions in coffee plantation and bushland, and was high (55/ha) in maize-sorghum farmland during the first trapping session of the wet season. Maize-sorghum farmland showed high fluctuation in rodent density among the different sessions than the other habitats (Table 9).

Table 9. Density of rodents (per ha) in the various habitat types during the four trapping sessions.

		Density per Trapping session					
Species	Habitat	Wet I	Wet II	DryI	DryII	Total	Mean
Mn	SCP	16	4	6	27	53	13
	CP	6	2	--	--	8	2
	MSF	55	21	33	8	117	29
	BL	4	2	--	--	6	1
	NF	12	14	4	2	32	8
Sa	SCP	25	8	12	29	74	19
	CP	6	4	4	2	16	4
	MSF	18	4	6	--	28	7
	BL	53	69	59	45	226	57
	NF	21	31	16	10	78	20
Ad	SCP	14	2	8	23	47	12
	CP	4	--	2	--	6	1
	MSF	18	8	10	4	40	10
	BL	14	2	12	2	30	8
	NF	6	4	--	--	10	3
Mm	SCP	12	--	12	18	42	11
	CP	--	--	--	--	0	0
	MSF	4	--	--	4	8	2
	BL	6	4	--	--	10	3
	NF	--	--	--	--	0	0
Ls	SCP	--	4	8	12	24	6
	CP	--	--	--	--	0	0
	MSF	4	2	6	10	22	6
	BL	--	6	6	8	20	5
	NF	8	12	4	6	30	8
Lf	SCP	--	--	--	--	0	0
	CP	--	--	--	--	0	0
	MSF	--	--	--	--	0	0
	BL	10	14	10	12	46	12
	NF	16	20	12	8	56	14
Me	SCP	--	--	--	--	0	0
	CP	--	--	--	--	0	0
	MSF	10	8	10	4	32	8
	BL	2	6	4	2	14	4
	NF	6	4	--	--	10	3
Total		351	255	245	236	1087	271

SCP = Sugarcane plantation, CP = Coffee plantation, MSF = Maize-sorghum farmland, BL = Bushland, NF = Natural forest (Mn = *M. natalensis,* Sa = *S. albipes,* Ad = *A. dembeensis,* Lf = *L. flavopunctatus,* Ls = *L. striatus,* Mm= *M. musculus and* Me = *M. erythroleucus*)

The maximum biomass (20323.1 g/ha) was recorded in the first trapping session of the wet season and the minimum (12619.8 g/ha) was in the second trapping session of the dry season. The biomass decreased from the first wet session towards the second dry session (Table 10). The highest mean biomass (4825.316g/ha) was contributed by *S. albipes,* followed by *M. natalensi*s (2494.22g/ha). The least (465.72g/ha) was contributed by *M. musculus*. The maximum mean biomass per habitat was estimated from bushland (2771.3 g/ha), followed by maize-sorghum farmland (2054.38 g/ha) and minimum mean biomass was estimated from the coffee plantation (251.88 g/ha). The biomass for each species and habitat type is given in Table 11.

Table 10. Biomass (g/ha) of rodents in each habitat during the different trapping sessions (figures in parentheses are mean body weight).

		Biomass per Trapping session					
Species	Habitat	Wet I	Wet II	Dry I	Dry II	Total	Mean
Mn	SCP	908.8	227.2	340.8	1533.6	3010.4	752.6
(55.4)	CP	310.8	103.6	0	0	414.4	103.6
	MSF	3283.5	1253.7	1970.1	477.6	6984.9	1746.2
	BL	218	109	0	0	327	81.8
	NF	650.4	758.8	216.8	108.4	1734.4	433.6
Sa	SCP	1512.5	484	726	1754.5	4477	1119.3
(57.5)	CP	343.8	229.2	229.2	114.6	916.8	229.2
	MSF	1058	235.1	352.68	0	1645.78	411.4
	BL	3015.7	3926.1	3357.1	2560.5	12859.4	3214.9
	NF	1138.2	1680.2	867.2	542	4227.6	1056.9
Ad	SCP	1058.4	151.2	604.8	1738.8	3553.2	888.3
(72.54)	CP	288	0	144	0	432	108
	MSF	1263.6	561.6	720	280.8	2826	706.5
	BL	1029	147	882	147	2205	551.25
	NF	428.4	285.6	0	0	714	178.5
Mm	SCP	466.8	0	466.8	700.2	1633.8	408.5
(38.9)	CP	0	0	0	0	0	0
	MSF	170.4	0	0	170.4	340.8	85.2
	BL	212.4	141.6	0	0	354	88.5
	NF	0	0	0	0	0	0
Ls	SCP	0	169.2	338.4	507.6	1015.2	253.8
(39.9)	CP	0	0	0	0	0	0
	MSF	158.4	79.2	237.6	396	871.2	217.8
	BL	0	240.6	240.6	320.8	802	200.5
	NF	302.4	453.6	151.2	226.8	1134	283.5
Lf	SCP	0	0	0	0	0	0
(60)	CP	0	0	0	0	0	0
	MSF	0	0	0	0	0	0
	BL	584	700.8	584	233.6	2102.4	525.6
	NF	971.2	1214	728.4	485.6	3399.2	849.8
Me	SCP	0	0	0	0	0	0
(52.8)	CP	0	0	0	0	0	0
	MSF	535	428	535	214	1712	428
	BL	107	321.2	214.1	107	749.3	187.3
	NF	308.4	205.6	0	0	514	128.5
Total		20323.1	14106.1	13906.8	12619.8	60955.8	15239

Table 11. Estimated mean biomass of each species in the different habitats.

Habitat	Species							Total	Mean
	Mn	Sa	Ad	Mm	Ls	Lf	Me		
SCP	3010.4	4477	3553.2	1633.8	1015.2	0	0	13690	1955.657
CP	414.4	916.8	432	0	0	0	0	1763.2	251.8857
MSF	6984.9	1645.78	2826	340.8	871.2	0	1712	14381	2054.383
BL	327	12859.4	2205	354	802	2102.4	749.3	19399	2771.3
NF	1734.4	4227.6	714	0	1134	3399.2	514	11723	1674.743
Total	12471.1	24126.58	9730.2	2328.6	3822.4	5501.6	2975.3	60956	12191.16
Mean	2494.22	4825.316	1946.04	465.72	764.48	1100.3	595.06		

SCP = Sugarcane plantation, CP = Coffee plantation, MSF = Maize-sorghum farmland, BL = Bushland, NF =Natural forest (Mn = *M. natalensis,* Sa = *S. albipes*, Ad = *A. dembeensis,* Lf = *L. flavopunctatus,* Ls =*L. striatus*, Mm = *M. musculus and* Me = *M. erythroleucus*)

The abundance of rodents in all agricultural habitats was higher during pre-harvest than post-harvest session. The number of individuals captured during pre-harvest session and post-harvest session showed statistical difference (χ^2 =35.65, $p < 0.001$). Only in the case of *L. striatus,* there was increase in their number during the post-harvest session (Table 12).

Table12. Variation in pre-harvest and post-harvest rodent capture.

Species	Habitat	Pre-harvest	Post-harvest
M. natalensis	SCP	8	2
	MF	27	10
	SF	16	4
S. albipes	SCP	12	4
	MF	9	2
	SF	3	–
A. dembeensis	SCP	7	1
	MF	9	4
	SF	5	2
M. musculus	SCP	6	–
	MF	2	–
	SF	–	–
L. striatus	SCP	–	2
	MF	2	1
	SF	3	5
M. erythroleucus	SCP	–	–
	MF	5	4
	SF	5	2
Total		119(73.5%)	43(26.5%)

SCP = Sugarcane plantation, CP = Coffee plantation, MSF = Maize-sorghum farmland, BL = Bushland, NF =Natural forest

5.1.2. Snap-trapped Rodents

A total of 98 individual rodents of six species were captured in 1500 trap nights using snap-traps. *M. erythroleucus* was not recorded during the snap-trapping. The snap-trapped rodents and their relative abundance are given in Table 13. Five species were snap-trapped from bushland; four species from sugarcane plantation and maize-sorghum farmland; three species of *M. musculus, M. natalensis* and *A dembeensis* in the store house and natural forest habitat. Only one individual of *A dembeensis* was captured from coffee plantation**.**

Table13. Species composition and abundance of snap trapped rodents.

Species	No of individuals snap-trapped in each habitat					Total (%)
	SCP	CP	MSF	BL	NF	
M. natalensis	6	–	9	5	6	26(26.5)
S. albipes	10	–	5	9	9	33(33.7)
A dembeensis	4	1	6	–	–	11(11.2)
M. musculus	3	–	9	1	–	13(13.3)
L. striatus	–	–	–	3	3	6(6.1)
L. flavopunctatus	–	–	–	3	6	9(9.2)
Total	23	1	29	21	24	98(100)

SCP = Sugarcane plantation, CP = Coffee plantation, MSF = Maize-sorghum farmland, BL = Bushland, NF =Natural forest

A total of 14 pregnant female rodents of four species were captured by snap-tapping. The number of embryos of pregnant females varied from species to species (Table 14). The highest number (8-14) was recorded for *M. natalensis* and the least (4-5) was for *L. flavopunctatus*. Unlike *L. flavopunctatus* and *S. albipes*, the embryo count among individuals of *M. natalensis* showed great variation**.**

Table 14. Number of embryos recoded from snap-trapped pregnant females

Species	Number of females dissected	Number of embryo
M. natalensis	4	8−14
S. albipes	5	5−6
A. dembeensis	3	5−8
L. flavopunctatus	2	4−5
Total	14	

Contents of a total of 40 stomachs of six species of rodents were analysed for food items. The diet of *S. albipes* was predominantly plant leaves. In the diet of *M. natalensis*, monocot seeds, mainly maize and some sorghum were dominant, followed by leaves. Grass, monocot seeds and dicot seeds were the dominant food items of *A. dembensis*. The major food item in the stomach of *L. flavopunctatus* was body parts of earthworms and arthropods, while that of *L. striatus* was mainly arthropod parts. Monocot seeds, particularly maize and sorghum, plant leaves and grasses were almost equally seen in the diet of *M. musculus*. The food items that were not recognized were grouped under unidentified materials (Table 15). There was a significant variation ($P < 0.05$) in the proportion of the diet of each species, but there was no significant variation in the type of food items between wet and dry seasons ($p > 0.05$).

Table 15. Food items of six species of rodents in the stomach contents collected during wet and dry seasons.

		Diet Item						
Species	Season	S	PLG	PR	SF	A	EW	U
Sa	Wet	15.3	35	–	18.9	6.7	14.3	9.8
	Dry	12.1	33.1	3.2	16.4	9.4	13.7	12.1
Mn	Wet	40.5	16.3	3.2	14.2	5.8	6.5	13.5
	Dry	46	9.5	5.7	12.5	7.3	4.2	14.7
Ad	Wet	25.8	36	8.5	6.3	6.1	–	17.3
	Dry	29.6	31	6.8	7.5	10.5	–	14.6
Lf	Wet	5.6	15	12	–	17.6	24.8	25
	Dry	3.5	12.4	20	–	16.8	20.5	26.8
Mm	Wet	20.9	22.4	10.3	–	10.5	7.2	28.7
	Dry	26.7	20.8	13.4	–	7.9	4.7	26.5
Ls	Wet	10.5	20.3	5.5	2.5	29.5	15.1	16.6
	Dry	8	14.8	14.8	3.5	28.5	16.4	14

S = monocot + dicot seeds, PLG = plant leaves and grasses, PR = plant root, SF = sugar cane fiber, A = arthropod body, EW = Earth worm, U = unidentified material (Mn = *M. natalensis,* Sa = *S. albipes,* Ad = *A. dembeensis,* Lf = *L. flavopunctatus,* Ls=*L. striatus*)

5.1. 3. Rodents as Pests

An assessment for identification of rodent pests associated with maize and sorghum showed that three rodent species (*M. natalensis, A. dembeensis* and *M. musculus*) were pests of maize. The effect of these species on sorghum crop was minimal. Identification of rodent pests based on the capture rate during pre-harvest and post-harvest seasons reveled about 73.5% and 26.5%, respectively. The damage and contamination (Fig. 11a-d) observed on maize crops was about 10 % or 1.5 quintals out of 15, in the store house. Besides this, three species of rodents were captured by snap-trapping in the store house (four individuals of *M. natalensis*, two individuals of *A. dembeensis* and seven individuals of *M. musculus*, in 54 trapping nights, with 24.1% trap success). Stomach content analysis also clearly showed that these species were the major pests of maize crops mainly in the store and to a lesser extent in the field.

In addition to this, the stomach content analysis of rodents sampled from sugarcane plantation confirmed the presence of sugarcane fibers in the diet of *S. albipes, M. natalensis* and *A. dembeensis*. Some stalks and shoots of sugar cane plants in the field were also damaged by rodents (Fig. 12).

Figure 11 a-d. Damage and contamination on maize seeds in the store house by rodent pests. (Photo: Daniel B., February, 2010).

Figure 12. Pest of the sugar cane plantation, showing rodent damage.
(Photo: Daniel B., October, 2010).

6. DISCUSSION

Kingdon (1997) reported the wide distribution of *P. cooperi* in montane and transitional forests, which is similar result with the present study area. *C. fumosa* was live-trapped during the two wet trapping sessions from these habitats. Only two individuals of *C. niobe* were live trapped from the natural forest habitat during the second wet trapping session. A similar study by Yalden *et al.* (1976) indicated the distribution of this species in a similar altitudinal range (820-1500 m asl) in tropical deciduous forest. They also reported this species from southwest Ethiopia. The overall rodent species composition of the study area is comparable to the studies conducted in other regions of Ethiopia. Afework Bekele (1996a) in Menagesha State Forest reported six rodent species. Similarly, Yalden (1988b) recorded seven species of rodents from Bale Mountains. As the study was conducted around the town, the high human interference might have influenced the rodent species richness of the area.

Oguge (1995) reported 73% abundance of *M. natalensis* in a sub-humid grassland community in Kenya. The opportunistic behaviour enables *M. natalensis* to take advantage of changes in habitats, particularly in relation to food resources (Massawe *et al.*, 2005). This might have contributed to its abundance in the present study area. Tadesse Habtamu and Afework Bekele (2008) recorded such a least (1.35%) abundance of *M. erythroleucus* from a lowland area.

S. albipes, which is endemic species to Ethiopia (Yalden and Largen, 1992; Bulatova *et al.* 2002) is one of the three common species of rodents in the present study area in all habitats. The altitudinal range and the hot-humid climate of the study area overlap with the already documented environmental conditions for the distribution and abundance of *S. albipes*. According to Yalden *et al.* (1976), the distribution of *S. albipes* extends to areas as low as 1285 m asl at Merab Abaya and 820 m asl in the Godare Forest, which are humid forests. The present result is also consistent with the observation of this species in all habitats of Alatish National Park, including human habitats (Tadesse Habtamu and Afework Bekele, 2008). The wide distribution of this species in all the habitats of the parent study area might be due to its high environmental tolerance.

The other widely distributed rodent species in the present study area is *M. natalensis.* This is a common rodent species in East Africa, and was reported from different regions of Ethiopia (Yalden *et al.,* 1996; Lavrenchenko *et al*., 1998; Manyingerew Shenkut *et al*., 2006). This species is prolific and opportunistic (Taylor, 1968; Meehan, 1984; Mwanjabe, 1993), which might have helped to its dominance and wide distribution. *A. dembeensis* was the other widely distributed rodents, trapped from all the five habitats in the present study area. This is in agreement with other investigators, which documented the wide distribution of this species in the lowlands. For instance, Bulatova *et al.* (2002) reported this species from a similar altitudinal range and geographically adjacent region to the present study area in Gambela. The reason for the wide distribution of this species in the present study area could be that *Arvicanthis*, living in a habitat where there is a continuous supply of crop breed almost continuously (Taylor and Green, 1976). On the other hand, its opportunistic feeding and breeding behavior (Tilaye Wube, 1999) might have contributed to its adaptation to various habitats and hence, its distribution. The distribution of *M. erythroleucus* was restricted to three habitats. Odhiambo (2005) reported that this species settles sometimes in the perimeter of resource-rich habitat patches of maize farm. This could be the main cause for the limited distribution of the species in the study area.

L. flavopunctatus is the least distributed species in the present study area, which was trapped only from the natural habitats (bushland and natural forest). This result showed similarity as well as difference with previous studies on rodents. Yalden and Largen (1992) reported this species as the most widespread and abundant among the Ethiopian rodents. However, the absence of captured individuals of this species in agricultural habitats is comparable with the report by Happold (1974), who identified this species as moderate ecological tolerance confined to three or four habitats of forests and secondary growth and absence in farmlands. The highest adaptability to the natural habitats as well as competition in the modified habitats (farmlands and plantations) might have influenced its distribution. Competition between species has been viewed as having a key role in influencing the ecological, biogeographycal and evolutionary pattern of mammalian species (Millien and Loreau, 2000; Tilaye Wube, 2005). *L. striatus* was recorded from the four habitats. Happold (1974) identified this species as a species with wide ecological tolerance, which occurs in Savanna, forest and farmlands.

The observed distribution pattern of rodents in the present study area showed that they are not uniformly distributed in all habitat types. Afework Bekele (1996b) has reported uneven distribution of 12 species of rodents across different vegetation Zones in Menagesh Forest area. Generally, as there is no significant difference in the altitude (as mentioned in the description of the study area) of the different habitat types, the availability and quality of food, shelter resources and rainfall might be the main factors determining the distribution of the rodents in the study area.

In the present study, the diversity indices showed differences with the results in different study sites in Democratic Republic of Congo (Mukinzi *et al.,* 2005). The dominance of *S. albipes* in the bushland habitat and *M. natalensis* in the maize-sorghum farmland resulted in the reduced diversity indices than the natural forest habitat. According to Zar (1996), if the abundance of species is distributed evenly, there will be high species diversity, whereas, if few species have most of the total abundance, the species diversity will be low. The overall Simpson's similarity index was less compared with other studies.

Habitat association provides a useful way to determine how different species respond to environmental heterogeneity. Habitat selection has an adaptive basis (Martin, 1998). The abundance of rodents was significantly different among the habitats in the present study area, with the highest abundance in the bushland. Bushland and temporary farmland derived as a result of forest modification support more animals (and often more species) than the forest itself (Delany, 1986). High abundance of rodents in the bushland habitat in the present study area might be related to the diverse and densely grown plants that provide shelter, food and a hiding place from predators. Rodents were also abundant in maize-sorghum farmland next to bushland. The abundance of rodents in sub-Saharan African agricultural fields is well documented (Oguge, 1995; Caro, 2001; Massawe *et al.,* 2005; Petersen, 2006; Massawe *et al*., 2008). The cropping system of the area (inter-cropping system) possibly might have contributed to the abundance in this habitat as a result of continuous and alternative supply of food and shelter resources. Massawe *et al.* (2003) recorded higher rodent abundance in inter-cropped fields than in the mono-cropped fields in Morogoro, Tanzania. Sugarcane plantation had the third highest rodent abundance in the study area. Rao (2003) indicated that rodents colonise cane fields because they provide undisturbed habitat for burrowing, feeding, breeding activities in addition to protective cover from avian predators for most of the year. The abundance of rodents in the natural forest was greater than that of coffee plantation. The lowest abundance was recorded from coffee plantation habitat during the study period. This might be attributed to dense shade and the poor ground cover of the habitat. According to Iyawe (1988), habitat selection of different species of small mammals is mainly dependent on the vegetation of the habitat. The other major factor which might have influenced both the species richness and abundance in the coffee plantation habitat might be the continuous usage of weedicide and pesticides to protect the coffee seeds. Belmain (2007) reported the adverse impacts of chemical pesticides and rodenticeds on the overall flora and fauna in farmlands.

S. albipes was highly associated with bushland habitat (53.6%). Similarly, Makundi *et al.* (2005) reported that this species was more abundant in secondary bushland and forest-fallow land inter-phase than in cultivated fields and crop-fallow mosaics. According to Martin (1998), it is reasonable to assume that individuals demonstrating preference for high-quality habitats have a reproductive advantage over conspecifics in low-quality habitats. This would ultimately lead to a particular species being more abundant in some habitats than in others. *M. natalensis* had highest occurance in maize-sorghum farmland habitat. Massawe *et al*. (2008) reported a very high abundance (97.8%) of *M. natalensis* in crop fields in Tanzania. *L. flavopuctatus* had a complete preference to non-agricultural habitats (natural forest and bushland), constituting 45.1% in bushland and 54.9% in the natural forest. This shows similarity with higher abundance of this species in the bushland than in crop field (Tilaye Wube, 2005). The preference of *L. striatus* for natural forest was significant. Similar finding was reported by Caro (2001) from a dry deciduous forest in African National Park (western Tanzania), when there was high herb growth. The highest proportion of *M. musculus* was obtained from sugarcane plantation in the study.

During the present study, there was variation in abundance of rodents between seasons. The variation in abundance might be the result of availability and quality of food during the wet season following the six rainy months and, disturbance effect during the dry season. However, the two species (*M. musculus* and *L. striatus*) showed increase in their populations during the dry season. The high capture rate of *M. musculus,* during the dry season could be the result of migration from villages or the effect of migration from the nearest riverine habitat along Beko River. This could also be the cause for the whole increase in capture rate of rodents in this habitat during the second dry trapping session. Non-crop habitats such as river banks and steep slopes support weeds and other grasses, and provide refugia for rodents, especially after rodent dispersal during mechanized cane harvesting activity (Smith *et al.*, 2002). Thus, large number of rodents might have settled within these undisturbed areas until the cane canopy develops (second dry trapping session) sufficiently to provide enough protection and food, when rodents return to recolonise the sugarcane plantation.

The variation in trap success among different habitat types was significant in the present study area. The average trap success in the study sites was 18.23%. Yalden (1988a) reported a similar mean success rate of 18.7% from Harenna Forest, Ethiopia. The highest trap success was recorded during the wet season in the bushland habitat. This is highest as compared to most of the reports in Africa. The least trap success (1.4%) was recorded in coffee plantation during the dry season. This result is low compared to most other reports. Oguge (1995) reported 3% success rate from sub-humid grassland community in Kenya. Afework Bekele **(**1996b) reported a trap success of 1.6% from *Erica* and *Juniperus procera* habitat of Menagesha State Forest, Central Ethiopia. The wet **s**eason trap success (25.9%) in the natural forest habitat is higher than 21.5% success rate in riverine woodland in Alatish National Park (Tadesse Habtamu and Afework Bekele, 2008). On the other hand, the success rate during the dry season (10.5%) in this habitat is similar with the finding of 10.28% success rate from secondary forest in D. R. Congo (Mukinzi *et al.*, 2005). The difference in trap success might be due to the effects of habitat factors as the habitats vary in vegetation composition and cover.

The trap success in the maize–sorghum farmland habitat during the wet season was higher than the maximum trap success obtained in wheat farm (20.41%), bean (23.13%) and lentil (10.88%) farmlands recorded by Manyingerew Shenkut *et al.* (2006). Trap success in sugarcane plantation during the dry season was exceptionally higher than the wet season. Rodents appeared to move between habitats in response to the availability of food resources (Douangboupha *et al.*, 2009). This increase in trap success might be associated with the recolonisation from the adjacent riverine habitat. In the other habitats, trap success showed a decline towards the dry season. This might be attributed to the high anthropogenic effects (harvest) in maize-sorghum field, and weed control activities following rainy season in coffee plantation. In the same way, the interference of high number of cattle grazing, and the subsequent habitat disturbance within and around the natural forest habitat during the dry season could be the factors for the decline in trap success during the dry season. Moreover, the reduced availability of weeds, weed seeds and grasses during the dry season could have also played a role in this result.

The result from the present study showed that sex ratio of these rodents was significantly different. Higher proportions of the captured individuals were males. A similar result from Kenya revealed 64.3% males and 35.7% females (Oguge, 1995). A record of 64.6% male and 35.4% female ratio was also reported by Manyingerew Shenkut *et al.* (2006). Such significant difference might be the result of differences in the mobility of males. Males generally make wider field excursions than females as reported from the Kenya Rift Valley (Odhiambo and Oguge, 2003). The sexual responsibility of females to care for the litters might have limited their mobility, and hence limiting the chance of countering the baits.

All age groups were represented in all trapping sessions during the present study. Adult rodents accounted for the highest proportion. The capture rate of juveniles was more during wet season than the dry season. This could possibly be associated with the effect of rainfall. However, there were juveniles of *M. natalensis*, *A. dembeensis*, *S. albipes* and *M. erythroleucus* during the dry season. This is consistent with the findings of Tadesse Habtamu and Afework Bekele (2008), who observed juveniles of *Mastomys*, *Stenocephalemys* and *Acomys* species during the dry season. The presence of juvenile individuals during the dry season could be the result of extended rainfall, which might have resulted to extended recruitment of young individuals (Delany, 1986; Hubert and Adem, 1985). The highest sub-adult recruitment during the two wet sessions (about 60%) could be the expected outcome of the onset of breeding and birth, following the beginning of rainy months in March in the study area. The highest capture rate of adult individuals (33.7%) was recorded during the first wet trapping session. This might be the result of growth of juveniles to maturity from the previous peak rainy months (August to October) of the wet season. However, representation of all age groups in all trapping sessions implies continuous breeding of rodents in the study area.

There was significantly higher number of breeding females during the wet season than the dry season. Females in lactating and pregnant conditions were found in the population of rodents from the onset of rainy season to the end in Tanzania (Makundi *et al.*, 2005). Positive effect of rainfall in breeding of rodents has been documented (Happold, 1974; Taylor and Green 1976; Hubert and Adem, 1985; Leirs *et al.*, 1990; Massawe *et al*., 2005; Douangboupha *et al*. 2009). Even though, majority of the breeding females were trapped during the wet sessions, some lactating and pregnant individuals of *M. natalensis* and *S. albipes* were also trapped during the dry season. This could be the result of extended rainy months in the study area, which might have resulted in extended breeding period of rodents mediated through available food resources. The present study area also gets some rain even during the dry season. Together with this, the continuous breeding behaviour of the species might have contributed to this result (Afework Bekele and Leirs, 1997; Tadesse Habtamu and Afework Bekele, 2008). Reproductive activity for males followed a similar pattern with females; sexually active individuals appearing in the population more from the first and second wet trapping sessions. However, there were some scrotal males during the dry season as well. Afework Bekele (1996a) recorded reproductively active males both during wet and dry seasons.

The number of embryos varied from species to species and from season to season. The embryo count of *M. natalensis* and *A. dembeensis* showed higher fluctuation (the highest record in both cases being in the second wet session and the least in the second dry session) than *S. albipes* and *L. flavopunctatus*. Extended rainy seasons result in longer periods of breeding and higher litter size (Taylor and Green, 1976; Leirs *et al*., 1994). The reason for the observed difference in embryo count between seasons in the present study area might be that weeds and weed seeds might have high stimulating effect on their reproductive process. Tadesse Habtamu and Afework Bekele (2008) also reported lower number of embryo count when rodents reproduce aseasonally.

The population size of rodents from the live-trapping grid showed a continuous decrease from the first wet trapping session to the second dry trapping session. Population dynamics of rodents is characterized by seasonal fluctuation (Leirs, 1995; Petersen *et al.*, 2006). Similar to the present result, the trappable populations were low during the dry season while, it reached its peak during short rainy season in Tanzania (Petersen *et al.*, 2006). Seasonal distribution of food and quantity of rainfall are considered the major variables determining population dynamics of rodents in East Africa (Delany and Monro, 1986; Leirs, 1994; Quy *et al*., 2003). The onset of breeding in March, 2009, following the beginning of rainy season, food availability and less disturbance could be the possible reasons for the high population size during the first wet trapping session in the present study area.

The density of rodents in the present study is comparable to other studies in Ethiopia and Africa. The density of rodents ranged from 30/ha in coffee plantation to 352/ha in bushland. This is more or less similar to the finding in Wondo Genet, Ethiopia, with a density range of 64/ha in farmland to 297/ha in bushes, shrubs and scrubs (Dawit Kassa and Afework Bekele, 2008). Variation in rodent population density is a result of vegetation cover (Delany, 1964; Massawe *et al*., 2003). The observed variation is possibly attributable to the variation in ground cover within the habitats. The highest rodent density in the maize-sorghum farmland was 117/ha for *M. natalensis.* This is higher than the density (6-94/ha) recorded for this species in Alleltu Woreda, Ethiopia (Manyingerew Shenkut *et al.*, 2006). The density of *M. natalensis* showed higher fluctuation (8/ha - 55/ha) within maize-sorghum farmland. Leirs (1995) reported that population density of *Mastonyms* species shows wide fluctuation. The population density of most of the rodents in the bushland habitat showed less fluctuation. For instance, the density range of *S. albipes, L. flavopunctatus* and *A. dembeensis* in this habitat ranged between 45-69/ha, 10-14/ha and 2-14/ha, respectively in different trapping sessions. Similarly, more heterogeneous habitat in north Tanzania showed less fluctuation in population density (Makundi *et al*, 2005). The density of rodents during the first wet trapping session (351/ha) was higher than the density of rodents during the second wet session (255/ha). This might be associated with the assumption that agricultural activities (harvest) play a role for the abundance of rodent density in an area.

The biomass of rodents in the present study area varied among the habitats and trapping sessions. Maximum biomass was revealed in the bushland habitats, followed by maize-sorghum farmland. *S. albipes* constituted for the greater proportion of biomass, except in maize-sorghum farmland where *M. natalensis* contributed for most biomass. Similar studies in other farmlands showed the same highest contribution of this species to the biomass of the area. For instance, *M. natalensis* contributed for the greater proportion of biomass in three farmland grids in Alleltu Woreda, Ethiopia (Manyingerew Shenkut *et al.,* 2006). The biomass record in natural forest is much greater than the biomass per hectare record in coffee plantation.

Assessment of temporary variation in the abundance of rodents before and after harvest in three agricultural areas (sugarcane, maize and sorghum) revealed a significant difference. The abundance of rodents in the maize-sorghum farmlands reached highest during fruiting stages of the crops that were ready to be harvested. Similarly, Douangboupha *et al*. (2009) observed that the number of rodents were generally high in the fields during the latter stage of the growth of crops, until after harvest. Manyingerew Shenkut *et al.* (2006) also reported similar result in wheat, bean and lentil farmlands from Alelltu Woreda, Ethiopia. This implies that rodents highly feavour agricultural fields during maturity of crops, as they provide abundant and preferable food. The decline in capture rate during post-harvest period might be associated with shortage of food and shelter, which could have triggered emigration of the animals. The higher capture rate of *M. natalensis* and *M. erythroleucus* species when compared to the other species during post-harvest session implies the preference of these species to harvested areas more than the other species. The preference of cultivated areas of monocots as well as harvested land by *M. erythroleucus* has been reported from a similar investigation (Workneh Gebresilassie *et al*., 2004). This in turn, reveals the effective foraging activity of this species on fallen seeds. On the contrary, capture rate of *M. musculus* was zero during post-harvest sessions in agricultural fields, except in the store. Similar observations in Australia reported that in a crop flied-hay mosaic (analogues to crop-fallow land mosaic in this study site), populations of *M. musculus* moved from their long established home ranges in a hey-field to a field of ripening wheat and back to their permanent home ranges during post-harvest period (Stickel, 1979). In the same way, this species might use the store house and villages as strategic sites.

Information on diets has a significant role in determining the ecology of animals (Krebs, 1998). There was a significant variation in the proportion of the diet of each species in the present study area. The feeding habit of *A. dembeensis* as evidenced from the stomach content analysis is more of grasses, followed by dicot seeds. Taylor and Green (1976) reported that *A. dembeensis* feeds upon grasses, seeds and cereal crops when they are found near agricultural areas. The presence of arthropods in the diet of this species is consistent with observations of Tilaye Wube (1999). Cultivated monocot seeds were more prominent in the stomach content of *M. natalensis* during both seasons. This is similar with the findings of other studies in Africa. For instance, Oguge (1995) reported that seeds constituted over 60% of the monthly diet of this species, while arthropods and other plant materials constituted less than 20%. Wild herbs (leaves) and grasses together with sugarcane fibers were also identified as the major content of the stomach of *S. albipes*. The result from stomach content analysis showed that *S. albipes*, *M. natalensis, A. dembeensis* and *M. musculus* consume high proportion of seeds of cultivated monocots (maize and sorghum). The stomach content of *A. dembeensis, S. albipes*, and *M. natalensis* contained significant proportion of sugarcane fibers. A similar finding from the stomach content of rodents in Wonji sugarcane area, Ethiopia, revealed the predominance of sugarcane fibers in *S. albipes*, *M. natalensis* and *M. mahomet* species (Serekebirhan Takele *et al.*, 2008), implying the wide distribution of these species in sugarcane plantation.

In general, the feeding habits of rodents as revealed by the stomach content analysis indicated that almost all the cultivated crops (maize, sorghum and sugarcane) were under attack, even though the magnitude varies. The presence of both plant and animal matter in the diet of most of the rodent species reveals that these species are generalists in their diet, even if, the extent varies. According to Futuyma (2005), most rodents consume all sorts of plant materials, primarily seeds, leaves, stems, flowers and roots and animal matter.

Assessments in the yield loss in farmlands help to establish the economic status of specific pest, to justify expenditure on control, to measure the effects of environmental factors on the loss of yield caused by pests (Bukle, 1994). The observed damage on sorghum seed was less in the present study area. This might be due to the short period of storage in the store and difficulty to reach to the seeds in the field. Makundi *et al*. (2005) reported 94.9% of farmers in Tanzania considered the importance of maize damage by rodents as the most important. *M. musulus* was responsible for the loss from stored grains, amounting to at least 5-10%, most from farm and village stores (Macdonald, 1984). A committee constituted by the Government of India for assessment of storage losses in 1996 estimated a total loss of 9.33% on food grains, and rodents accounted for the majority of loss (Rao, 2003). In addition to this, 24.1% trap success of the three rodent species (*M. natalensis, A. dembeensis* and *M. musulus*) in the store house, together with the evidence from stomach content analysis enable to judge these species as major rodent pests in the study area. *Arvicanthis* and *Mastomys* species were identified as major agricultural pests in different areas (Afewerk Bekele *et al*., 2003; Petersen, 2006; Tadesse Habtamu and Afework Bekele 2008). Workneh Gebresilassie *et al*. (2004) observed *M. natalensis* acting as pest attacking shoots and seeds of maize, millet, barley and wheat. According to Oguge (1995), *M. natalensis* is a major cause of loss of field and stored cereals in Western Kenya.

Rodents have been observed damaging on some shoots of immature sugarcane plants, and climbing on the shoot. This is in agreement with the report of Rao (2003), that rodents can potentially damage sugarcane at all stages of its growth. In ratoon cane, rats gnaw the stems and apical meristems of young plants. Serekebirhan Takele *et al.* (2008) also reported damage of sugarcane stalks by rodents. Gnawing lower internodes of sugarcane, causes direct damage at the sugar cane formation stage of the crop. Even incisor injury to the cane is often associated with secondary losses in yield and quality because of red rot caused by *Physalospora tucamanesis* (Rao, 2003). In addition to the field observation, the stomach content analysis of rodents sampled from sugarcane plantation also confirmed sugarcane fibers in the diet of *S. albipes*, *M. natalensis* and *A. dembensis*, indicating that these species are pests of sugarcane plantation in the present study area.

7. CONCLUSION AND RECOMMENDATIONS

Vegetation cover, rainfall and human interference were the major factors affecting the abundance and distribution of rodents in the study area. Even though, the natural forest habitat is composed of diverse types of large trees, as it is frequently grazed by cattle in addition to the collection of fuel wood by the local people, it had less composition and abundance of rodents than the bushland habitat. The abundance of rodents in the natural forest habitat was also less than sugarcane plantation and maize-sorghum farmland grids. The effect of harvest on the rodent abundance was also clearly seen in sugarcane and maize-sorghum farmland habitats.

As far as habitat association is concerned, most of the rodent species in the present study area tend to prefer bushland habitat. This implies that a habitat with good ground vegetation cover and least interference is more suitable for rodents. The present study also confirmed that rodents were least associated with coffee plantation habitat. This was the effect of open ground as a result of continuous weed control activities (especially, usage of herbicides and weedicides), in addition to this, usage of insecticide could have direct or indirect effect on both the composition and abundance of rodents in this habitat.

The population of rodents in the present study area varied between seasons. The extended rainy season of the study area had greater role for the extended breeding months, resulting in peak population towards the end of the rainy season and just before harvest. The role of human interference for the decline in rodent population size both in the natural and modified habitats during the dry season was also high. The biomass of rodents varied among the habitats and trapping sessions. It was determined by the vegetation cover of the habitats. Maximum biomass was revealed in the bushland habitat. Thus, from the present result, it is reasonable to deduce that habitats with heterogeneous composition and dense vegetation cover contribute for highest animal biomass in the area.

The present study also showed higher rodent abundance during pre-harvest session than post-harvest session in the three agricultural habitats, implying that harvesting significantly affects the abundance of rodents. Based on the stomach content analysis, it is possible to conclude that most rodents are opportunistic in their feeding, in that they depend on the available resources. Rodent pests had high impact on maize, especially in the store. Thus, in addition to infestation in the store, the site could serve as a potential source of rats that can reinvade the surrounding fields when conditions become suitable.

Based on the results of the present study, the following recommendations are suggested:

- The foliage of sugarcane, sorghum and maize should be removed regularly to eliminate nesting microhabitats and breeding sites for rodents.
- Reducing the fecundity of populations and hence, reducing the populations' ability to respond to high resource availability is the best strategy for rodent pest control.
- Rodent control should be advocated during the vegetative stage of cereal crops when rodents immigrate to and try to establish themselves in farmlands.
- Habitat manipulation should be taken as the main rodent control strategy. As in-crop weed control reduces competition within the crop and improves yields, it also contributes for rodent control.
- Effective management of rodent populations should focus on protection of grain stores after harvest. This could be done by limiting access to stores by creating walls and roof that are rodent-proof.
- It is important to develop rodent control strategies before they move between stores and field habitats. Distance between stores and fields should be taken into account during crop production.
- Training, demonstration and publicity programmes in scientific preservation of food grains and pest control technique should be given high attention.
- Strategies for effective management of rodents both in the field and in stores should depend on ecological information and field data to provide vital feedback in the design of sustainable management.

- The trend of usage of herbicides and pesticides in coffee plantation should be done in a scientific way and should be taken as only integral part of IPM, so that the effect could not threaten the biodiversity of the area.
- Ecologically-based rodent pest management should be given priority, so that the control method becomes both cost-effective as well as ecologically safe.

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Appendix. Lists of collected spices, herbs and medicinal plants and introduced exotic spices maintained at Tepi National Spices Research Center.

Botanical name (Scientific name)	**Vernacular name**	**Growing sites**	**Parts used**	**Uses**
Korarima (*Aframomum corrorima*)	Offio (K)	Natural vegetation	Seed	Spice/condiment
Wild Korarima (*Aframomum spp.*)	Sheeti Ogio (K)	Natural vegetation	-	-
Turmeric (*Curcuma domestic*)	Irdo (K)	Home garden	Rhizome	Spice, cosmetics
Basil (*Ocimum basilicum*)	Diro	Home garden	Leaf, Soft stem	Herb
Mustard (*Lepdium sativum*)	Shipho	Home garden	Seed	Spice
Coriander (*Coriandrum sativum*)	Depo	Home garden	Seed, Fruit, Leaf	Spice Condiment
Rue (*Ruta chalepensis*)	Chedramo	Home garden	Seed, Soft stem	Herbs, Spice, Medicinal, Condiment
Long pepper (Piper cappanse)	Turfo	Natural vegetation	Seed	Spice, Condiment
Ginger (*Zingiber officinale*)	Yanjibelo	Cultivated	Rhizome	Spice, Medicinal
Chillies (*Capsicum frutesence*)	Mito	Home garden	Fruit	Spice
Wild black pepper (*Piper guineense*)	-	Natural vegetation	-	Close relative to pepper
Anethum (*Anethum graveolens*)	Mechwolago	Home garden	Seeds, Soft stem	Spice, herbs
Black cumin (*Nigella sativa*)	Aefo	Field	Seed	Spices, Condiment, Medicinal
Fenugreek (*Trigonella foenum graecum*)	Abish	Field	Seed	Spices, Medicinal
Ethiopian carawy (*Trachspermem ammi*)	-	Home garden	Seed	Herb
Laurel or bay leaf (*Laurel nobilis*)	-	research center	Leaf	Spices, Condiment, Medicinal
Pepper (*Piper nigrum*)	-	Research center	Fruit, Seeds	Spices, Condiment
Rosemary (*Rosemarinus officinalis*)	-	Home garden	Leaf, Soft stem	Herbs, Condiment
Cinnanmon (*Cinnamomum verum*)	-	Research center	Bark, leaf	Spices, Condiment

Cardamom (*Ellettaria cardamoum*)	-	Research center	Seed	Spices
Majorama spp.	-	Research center	Leaf, soft stem	Herbs, Spices
Vanilla (*Vanilla fragrance*)	-	Research center	Seed bean	Spices, Condiment
Annato (*Bixa orellana*)	-	Research center	Seed outer part	Dying, Cosmetics
Cocoa (*Theobroma cacao*)	-	Research center	Bean	Stimulant
Lavender (*Lavandulla spp.*)	-	Research center	Leaf	Condiment, Herb, Cosmetics
Mint (*Mentha spp.*)	-	Home garden	Leaf	Condiment
Majoram (*Origanum spp.*)	-	Research center	Leaf	Medicinal, Cosmetics
Camum or Bishops weed or Ethiopian caraway (*Trachyspurmem ami* Sprague ex Turill)	-	Home garden	Seed	condiment
Garlic (*Alliums spp.*)	-	Home garden	Bulb, leaf	Condiment, Medicinal
Sage (*Saliva officinalis*)	-	Home garden	Leaf	Medicinal
Lemon grass (*Symbopogon spp.*)	-	Research garden	Leaf	Medicinal
Thyme (*Thymus spp.*)	-	Home garden	leaf	Condiment, Medicinal
Vetivar grass (*Vetivaria zizanioides*)	-	Research center	Rhizome	Cosmetics

DECLARATION

I, the undersigned, declare that the information provided in this work is an original work, and that it has not been presented in other universities or colleges, seeking for similar degree or other purposes.

Name | Date | Signature

Advisor | Signature