ADDIS ABABA UNIVERSITY

GRADUATE STUDY PROGRAM

DEPARTMENT OF ZOOLOGICAL SCIENCES

Species Composition, Distribution, Abundance and Economic Importance of Rodents in Choke Mountains, East Gojjam, Ethiopia

PhD Dissertation

By

Getachew Simeneh

Advisor: Prof. Afework Bekele

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Approval by Examining Committee

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Abbreviations

ACIAR = Australian Centre for International Agricultural Research

BIDNTFE = Biodiversity Indicators Development National Task Force Ethiopia

CMR = Capture-Mark-Release

EMSA = Ethiopian Meteorological Survey Authority

FAO = Food and Agricultural Organization

GPS = Geographical Position System

ITCZ = Inter-Tropical Convergence Zone

IUCN = International Union for Conservation of Nature

MNA = Minimum Number Alive

MWR = Ministry of Water Resource

ORDA = Organization for Rehabilitation and Development of Amhara

SPSS = Statistical Package for Social Sciences

Abstract

Studies on population ecology and economic significance of rodents were conducted in Choke Mountains between October 2013 and January 2016. Rodents were surveyed in eight habitats comprised of natural and human modified landscapes. It was conducted in live and snap trap grids established on each habitat. Eight rodent species were recorded in the Choke Mountains region: Arvicanthis abyssinicus, Otomys typus, Stenocephalemys griseicauda, Mastomys natalensis, Rattus rattus, Lophuromys flavopunctatus, Tachyoryctes splendens and Hystrix cristata. Arvicanthis abyssinicus and Stenocephalemys griseicauda are endemic to Ethiopia. There was significant variation in the spatial distribution of rodents ($p<0.05$). Species richness and diversity was highest in Euryops-Lobelia shrub ($n=4$, $H=1.257$) and Festuca-Alchemilla grassland ($n=4$, $H=0.979$) habitats. A. abyssinicus was the most widely distributed species captured from six habitats (75%). In eight trapping sessions, about 1,473 rodents were captured from the live and snap trap grids. Abundance of rodents varied among habitats of different management level ($p<0.001$). The highest proportion of trapped rodents was recorded in protected habitats: Festuca grassland (22.51%) and Erica forest (15.89%). Rodent abundance was significantly lower in livestock dominated habitats: open grazing fields ($p=0.0006$), afroalpine shrubs ($p<0.05$) and moorlands ($p<0.05$). A. abyssinicus was the highest in relative abundance (36.99%). Rodent abundance varied on seasonal basis ($p<0.05$). It was higher during the wet (57.09%) than the dry season (42.91%). However, the seasonal variation in the protected habitats was not significant ($p>0.05$). Species exhibit seasonal reproduction following rain. Plant materials occupied the dominant portion (62.08%) in the diet of the rodent species. Among the rodents, A. abyssinicus, O. typus, M. natalensis, and R. rattus were found to be crop pests. Croplands were seasonal refugee sites for the pest species. The dry season rodent abundance in barley fields was highly significant ($p<0.001$). Rodent abundance in barley fields reached peak (36%) at maturity stage of the crop, and declined after harvest (9.6%). Rodent abundance in fragmented barley fields interspersed with fallow lands was higher (62.13%) than those fields cultured in continuous system (37.87%). Rodent pest population density and crop damage was higher during the 2015/16 crop year (227/ha, 29.95%) than the 2014/15 (102/ha, 17.04%). Rodents may favour the extended rain period that occurred during the crop year. Rodenticides (60.8%), field sanitation (51.2%) and trapping (38%) were rodent control techniques practiced by farmers. Even with rodent control practices, farmers (82%) perceived crop damage by rodents was uncontrollable. Farmers lack technical support from selection to application of rodenticides. Annually, 23.5% pre-harvest yield loss was estimated from barley fields. This much yield loss is unbearable for small landholding people of the region that only depend on crop production. Livestock grazing pressure and disturbance are major threats to rodents and the whole biodiversity in Choke Mountains. Protection of this ecosystem has great importance to maintain rodent species, benefit from their ecological roles and minimize crop damage caused by pest rodents.

Key words/phrases: Choke Mountains, crop damage, rodent, species composition

1. Introduction

1.1. Background of the study

1.1.1 General description

Rodents are a group of small mammals represented by order Rodentia. Commonly, they are classified into three major suborders: Sciuromorphs (squirrel forms), Hystricomorph (porcupine form) and Myomorphs (rat forms) (Kingdon, 1997). Rodents are among the successful groups of mammals (Stanbury, 1972). With 21 living families, 443 genera, and over 2,700 species, the group accounts for 42% of all mammal species (Alpin *et al.,* 2003). Most of the rodent species, however, belong to suborder Myomphora. Family Muridae alone consists 1,325 (nearly two-third) species of worldwide distribution (Vaughan *et al.,* 2000).

Rodents share a derived tooth structure specialized for gnawing (Macdonald, 1984; Wilson and Reeder, 1993). They possess one pair of sharp and enlarged incisors in each jaw, which grow continuously throughout their life (Davis, 1963; Weisz, 1973; Nowak, 1999). These ever-growing incisors are self-sharpening and they are separated from cheek teeth by diastema. Because canines and some cheek teeth are absent in rodent dentition, they have a broad diastema between incisors and premolars of both upper and lower jaws. The softer posterior dentine wears away as the incisors grind each other. With the exception of silver mole rat, which has 28, the number of teeth in all species does not exceed 22 (Macdonald, 1984; Nowak, 1999).

On the other hand, rodent species have great diversity in mode of life, morphology, ecology, and behaviour, which is very common for large number of species (Wilson and Reeder, 1993). Their diversity can be explained from tiny pigmy mice to big capybaras; from arboreal flying squirrels to subterranean mole rats or semi-aquatic (e.g. beavers and water voles) (Vaughan *et al.,* 2000; Feldhamer *et al.,* 2007), and move by leaping, climbing, gliding and swimming

(Delany and Happold, 1979). The variation in body weight ranges from 5 g to 50 kg (Vaughan *et al.,* 2000). The harvest mouse (*Micromys*) is the least, which weighs 5-8 g and some rodents such as squirrels, beavers and porcupines have medium weight. Capybara is the largest of all rodents. The African small pygmy mouse (*Mus muscloides*) and the crested porcupines (*Hystrix cristata*) weigh 7 g and 12–27 kg, respectively (Delany and Happold, 1979; Kingdon, 2004). Rodents also show variation in social organization that includes solitary, pair-forming, and highly social groups.

1.1.2. Distribution

Rodents are nearly worldwide in distribution, capable of colonizing from the coldest to the driest regions (Kingdon, 1997). Nevertheless, species vary in geographic distributions, whic exhibit spatal patterns reflecting both recent ecology and physiogeographic history (Krytufek and Griffths, 2002). Thus, continents are endowed with different genera and families. In Africa, there are about14 rodent families comprising 89 genera and 381 species (Singleton *et al.,* 2007). The genus *Mastomys* (Stenseth *et al.,* 2001) and *Arvicanthis* (Kingdon, 1974) are among the most widespread African groups. Of the Nile rat species, *Arvicanthis niloticus* occupies a wide distribution and ecological range. It is the most abundant rodent species of Serengeti (Senzota, 1982).

Locally, rodent species show distinct distributions along elevational gradients (Yalden, 1988b; Yalden and Largen, 1992). This is because such gradients on mountain chains, form different vegetation zones. For instance, on Mount Elgon, *Dendromus mesomelas*, *Grammomys dolichurus*, *Graphiurus murinus*, *Lophuromys flavopunctatus*, *Otomys barbouri*, *Rhabdomys pumilio* and *Tachyoryctes ruddi* inhabited in the moorlands and tussock-grasslands between 3700 and 4321 m a.s.l. (Clausnitzer and Kityo, 2001), while *Dasymys incomtus* was restricted to the *Erica excelsa* forest at about 3500 m a.s.l. In Bale Mountains, Ethopia, *Lophuromys melanonyx*, *Stenocephalemys albocaudata* and *Arvicanthis blicki* are characteristic of the afroalpine belt above 3600 m a.s.l., which is characterised with different grasses and herbs (Sillero-Zubiri *et al.,* 1995). Despite the large air temperature fluctuation inherent to afroalpine habitats, they are able to avoid extreme cold and retain constant temperature by digging burrows of about 50 cm in depth (Sillero-Zubiri *et al.,* 1995). Species of Otomys are very dominant in the Afro-alpine belt of Mount Kenya (Coe and Foster, 1972).

There are different reports on the relationship between altitude and rodent species richness. An increase of species richness with increasing altitude was evident for the Bale Mountains in Ethiopia (Yalden1988, Sillero-Zubiri *et al.,* 1995), the western slopes of the Andes (Pearson and Ralph, 1978) and in Texas (Owen, 1990). A decrease of species richness with increasing altitude has been reported for the Drakensberg Mountains in South Africa (Rowe-Rowe and Lowry, 1982; Rowe-Rowe and Meester, 1982), for Mount Kulal in North Kenya (Martin, 1986), and for the Ruwenzori Mountains (Misonne, 1963). On the other hand, McCain (2006) reported high species richness in intermediate elevation peaks. These peaks are related to points of optimal environmental conditions, sites where species overlap, or locations where distinct vegetation communities occur in close proximity (Lomolino, 2001). Thus, rodent species richness along altitudinal gradients may be a function of habitat complexity and heterogeneity and not exclusively of elevation (Bond *et al.,* 1980; Happold and Happold, 1992).

1.1.3. Habitat selection and Species diversity

Rodents are able to adapt and inhabit in a wide range of habitats, ranging from arid savanna grasslands to wetlands, scrubland to secondary and primary forests (Delany, 1974; Nel, 1978). However, species tend to prefer few habitats among others (Happold and Happold, 1991). Habitat selection is a consequence of decisions: first, where to live and establish the home range; and second, where to shelter and forage within a habitat (Morris, 1996). It mainly depends upon the vegetation type and life history strategies of the species (Iyawe, 1988:

Krasnov *et al.,* 1996; Fitzherbert *et al.*, 2006). Species often prefer habitats within which they can maximize fitness, food quality and quantity, and will rarely choose or totally avoid habitats that do not meet these requirements (Kiringe, 1993). Within a habitat where the species carry out their biological functions, there are several microhabitat components that affect species behaviour of site selection (Traba *et al.,* 2010) and habitat use (Maitz and Dickman, 2001). Thus, there is clear association between rodent species and microhabitat conditions (Sillero-Zubiri *et al.,* 1995).

One of the microhabitat features that attract small mammals is availability of cover against potential predators. Rodents primarily prefer densely vegetated microhabitats (RoweRowe and Meeter, 1982; Iyawe, 1988). Vegetation cover provides shelter from predators and nesting sites (Bonaventura *et al.,* 1991; Altricher *et al.,* 2004). Lin and Batzli (2001) found that increased cover resulted in higher habitat quality for prairie voles. Instead of scarce vegetation, the presence of dense vegetation tends to form closed ground cover making it a more favourable habitat for rodents to avoid being predatored up on (Monadjem, 1997). In this context, habitats like bushland, tall grassland and forests provide conducive microclimatic conditions to rodent species. For instance, habitat preference of *Otomys* species and *Rhabdomys pumilio* strongly correlates with the presence of dense grass cover (Bond *et al.,* 1980). Vegetation cover dependent anti-predator behaviour of rodents can affect the fitness of individuals (Lima and Dill, 1990; Curio, 1993). It is one of the variables that influence the spatial distribution and population density of rodents living in the delta of the Paraná River (Bonaventura *et al.,* 1991; Altricher *et al.,* 2004).

Site selection in rodents may also depend on physical characteristics of the habitat (Odhiambo, 2000). Nature of soil is among these important habitat factors (Massawe *et al.,* 2008). It is a primary factor influencing selection of burrow sites by semi-fossorial rodents (Desy, 1998). For instance, site selection by the African giant rat (*Cricetomys gambianus*) is influenced by the characteristics of the soil in its environment (Ajayi, 1977). It has strong link with burrowing efficiency, which is affected by soil hardness (Luna and Antinuchi, 2006). Thus, species prefere well drained soils that facilitate easy burrowing (Desy, 1998). Therefore, soil structures and soil types are some of several factors that may affect rodent abundance in a given habitat (Massawe *et al.,* 2008).

Site selection by rodents also depends on substrate particle size, which affects foraging efficiency of rodents (Wasserberg *et al.,* 2005) and their ability to construct and maintain burrows (Luna *et al.,* 2002; Romanach *et al.,* 2005). A heterogeneous substrate provides more spaces for species to carry out their activities. Like wise, rodents can establish burrow under objects such as roots of trees, piles of dead trees and stones to provide insulation against heat (Hill *et al.,* 1955). For instance, fallen woody debris is an important microhabitat component for the semi-arboreal cotton mouse (McCay, 2000).

Generally, habitat factors such as primary production, complexity and level of disturbance are crucial in regulating the population ecology of rodents. Rodent species richness and community structure have strong assciation with habitat productivity and complexity (Avenant, 2000). This is related with the inherent strong link between rodent species abundance and habitat quality, provision of sufficient food and cover (Pusenius and Schmidt, 2002). Species composition varies with shrub and herb diversity, cover, and density (Munger *et al.,* 1983; Brooks, 1995). According to the habitat heterogeneity hypothesis, an increase in habitat heterogeneity leads to increase in species diversity (Cramer and Willig, 2002). A heterogenous habitat provides variety of resources (Monadjem, 1997; Cramer and Willig, 2005), thus promote greater specialization and coexistence of great number of species (Brown and Lomolino, 1998). Rodent species diversity is positively correlated with diversity of flora (Li *et al.*, 2003).

Forests are among the most important habitats in rodent species assemblage and diversity associated with the diverse microhabitat conditions apparent in rich forests (Pereyra *et al.,* 2003).

On the other hand, any kind of primary habitat modification has a serious effect on the species composition, diversity and total biomass of small mammals (Delany, 1971). This is associated with their sensitivity to changes in ground cover and food resource base. If large and extensive habitats become fragmented into small isolated parts, local extinction of species may follow, affecting species diversity in natural ecosystems (Sousal, 1984). Human disturbances such as deforestation, burning and livestock grazing affect rodent abundance through habitat modification (Juch, 2000). In areas with fragments of vegetation and serious human interference, rodents are the main fauna with high mobility (Li *et al.,* 2003).

Because of their rapid responses to local environmental changes, rodents are suggested as useful indicators of habitat conditions (Zhou *et al.,* 2002). Thus, some rodents in specific habitats are viewed as model organisms for the study of ecological processes and serve as good indicators of environmental quality (Linzey and Kesner, 1997; Aplin *et al.,* 2003; Avenant, 2011) and environmental gradient (Heaney, 2001). For instance, several studies on the effects of habitat fragmentation have been carriedout using rodents as model organisms (Kim *et al.*, 1998; Lambert *et al.*, 2003; Wu and Fu, 2008; Bentley, 2008). Therefore, monitoring population ecology of rodents is an important method in detecting the status of ecosystem functioning. Knowledge of their abundance and diversity may facilitate the management of nature reserves and future development of natural areas (Avenant, 2000).

1.1.4. Population density and Dynamics

Rodents exhibit seasonal and inter-annual population flactuations. Accordingly, large-scale rodent population cycles are widely reported in many parts of the world (Boonstra *et al.,* 1998). Inter-year and multi-year cycles of voles were reported in agricultural areas of the Palouse, northwestern United States (Johnson, 1986). Similarly, Leirs (1995) reported fluctuations in populations of different *Mastomys* species in Africa with maxima of up to 1000 individuals/ha in outbreak years and several hundreds during usual seasonal peaks. Rodent cycling is largely resulted from interactions between limiting factors of the environment and life history characteristics of species (Brown and Harney, 1993). Including the reproductive behaviours of the species, climate, food and disease are the most recognized factors that regulate populations of rodents (Mununa, 1996).

Reproduction is the most vital source of recruitment that influences population density of rodents (Leirs, 1995). Rodents have short breeding cycles (Vaughan *et al.,* 2000) and extraordinary explorative and adaptive abilities, capable of exerting changes on population structures (Spradling *et al.,* 2001). However, the onset of breeding in rodents depends on the presence of rich food source (Jackson and Vanaarde, 2004). Thus, it often coincides with the time of the year that the habitat is rewarding (Shanas and Haim, 2004). For this reason, reproduction activities exhibit seasonal pattern in relation to variations in rainfall; reaching its peak during the rainy season and declining during the dry season (Taylor and Green, 1976; Delany and Monro, 1986; Afework Bekele and Leirs, 1997). Thus, seasonal changes in population dynamics of rodents were widely reported following the appearance variety of plant materials during the rain season (Happold and Happold, 1989; Massawe *et al.*, 2006; Tadesse Habtamu and Afework Bekele, 2008). In addition, rodent survival and maturation are affected by precipitation in the preceding few months (Leirs *et al.,* 1997). Consequently, the seasonal distribution and quantity of rainfall are considered as major climatic variables in determining population dynamics of rodents (Delany and Monro, 1985).

The effect of habitat alteration on population dynamics of small mammal species is widely reported (Wilcox, 1980; Wilcox and Murphy, 1985; Adren, 1994). One category of small mammals that is likely to respond to such changing habitats is rodents (Cheeseman, 1977; Neal, 1984). Habitat alteration by domestic or wild species of large mammals could bring about cover removal, consequently leading to depletion of rodent populations (Taylor and Green, 1976). Excessive livestock grazing for instance affects the quality of habitats suitable for the rodent community through a reduction in vegetation cover (Schmidt *et al.,* 2005; Karmiris and Nastis, 2007; Bakker *et al.,* 2009). Besides, diffuse competition from large mammalian herbivores suppresses populations of small mammals through resource limitation (Sinclair, 1972).

Predation likely plays a large part in most phases of population fluctuations (Boonstra, *et al.,* 1998; Korpimäki and Norrdahl, 1991; Korpimäki and Krebs, 1996; Korpimäki *et al.,* 2002). According to models of predation risk, animals that are exposed to predators have a higher risk of mortality (Sinclair and Arcese, 1995). However, behavioural responses to predation risk may change with sex, age, and reproductive condition. Young animals may be especially vulnerable to predation because they may not have learned appropriate strategies to avoid predators. What so ever, predators can have impacts on demography by influencing parameters such as survival, reproduction, emigration and immigration (Lima and Dill, 1989), while predator removal results in increased densities, survival, immigration, and earlier breeding (Taitt and Krebs, 1983; Perrin and Johnson, 1999; Oli, 2003; Salo *et al.,* 2010).

1.1.5. Feeding behaviour

Adequate information on the food and feeding habits of various rodents is vital to a proper understanding of their ecology, modes of life and their control

(Taylar and Green, 1976). Leirs (2003) reported diet diversity (large quantities of green vegetation, fruits, seeds and animal prey) in rodents. Like wise, African murid rodents have been described as omnivores, with the diet often including arthropods, and the plant portion varying from foliage to seeds to other plant parts (Kingdon, 2004). Accordingly, *Arvicanthis testicularis*, in northern Nigeria, was found to be more of a generalist omnivore, including leaves, seeds, and insects in the diet (Rabiu and Fisher, 1989).

Nevertheless, rodents frequently display food preferences (Best *et al.,* 1993). For instance, a study on food habits of four common species of African rodents: the giant rat (*Cricetomys gambianus*), bláck rat (*Rattus rattus*), multimammate rat (*Mastomys natalensis*) and pygmy mouse (*Mus minutoides*) showed vegetable items forming the bulk of the food, while animal food component, mainly insects, were used at lower magnitude (Moses *et al.,* 1979). *A. niloticus* was a specialist grazer in the Serengeti (Sinclair, 1972). Oguge (1995) reported species of *Mastomys*, *Mus*, and *Gerbilliscus* in Kenya as omnivorous but mainly granivorous. In Ethiopia, *Arvicanthis dembeensis* preferred more monocot foliage and seeds, with some insects taken (Workneh Gebresilassie *et al.,* 2004). Diet shift by rodents may occur at times of competition and limitation of the more preferred food items. For instance, folivory may be an alternate strategy in some savanna rodents that facilitates coexistence within granivore guilds when seed resources are limiting (Kinahan and Pillay, 2008).

Predators are the major threats affecting foraging activities of rodents. Thus, in risky situations, rodents tend to alter their foraging behaviour. For example, they preferentially forage in sheltered microhabitats (often under vegetative cover) to hide from avian predators (Kotler *et al.,* 1991), in spite of the risk of predation by snakes in sheltered microhabitats (Bouskila, 1995). Moreover, foraging may be maximaized during precipitation or in the absence of moonlight as it reduces the ability of vertebrate predators to detect and capture rodents (King, 1968). Rodents may also avoid forest edges, where vertebrate predation risk is greater (Morris and Davidson, 2000), or forage more intensively close to refuges and escape routes (Brown and Morgan, 1995).

1.1.6. Ecological role

Rodents have eological roles, which they contribute by the trophic positions they occupy in the community. They have an important role in maintaining the structure and function of an ecological system (Shuai *et al.,* 2006). Herbivorous rodents can shape plant communities and influence their dynamics through defoliation or seed predation (Brown and Heske, 1990; Hulme, 1994). Seed dispersal allows plants to colonize new habitats (Conrey and Mills, 2001; Duckwitz, 2001; Pearson *et al.,* 2001). Consequently, rodents in sub-Saharan Africa are found to be important agents in the preservation of plant species diversity (Linzey and Kesner, 1997). Like wise, in the northeastern United States, meadow voles (*Microtus pennsylvanicus*) enhance community succession by removing seedlings and paving the way for invasion of trees (Manson *et al.,* 2001). On the other hand, the endemic giant mole rat (*Tachyoryctes macrocephalus*) in the Bale Mountains, Ethiopia, maintain the afroalpine vegetation in a permanent pioneer stage through turning over the soil (Yalden, 1985; Tallents, 2007).

Physical modifications of habitats increase habitat heterogeneity and facilitate resource flow (Jones *et al.*, 1994). Rodents alter the physical structure of the environment by surface tunneling, construction of leaf or stick nests, arranging gravel around burrow entrances, or stripping bark from trees (Wolfe-Bellin and Moloney, 2000). Thus, increase landscape heterogeneity and subsequently open space to different species by creating unique patches of habitats (Davidson *et al.,* 2008; Yoshihara *et al.,* 2009). Beavers for instance create habitats for varieties of wetland species by physically modifying river courses through building dams (Pollock *et al.,* 1995). The burrows of the Siberian marmot (*Marmota sibirica*) provide shelter and refuge to corsac foxes (*Vulpes corsac*) on the Mongolian steppes (Murdoch *et al.,* 2009). Burrowing in subterranean rodents also enhance soil aeration and mixing up of the components (Kingdon, 1997).

Rodents also contribute in maintaining ecosystem integrity serving as a food source to different animal species. They form the most important prey base supporting diversity of carnivores and raptors (Hanski *et al.,* 1991; Korpimäki and Norrdahl, 1991; Torre *et al.,* 2007). For instance, in India, Jungle cat (*Felis chaus*), caracal (*Caracal caracal*) and golden jackal (*Canis aureus*) feed on rodents as vital food item (Mukherjee *et al.*, 2004). Similarly, mole rats are the most important food items for the endangered Ethiopian wolf (*Canis simensis*) (Sillero-Zubiri and Gottelli, 1995; Zelalem Tefera *et al.*, 2005; Sillero-Zubiri *et al.*, 2008).

1.1.7. Rodents as crop pest

In many agro-ecosystems, rodents are major constraint to crop production (Makundi *et al.,* 1999). Globaly, many rodent pests have been recorded for a wide range of damage and losses in cereal, legume, vegetable and tuber crops (Makundi *et al.,* 1999; Pech *et al.,* 2003; Palis *et al.,* 2007). In Australia, four of the 67 rodent species are known agricaltural pests, of which the house mouse (*Mus domesticus*), is very common (Caughley *et al.,* 1994). In Europe, five of the 61 species, in India, 12 of the 128 species and in Indonesia, 13 of the 164 species are major agricatural pests (Singleton *et al.,* 2007). In Africa, 77 of the 381 species are agricatural pests (Taylor and Green, 1976; Leirs, 1999).

Rodent species ranging from the multimammate rat (*Mastomys natalensis*) to the giant rat (*Cricetomys gam*bianus) and the crested porcupine (*Hystrix cristata*) are important crop pests. In Africa, species under the genus *Mastomys* and *Arvicanthis* are very common crop pests (Taylor and Green, 1976; Leirs, 1999). For instance, in Tanzania, damage to maize crop is largely attributed to *Mastomys natalensis* (Massawe *et al.,* 2006) and *Arvicanthis nilotics* (Makundi *et al.,* 1991). *M. natalensis* was found occupying more than 98% of the rodents in maize fields from Tanzania (Massawe *et al.,* 2003). *Arvicanthis nilotics* is a major agricultural pest widespread across most of northern, western, central, and eastern Africa, reaching densities of more than 100 individuals/ha in good rainfall years (Poulet and Poupon, 1978). *Arvicanthis dembeensis* and *Mastomys erythroleucus* were common in maize fields from central Ethiopia (Afework Bekele and Leirs, 1997). In the Tigray region of northern Ethiopia, *Stenocepalemys albipes, Mastomys awashensis* and*Arvicanthis dembeensis* are the major rodent pests in wheat and barley fields (Meheretu Yonas, 2012; Meheretu Yonas *et al.,* 2014)

Globally, the annual crop damage due to rodents could reach about 30% in both pre-harvest and post-harvest conditions (Singleton, 2001). In terms of money, rodents consume food crops worth $ 30 billion on average globally (Feldhamer *et al.,* 2007). For instance, in cane fields of Australia, rodents destroyed sugarcane valued 50 million US $ in only the 1999 harvest season (Rao, 2003). In Asia, rodents are the most troublesome pests of rice crops. They have long been reported as having a substantial impact on rice crops in India (Rao and Joshi, 1986). Hart (2001) estimated 25% in the field before harvest and 25-30% postharvest overall losses of grain due to rodents in India. According to Singleton (2003), a loss of 6% of Asian rice production amounts to approximately 36 million ton: enough rice to feed 220 million people in Indonesia every year.

In developing countries where agricultural activities predominate, rodent infestation poses a serious threat of not only reduced income but also widespread food shortages (Milan, 1990). For instance, in Africa, damage during outbreaks is profound. Following the 1951 and 1962 outbreaks in western Kenya, Taylor (1968) reported a 20% loss of maize and 34-100% loss of wheat and barley. In Tanzania, up to 412,500 ton maize crop damage was estimated per year by the multimammate rat (Makundi *et al.,* 1999). In Ethiopia, a study conducted on maize fields reported about 20-26% damage due to rodents (Afework Bekele *et al.,* 2003). In a recent survey conducted in the highlands of Tigray, farmers estimated 8.9-44% preharvest loss in annual cereal production (Meheretu Yonas *et al.,* 2010).

Rodent damage in a crop field exhibits spatial distribution. At low population densities of *Rattus* sp., Buckle *et al.* (1985) and Schaefer (1975) reported erratic damage in rice fields, sometimes clustered or sometimes uniform. Nevertheess, at high population densities of *Rattus* sp., the centre of the field was the most damaged. In Australian orchard systems, *R. rattus* populations showed high levels of damage around the orchard edge (up to 90% of first row crops) (Elmouttie and Wilson, 2005), with very little damage within the orchard interior (White *et al.,* 1997). The distinct fruiting and flowering seasons in Australian orchards, made *R. rattus* populations reliant on non-crop habitat resources adjacent to the orchard to maintain population densities (Elmouttie and Wilson, 2005). Nevertheless, in Hawaiia, rodent damage was distributed much more uniformly throughout entire orchard systems (Tobin, 1992). *R. rattus* populations were found living within the orchard system, in both arboreal nests and burrows within the orchards (Tobin *et al.,* 1996).

Rodent damage follows crop phenology, and most of the damages occur during the sensitive young seedling stage and just before harvest (Fiedler, 1994; Stenseth *et al.,* 2001). Rice field rats cause more damage during the growth of rice (Tristiani and Murakami, 1998), and also during the ripening stages, where rodents cut the thickened and hardened tillers to bring down the panicles which they may hoard in their burrows (Sridhara, 1992). The flowering and harvest stages of wheat and barley crops were indicated as the main crop developmental stages coinciding with high rodent abundance and damage in experimental fields in northern Ethiopia (Meheretu Yonas *et al.*, 2014). In Tanzania, 40–80% damage was estimated at sowing and seedling stage of maize crop (Mwanjabe and Leirs, 1997). Multimammate mice dig up planted maize seeds but never cause damage during the growth of maize plants until cobs start ripening (Makundi *et al.,* 1999). Population of *Apodemus sylvaticus* damage sugar beet only in the two weeks after seeds sowed (Peltz, 1989).

Farming practices, change in climatic factors and the intrinsic characteristics of the pest species are among the factors that possibly influence the occurrence and severity of rodent attacks on crops (Makundi *et al.,* 1999). Certain characteristics of the species, such as high reproductive capacity and dispersal are thought to contribute to the success (Leirs *et al.,* 1996). Their potential to breed quickly, lead to infest and cause serious economic damage on crops (Fiedler, 1994). Rodent outbreaks are linked with wet years when prolonged rainfall allows better survival of the young. The growth period of rice in India for instance coincides with the monsoon rains during which rodents show peak breeding activity causing the buildup of large rodent populations, and thus resulting severe crop damage (Parshad *et al.,* 1989).

Problems related with land preparation and farming system aggravate rodent pest infestation and crop damage intensity. Apart from the biological characteristics of *Mastomys natalensis*, farming practices and land preparation problems (Massawe *et al.,* 2005) are responsible for the high population densities of this species. In irrigated field under continuous cultivation, intensive breeding of rodents are observed due to continuous availability of food sources (Workneh Gebresilassie *et al.,* 2006). The utilization of irrigation during the dry season will create a favourable condition for the continuous damage by rodents (Fitzgibbon, 1997).

Like wise, the presence of different vegetations close to crop fields increase attractiveness and accessibility of the fields for rodents, since they may serve as refugia or dispersal corridors (Brown *et al.,* 2001). Key (1990) and Redhead and Saunders (1980) reported a strong correlation between rodent damage caused to maize and sugar cane and the presence of uncultivated land. Large monocultures in Tanzania experience less rodent damage than small holder fields that are interspersed with fallow land (Myllymäki, 1987). Pest species can get sufficient shelter if shrubs and outcrops are not cleared around farmlands (Manyingerew Shenkut *et al.,* 2006). They involve movements between refuge habitats and crop fields according to seasonal changes in food supply (Hansson, 1977; Chambers *et al.,* 1996). In Australian orchard fields, *R. rattus* populations utilised non-crop habitats as a source of alternate food resources during periods of low nut availability (Elmouttie *et al.,* 2009). In sub-Saharan Africa *Mastomys natalensis*, use grass stems and rhizomes as alternative food source around non-crop fields (Taylor and Green, 1976).

Problems related to the tillage system and crop schedule open opportunities for pest invasion. The practice of zero tillage instead of conventional tillage provides habitat and consistent cover for small mammals (Uri *et al.,* 1999), and may allow them to establish permanent burrow systems in agricultural fields. When irrigation over a large area is not synchronized, adjacent fields will have crops of different ages and rats may move between fields to benefit from the optimal crop stages during a prolonged period (Brown *et al.,* 2001). With asynchronous planting schedules of rice crops, rodents will obtain food and shelter for longer periods and plots of early maturing varieties suffer more damage even up to 100% (Singh *et al.,* 1994).

Countries in North America and Europe are best equipped to develop rodent control techniques. As a result, rodent pests are not very serious agricultural problems in some of the temperate regions compared to the tropics and subtropics (Singleton, 2001). However, farmers in many parts of the world, particularly those in developing countries, tend to view economic losses due to rats and mice as unavoidable (Singleton, *et al.,* 1999). Current management practices in agro-ecosystems mostly rely on culling animals using poisons and traps (Fiedler and Fall, 1994; Singleton *et al.,* 2007). The use of poisons can pose a considerable threat to non-target species (Hegdal and Colvin, 1988) and the environment because poisons are unspecific and highly toxic. In addition, strategies used in controlling rodent pest species should consider their ecological, economic and public health importances (Gratz, 1997; Stenseth *et al.,* 2001).

Rodent management and control should target in bringing down the rate of reproduction to reduce their population. Rodent control activities would be more effective if applied during the pre-breeding season, which also coincides with the reproductive phase of the vegetation around (Workneh Gebreselassie *et al.,* 2004). Further, as rodents get shelters in the area of natural vegetation around farmlands throughout the seasons, it is adviseable to follow clean farming practices, clearing shrubs and rocky outcrops in areas around farmlands, as ecological means of rodent control (Manyingerew Shenkut *et al.,* 2006). To keep fields and field edges clear of weeds and active weeding strategies have been promoted as rodent control measures (Green and Taylor 1975; Drost and Moody, 1982). Ramesh and Katiyar (1985) reported a 49% reduction in the burrows of pest species when a vacant land around wheat fields is plowed.

1.1.8. Conservation status

Rodent species represent 51–52% of mammalian extinctions in the last 500 years (Ceballos and Brown, 1995; Macphee and Flemming, 1999). Despite the potential importance, rodents are one of a small number of vertebrate groups where the effort put into eradication and control vastly outweighs that put into conservation (Amori and Gippoliti, 2000). Conservation initiatives continue biased towards the most studied and attractive mammal groups and species or on an opportunistic basis, despite increasing evidence of many rodent species sustaining ecosystems structures and functions. Thus, about 384 species of rodents are classified as 'vulnerable', 'endangered' or 'critically endangered' (IUCN, 2000).

Habitat loss and related disturbances together with resource competition are major threats to rodent populations. In isolated and diminished habitats, the probability of wildlife species extinction through demographic, environmental or genetic stochasticity will increase (Wiens, 1976; Harris, 1984; Goodman, 1987; Adren, 1994). Repeated cycles of fragmentation and regrowth are likely to lead to the extinction of forest dependent species and their replacement by habitat generalists (Corlett, 2000). Livestock overgrazing of pastures influences grassland rodent species causing habitat loss and food scarcity. It is a powerful driver of plant population dynamics and community succession (Milchunas and Lauenroth, 1993; Fuhlendorf *et al.,* 2001), and influences the abundance and distribution of the animal communities inhabiting grasslands (Kruess and Tscharntke, 2002; Schmidt *et al.,* 2005; Coppedge *et al.,* 2008).

1.1.9. Statement of the problem

About 81 rodent species are recorded in Ethiopia (Afework Bekele and Yalden, 2013), of which 22 are endemic. Highlands (> 2000 m a.s.l) support 60 per cent of Ethiopia's rodent fauna, among which at least 14 endemic species occur in the northwestern, central and southeastern highland plateaus (Yalden and Largen, 1992). Rodents are the main natural grazers of the afroalpine community. In the Bale Mountains, 15 of the 47 mammal species are rodents. The giant mole rat, *Tachyoryctes macrocephalus*, Blick's grass rat, *Arvicanthis blicki*, and the brush-furred mouse, *Lophuromys melanonyx*, are endemic species restricted to the southern highlands of Ethiopia (Yalden, 1988b). *Stenocephalemys* comprises two endemic species: *S. albocaudata*, endemic to

Bale, and *S. griseicauda*, which has a wider distribution including the Bale and Simien Mountain National Parks (Yalden *et al.,* 1976).

Rodent species richness in the Simien Mountains National Park (the northwestern highland) (Mesele Yihunie and Afework Bekele, 2012) and Guassa area (the central highland) (Yalden *et al.,* 1976; Hillman, 1993; Zelalem Tefera *et al.,* 2012) was not as high as in Bale Mountains. The rodent species in the Simien Mountains National Park were: *Lophuromys flavopunctatus*, *Arvicanthis abyssinicus*, *Stenocephalemys griseicaudata*, *Otomys typus*, and *Tachyoryctes splendens* (Mesele Yihunie and Afework Bekele, 2012). In the Guassa area, Zelalem Tefera *et al.* (2012) reported four rodent species: *Lophuromys flavopunctatus, Arvicanthis abyssinicus, Stenocephalemys griseicauda* and *Otomys typus*.

The ever-increasing demand for agricultural land in Ethiopian highlands resulted in increased intensity of livestock grazing and cultivation on marginal lands. For instance, most livestock production (95%) takes place on afroalpine grasslands (>3,000 m a.s.l.) which are home to eleven species of endemic rodents (OARDB, 2007). The Bale Mountains have been under increasing pressure from a rapidly growing pastoralist population and their livestock (Sillero-Zubiri *et al.,* 2011). Wildlife in almost all parts of these unique highland ecosystems therefore encountered habitat loss and fragmentation problems (BIDNTFE, 2010), which is one of the primary threats for maintaining biological diversity (Harris, 1984; Wilcox and Murphy, 1985).

Survey on biodiversity and related ecological variables has conservation importance. The Choke Mountains region is a part of the northwest highlands of Ethiopia. It is one of the afromontane regions of the country. However, this unique ecosystem is not protected or not properly managed. Thus, the region is considered as biodiversity hot spot. Most previous studies on small mammal populations targeted the protected southwestern forest, south and southeastern highlands, the Rift Valley, the Simien massifs and few isolated forest blocks of central Ethiopia (Muller, 1977; Rupp, 1980; Yalden, 1988b; Sillero-Zubiri *et al.,* 1995; Afework Bekele, 1996b). Nevertheless, there is no scientific document on the mammalian fauna of the Choke highlands other than speculations on local extinction of the Ethiopian wolf. Therefore, this study is supposed to fill the existing knowledge gap on rodent population ecology in the area. Furthermore, it may open the gate for other researchers who would like to conduct further investigation on the biodiversity of this region.

In this regard, information on diversity and distribution of rodents was addressed to understand how variation in landscape and microhabitat conditions affects biodiversity. Most imortantly, the researcher supposes anthropogenic caused problems as a major threat to the rodent populations in the Choke Mountains region. To elucidate the extent of human influence, studies on rodent population size, diversity and distribution were designed in different habitats of varied human influence. Assessment was made to determine which of the measured habitat parameters strongly influence the diversity and abundance of rodents.

In Ethiopia, studies on economic loss associated with rodent crop pest species are very limited. Better understanding of the ecological and environmental factors influencing rodent occurrence and distribution in agricultural landscapes can help to determine when and where rodent management might be needed. Thus, the study included the ecology of rodent pest species, their damage on field crops and attempts to identify eco-friendly and cost effective rodent pest control techniques.

1.2. Objectives of the study

1.2.1. General Objective

The general objective of this study was to examine the diversity, ecology and economic importance of rodents in the afromontane highland ecosystem of Choke Mountains and the surrounding agro-ecosystems.

1.2.2. Specific Objectives

- To identify the rodent species composition in both natural and human modified ecosystems
- To investigate the pattern of rodent species distribution within the natural ecosystem and agricultural fields
- To examine habitat variables potentially effecting rodent distribution and capture success
- To investigate seasonal variations in the abundance of the rodent species
- To investigate and compare the variation in the diet composition of the rodent species over different seasons
- To investigate factors affecting the population of rodent pests in crop fields
- To estimate the magnitude of economic loss inflicted by rodent pests in crop fields
- To examine rodent pest control strategies by the local people
- To identify major anthropogenic threats on the rodent populations of the Choke Mountains region

2. Study area and Methods

2.1. Description of the study area

2.1.1. Location and Biophysical descriptions

The Choke Mountains region is one of Ethiopian highlands located in the Amhara National Regional State, East Gojjam Zone, northwest of Debre Markos town. It is about 330 km north of the national capital Addis Ababa by road. This highland lies at latitude $10^{o}41'$-$10^{o}44'$N and longitude 37^{o} $50'$-37^{o} $53'$E. Especially, the central peak is located at $10^{0}42'$N and $37^{0}50'$E. Elevation of the mountain chains ranges from 2800 to 4070 m a.s.l., and occupy a total area of 17443 km^{2} (Ermias Teferi *et al.,* 2010). The mountain chains encompass six districts. Nevertheless, this study targeted mountains between Sinan (Digo Tsiyon town) and Bibugne (Rob Gebeya town) districts (Fig. 1).

The main geological unit in the area is the Tarmaber Guassa formation, which represents Oligocene to Miocene basaltic shield volcanoes with minor trachyte and phonolite intrusions. The dominant soil units covering the Choke Mountains are Haplic Alisols (deep soils with predominant clay or silt-clay texture) with 25% coverage, Eutric Leptosols (shallow soils with loam or clay-loam texture) and Eutric Vertisols (deep soils with clay texture and angular/sub-angular blocky structure) with percent share of 34 and 26, respectively (MWR, 1998). However, because of active morphological processes like erosion and landslide, soil depth in the area could vary between zero and several meter.

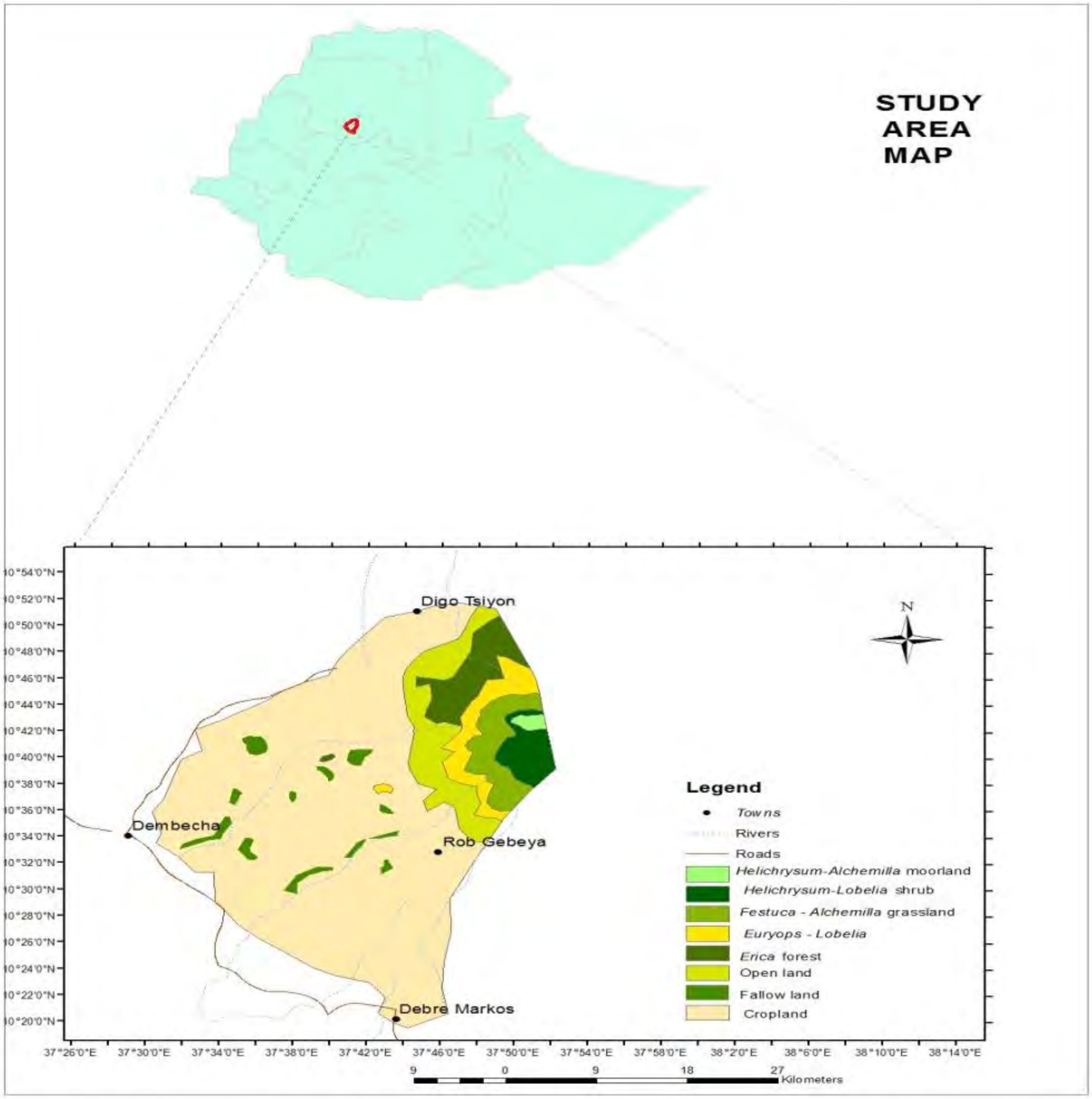


Figure 1. The top map shows the geographic position of Choke Mountains in Ethiopia. The bottom map shows the different habitats from which rodents were sampled in the current study

The ecosystem in the Choke Mountains is characterized by high altitude afroalpine vegetation comprising different habitat types, including moist moorland sparsely covered with giant lobelias (*Lobelia* spp.), *Euryop*s sp., *Helichrysum* sp., lady's mantle (*Alchemilla* sp.), Guassa grass (*Festuca* sp.) and other grasses (Plate 1). Natural woody plants have very little coverage; heather *Erica* sp. (locally called Asta) and *Hypericum revolutum* (locally called Amijja) which occur in patches. Because of its economic value, *Arundinaria alpine* (bamboo) is a dominant homestead plantation. Likewise, *Erithrina brucei* (locally called Korch) and *Hygenia abyssinica* (locally called Kosso) are very common plants around villages and Churches, which are used by residents for the purpose of household fences.

a) *Euryops* sp. b) *Helichrysum* and *Lobelia* sp.

c) *Erica* sp. d) *Festuca* sp.

Plate 1(a-d). Some of the vegetations in Choke Mountains (Getachew, 2013)

Endowed with special topography and highland vegetation, the Choke area has economic as well as potential significance in maintaining the balance of natural processes. The mountain chains are the water tower of the upper Blue Nile river system in Ethiopia. They are the source of more than 59 rivers, and 273 small springs, which are the main tributaries of upper Blue Nile (Ermias Teferi *et al.,* 2010). Potentially, the resources have also key roles in the maintenance of ecosystem stability, flood control, climatic stabilization, and scientific research and training.

The Choke Mountain Range is also rich with productive wetland ecosystems. They range from sedge swamps to seasonally flooded grasslands, which covers more than 3,386 km^2. Out of this figure, seasonal wetlands with high and low moisture, and open water constitutes 3,000 km^2 and 46 km^2, respectively (Ermias Teferi *et al.,* 2010). These habitats are homes for different resident bird species and wintering areas for several migratory groups. Together with the scenic beauty of landscapes, the wetland resources of Choke are potential recreation sites. The existence of an impressive landscape (the four stepped mountains locally called as Arat Mekeraker), unique flora and the cool temperate agro-ecological (Wurch) zone are important attractions of the mountain.

However, the level of biodiversity and their habitats is under progressive deterioration. Therefore, the ecosystem is considered as one of the Ethiopian Biodiversity Hot Spots. Because of long history of human settlement and increased population pressure, the biological diversity is highly damaged. Most landscapes have lost the natural vegetation cover, and soil fertility is depleted. Above all, the unprotected nature of this important and unique ecosystem has aggravated the rate of biodiversity crisis including local extinction of several animal species unique to afroalpine habitats.

The livelihoods of residents depend on biomass based subsistence economy. Therefore, biomass is the source for their fundamental needs like food, fuel, construction and for making traditional crafts, most of which are collected from the immediate natural environment. There is no restriction for the local community to use the natural resources almost in all ranges of the mountain chain. Mountain landscapes including those high altitude ones have been cleared for the purpose of settlement and agricultural expansion. Currently, the land up to 3300 m a.s.l. is used for crop growing. Livestock grazing in far higher grounds is very common (Plate 2).

Plate 2. Evidence of active livestock grazing pressure in Choke Mountains (Getachew, 2013)

2.1.2. Climate

The mean annual temperature in the study area is 16.7^{0}C and mean minimum and maximum temperature is 10.8^{0}C and 22.6^{0}C, respectively. The time between February and May is known as the warmest. During these periods, the average temperature could reach up to 17.8^{0}C, whereas during the coldest months between June and August, the average monthly temperature reaches to 15.6^{0}C (Belay Semane, 2011). The Ethiopian Meteorological Survey (EMSA) divides the local climate into three seasons. The dry season “Bega” (November-

March), the short rain season “Belg” from April to May, contributing to about 10% of the annual rainfall and “Kiremt”, the main rain season from June to September, contributing 90% of the annual rainfall.

Seasonal precipitation in the area has tight correlation with the movement of Inter-Tropical Convergence Zone (ITCZ), resulting in high rainfall during May-October. Nevertheless, the distribution of precipitation within the ranges of Choke is far from uniform. Average annual precipitation ranges from 600 - 2000 mm yr^{-1}, and exhibits strong local variability associated with topographic gradient (Belay Semane, 2011). The rainfall distribution during the study period (2014 – 2015) is presented in Fig. 2. The mean monthly rainfall record during this period was 134.75 mm. Due to occurrence of Eleno in 2015, there was prolonged rain season, which resulted in increased mean monthly rainfall of 145.83 mm.

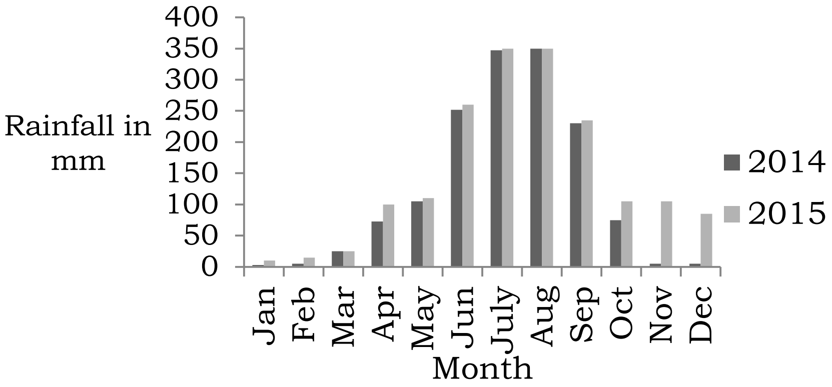


Figure 2. Rainfall data between 2014 and 2015

2.1.3. Economic Activity

Agriculture is the major subsistence income source of the people around Choke Mountains. The major crops cultivated in the area are potato (*Solanum tuberosum*) and barley (*Hordeum vulgare*), the bulk of it produced for household consumption. Sheep, cattle and horse husbandry are the key economic strategy besides crop production. This area is home to more than 132,069 families who are engaged in traditional farming (ORDA, 2011). The mountain ranges are densely populated with an average of 260-270 people per km^2. Therefore, settlements and agricultural activities are common in the mountain chains between 2800 and 3600 m a.s.l. (Belay Semane, 2011).

For this reason, the natural resources mainly land, biodiversity and water are under intense pressure. The productive capacity of the land is declining because of depletion of soil nutrients. The farming communities in the area are therefore facing severe constraints. The people are food insecure, and at the same time, face shortage of livestock feed, fuel wood and water scarcity. Farmers in the area are looking for another option to cope with the declining crop yields. Nowadays, the land holding part of the people is planting trees for commercial purpose as a subsidy for the declining crop yield and for fuel source. Every year more and more agricultural land is being converted into eucalyptus plantation, which ensures income security for local residents.

Those unable to farm are largely engaged in sheep rearing using communal grazing lands. The majority of landless productive youngsters are very known by local migration to towns for employment. In general, environmental degradation caused by humans together with climate change problems resulted in environmentally insecure, economically poor, food insecure and socially unrest people. The combination of all these triggered to natural resource conflict within Woreda and among Kebeles in the area.

2.2. Methods

2.2.1. Preliminary activity

2.2.1.1. Field survey

A preliminary survey of the study area was conducted in October 2013. In the process, essential information on the apparent status of the ecosystem and its physical and biological components was collected. At macro-habitat level, habitat and vegetation types were studied following the different landscapes. Vegetation studies were made across established grids of 4.5 km^2 area. For this purpose, randomly selected sample quadrats were used, and data on vegetation composition, coverage and proportions were recorded. Based on the recorded data, available natural habitat types were identified, and then described depending on the dominant plant species (*Helichrysum - Alchemilla* scrub, *Helichrysum- Lobelia* shrub, *Festuca - Alchemilla* grassland, *Euryops - Lobelia* shrub and *Erica* forest). Thus, from each habitat type, one sample grid was taken across altitudinal gradients (3500-3900 m a.s.l.). Additional study sites were randomly selected from human modified habitats of crop fields, fallow lands (covered with secondary growth) and open pastureland habitats (covered with short grasses) between 3200 and 3300 m a.s.l.. Different from all, croplands were represented with four experimental barley fields for the purpose of crop damage analysis.

Generally, during the preliminary survey, eight sample study sites (Table 1) assumed to represent all available habitat types and landscapes were selected. As described in the introduction part, this study was conducted in highly disturbed highland ecosystem where the vegetations in almost all mountain ranges are exposed to excessive livestock grazing. The *Erica* forests and few *Festuca* dominated mountain landscapes are the only livestock free habitats that are protected by the community. Therefore, the study regarded habitats of different management levels.

Table 1. List of sampled study sites and their altitude

Study sites	Altitude (m asl)	Coordinates
Helichrysum - Alchemilla scrub	3900	10^{0}42.913'N & 37^{0}52.218'E
Helichrysum- Lobelia shrub	3800	10^{0}40.588'N & 37^{0}50.763'E
Festuca - Alchemilla grassland*	3700	10^{0}40.302'N & 37^{0}48.363'E
Euryops - Lobelia shrub	3600	10^{0}40.410'N & 37^{0}46.481'E
Erica forest*	3500	10^{0}42.034'N & 37^{0}44.019'E
Open pastureland (short grasses)	3300	10^{0}40.832'N & 37^{0}41.841'E
Fallow land (secondary growth)	3200	10^{0}39.613'N & 37^{0}40.169'E
Cropland (barley field)	3200	10^{0}39.538'N & 37^{0}40.108'E

(* community protected habitats)

In addition to this, assessments on social, cultural, and economic activities of the community were made through informal discussions. Important information that served as springboard for the bioeconomics study were collected. For instance, experimental plots of crop fields were arranged and inputs that used as a guideline for attitude survey study were also collected from the people.

In general, this stage of the study was the most important part in which the foundation for the actual activity of data collection was laid. In the process, the role of local residents was identified. One of the great achievements was acceptance and support from the community side. The strong challenge for strange visitors and researchers seen in the Choke Mountains is the bad reaction from the local residents. The majority of landless people around Choke area are largely dependent on the unprotected mountain ecosystem resources for livelihood. Therefore, the offensive reactions from the local people emanate from conflict of interest not to lose the benefit in connection with conservation activities.

2.2.1.2. Design of rodent trap grids and location of rodent trap stations

In each of the six sampled experimental habitats (*Helichrysum – Alchemilla* scrub, *Helichrysum - Lobelia* shrub, *Festuca* grassland, *Euryops - Lobelia* shrub, *Erica* forest and open land) a permanent live trapping grid of 70 x 70 m (4900 m^2) size was established (Fig. 3). However, because the size of individual barley fields was small, live trapping grids in crop fields and the fallow land were covered 50 x 50 m (2500 m^2) area. After establishing grids, trap stations were fixed following each vertical grid with an interval of 10 m distance. Therefore, the total number of trap stations fixed in each live trapping grids of the fallow land and cultivated fields were 25. While in each of the remaining six live trapping grids mentioned above, the total number of trap stations was 49.

Trap stations were marked with white scotch tape, at a considerable distance above the traps. At the trap station level (microhabitat), vegetation structure and plant species composition were recorded seasonally within 4 m^2 quadrats placed at all trap stations. Vegetation cover was estimated grouping the plant species into grasses, herbs, shrubs and trees. In addition, the proportion of each plant species was estimated as the percentage of the area of the quadrat covered. Finally, based on the recorded vegetation type and vegetation structure (abundance, density and aerial cover), trap stations were classified into sixteen categories.

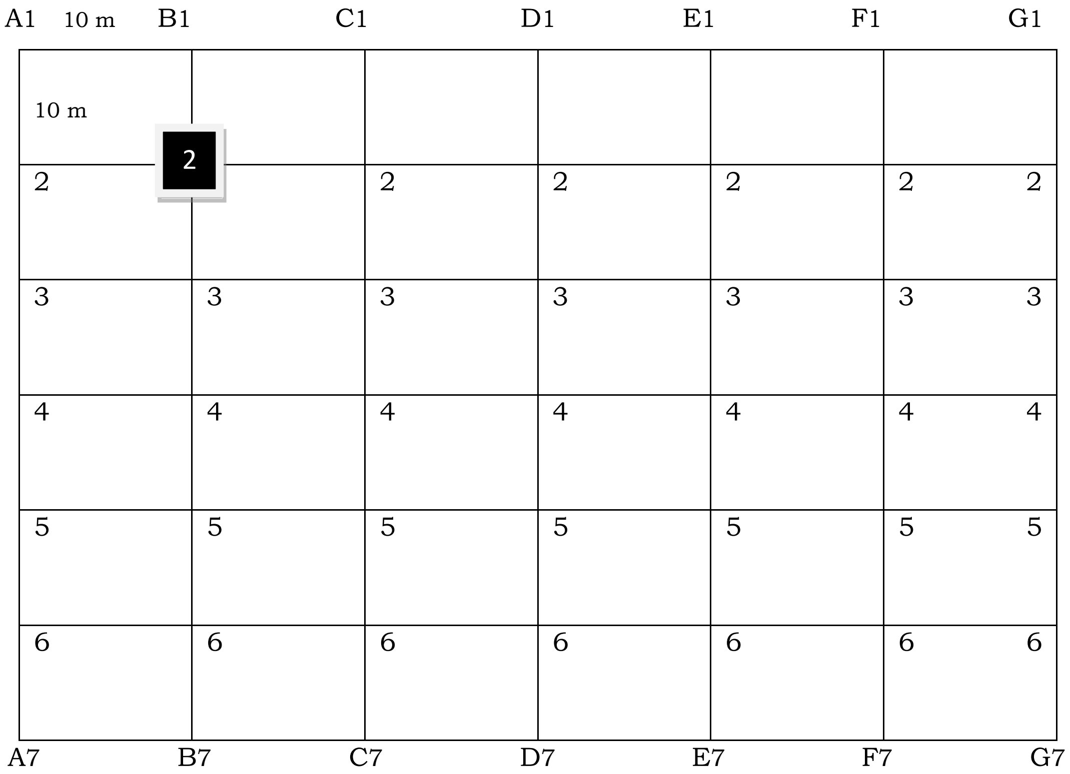


Figure 3. Diagrammatic representation of grids and trap stations (the dark box assumed to represent the 4 m^2 quadrat in trap stations for microhabitat study)

Removal trapping grids were also established mainly for morphometry, stomach content analysis and embryo count. Two line grids that contain 10 trap stations each were created. These grids were located at about 200 m from the live trap grids but with similar habitat feature or along the surrounding matrix. Therefore, 20 snap trap stations were set adjacent to each live trapping grid.

2.2.2. Data collection

Data on rodent species composition, distribution, abundance, habitat association, population structure, reproductive condition and diet were collected by trapping rodents using both Sherman and snap traps. Sherman live traps were used in live trapping grids. In these grids, data were collected through Capture - Mark - Recapture (CMR) method. Pre-baited traps (with peanut butter) were placed on each trap station and left covered with hay and plant leaves to provide protection against strong heat/cold and predators.

Rodent trapping was carriedout in eight sessions between December/2013 and September/2015. Each trapping session continued for three consecutive nights. Traps were checked twice a day, during early morning (between 07:00 and 09:00 hours) and late afternoon (between 05:00 and 06.00 hours). In every visiting session, live trapped rodents were kept in polyethylene bag. Grid and trap station number, the time, date and month, body mass, sex, age and reproductive condition of each were recorded. Approximate age (young, sub-adult and adult), pelage colour and reproductive condition (for females closed or perforated vagina and scrotal or abdominal testes for males) were recorded (Afework Bekele, 1996b). Females with enlarged nipples and large swollen abdomen were identified as pregnant. Finally, the live trapped rodents were marked by toe clipping (Linzey and Kesner, 1997; Clausnitzer, 2003) and released safely on the site they were trapped.

The body length, length of hind foot, tail and ear length of the snap trapped rodents were recorded. Further more, diet study and embryo count were carriedout on the pecimens. Diet study was conducted on 172 rodents. In the field, the stomach was removed and put in specimen tube with formalin (Cole, 1975). In the laboratory, the contents were collected separately, dried and identified by a dissecting microscope. Then the components were sorted into categories (starch grain, monocot leaves, dicot leaves, stem and root tissue, animal matter and unidentified components), and uniformly placed on a 1 x 1 mm grid petridish. Finally, the relative area of the fragments in each food category was estimated as the number of grid intersections covering them. Mono and dicotyledonous plant tissues were identified by the shape and arrangement of epidermis cells.

The studies on rodent caused field crop damage were conducted in barley crop. Data were collected during the two successive crop seasons between 2014 and 2016. Four experimental crop fields of 1600 m^2 each were selected from two locations characterized with distinct growing systesm. Two of the experimental barley fields were isolated plots situated in a matrix of fallowland. The remaining two were from continuous monoculture system. The distance between each replicate in both locations was about 200 m.

Three 2 x 2 m rodent exclusion plots were built as control unit in all experimental fields. The plots were constructed from fine mesh 1.5 m high above the ground and anchored 50 cm deep the ground (Aplin *et al.,* 2003). They were positioned at 10 m interval and encompass different locations in the crop fields. Pest species composition, abundance and density were collected by trapping rodents. It was carriedout from the time of land preparation through the different growing stages of the crop (after sowing, in the vegetative stage, and after fruiting stage before harvest) and after harvest. Both live and snap traps were used and trapping was undertaken in 45 trap stations. Live trapping was carriedout in 25 sites within the crop field. The remaining 20 removal trapping sites were arranged in the surrounding non-cultivated mosaic fields. The experimental cropfields were kept from damage and disturbance through regular supervision carriedout daily from dawn to dusk.

Crop damage data were collected from the date of sowing to maturation. Seed predation that occurred during sowing was studied in six 1 x 1 m quadrats randomly selected from each experimental field. In each quadrat, the emerged plants were counted separately (Aplin *et al.,* 2003). Similarly, the emerged plants in the control plots were counted separately. Sowing details of the farmers were used during the emergence count. Damage assessments were carriedout during the vegetative and booting stages and at maturity before the farmer's intended date of harvest. The number of damaged and undamaged tillers on the individual barley plant was counted in randomly sampled six 1 x

1 m quadrats (Aplin *et al.,* 2003). During sampling, emphasis was given to each half field (the edge, middle and edge). To determine yield loss at harvest, including the control plots, the barley yield in randomly selected 1x1 m plot area was collected and measured separately.

Data on the attitude of farmers towards rodent pest species, level of crop damage, yield loss and economic cost, management strategies and related concepts were collected using questionnaire technique. Among the people inhabited in the Choke Mountains, 250 respondents were randomly selected. The questionnaire was comprised of open and close-ended questions. The respnses of every respondent were collected independently. By doing this, important feedbacks were collected on the following points:

- The size of cultivated field/family
- Major crop types grown
- Ranking the status of different pests affecting crops
- Most vulnerable crop type
- Land preparation
- Sowing schedules
- Ranking of crop damage according to crop phenology
- Factors favouring rodent abundance and crop damage
- Crop yield loss estimation
- Rodent management techniques/approaches
- Economic cost for pest control
- The appropriate time to control rodents

2.2.3. Data analysis

The trapped rodents were identified at species level by comparing the different specimens with specimens found in the Zoological Museum of Addis Ababa University. The taxonomic characteristics listed in Yalden *et al.* (1976), Afework Bekele (1996a) and Nowak (1999) were also used. Shannon–Wiener diversity indices were applied to compute species diversity and comparison was made with *t*-test (Hutcheson, 1970).

Shannon–Weiner diversity index formua:

$$H' = -\sum (pi)\ (\ln pi)$$

Where,

H' is the diversity index, and

pi is the proportion of total sample belonging to the i^{th} species.

Rodent species dominance was computed using Simpson's Index of Dominance (D)

$$D = \sum n\ (n-1)/N(N-1)$$

Where,

N= the total number of individuals of all species

n= the total number of individuals of a particular species

Rodent abundance was measured by trap success rate. In each grid, trap success was expressed in terms of captures per trap night called as Trap Success Index (TS), which was applied to determine the relative abundance of each species (Mills *et al.,* 1991). Analysis of Repeated Measurement technique was used to test the TS of the different habitats among the seasons (Zar, 1996).

$$TS = (\text{number of individuals} \ / \ \text{number of traps} \times \text{nights}) \times 100$$

Population number of rodents in each live trapping grid was estimated by Minimum Number Alive (MNA) method (Krebs, 1999). Density of each species was determined from the total population (Mares and Ernest, 1995). In each trapping session and grid, the density of a species was estimated as the total population number per hectare (10,000 m^2). The effective trapping area of the grids was determined with a border strip added to represent half the distance between trap stations, that is, 5 m. The approach was developed from the assumption that the traps were sampled from a larger area than that defined by the trap stations' corners (Krebs, 1999).

Habitat preference of species was assessed based on the proportion of captures in the study grids following Happold and Happold (1989). The more frequent captures in a particular grid is an indicative of a preference of species for that habitat (Martin and Dickinson, 1985). If a species shows no preference, the proportion of captures in each habitat is supposed to be equal. Any significant deviation from this null hypothesis was considered as habitat preference. The deviation was tested using a replicated goodness of fit test (Sokal and Rohlf, 1981). The association of the rodent community with altitude (vegetation zonation) was analysed using a similarity distance matrix (Dij) or the dissimilitude matrices (Manly, 1997).

$$Dij = 1 - Sij$$

The similarity index of Jaccard (Sij) between areas i and j is given by:

$$Sij = a/(a+b+c)$$

Where,

a= the number of species present in both i and j
b= the number of species present in i but not in j
c= the number of species present in j but not in i

The temporal variation on trap success was analysed using Chi-square test. Similar test was carried out to evaluate trap success per habitat and vegetation cover of each life form. In addition, the presence or absence of captures of each rodent species at microhabitat scale and the vegetation cover of each plant species and life form per trap station were tested.

Biomass of rodent was estimated as per hectar total weight of the trapped population. The temporal and spatial variations were analyzed using Chi-square test. Descriptive statistics was used to describe the sex, age and reproductive conditions of the trapped rodents. The variance between seasons was analyzed using Chi-square test. The diet of rodents was described as the mean percentage of the relative volume of a food item obtained from the stomach content analysis procedure.

Seed losses during sowing were determined by comparing the actual plant emergence recorded in the sample quadrats with the potential emergence from the control plots. Crop damage that occurred during the vegetative and booting stages was estimated following (Rennison, 1979) using the formula:

$$\% \text{ cut tillers} = 100(a/b)$$

Where,

a = number of cut tillers in sample

b = total number of tillers in sample

The total yield loss caused by rodents was estimated by comparing the barley yield in randomly sampled plots on the treatment part from the control plots. Variability test within the sampled plots and between farmlands was cariedout using Chi-square. Descriptive statistics and Chi-square were used to summarize and analyze the responses of farmers. All the data in this study were recorded and analyzed in SPSS Version 16.0 statistical program.

3. Results

3.1. Species composition and distribution

The rodents trapped in the different habitats of the Choke Mountains were comprised of eight species identified as *Mastomys natalensis, Arvicanthis* *abyssinicus, Lophuromys flavopunctatus, Stenocephalemys griseicauda, Rattus rattus, Otomys typus, Tachyorctes splendens* and *Hystrix cristata.* Among these species, *Tachyorctes splendens* and *Hystrix cristata* were not trapped. The presence of *T. splendens* was recognized directly from individuals encountered during the field survey, where as *H. cristata* was confirmed indirectly from the hard spiny integument sheded from individuals. *A. abyssinicus*, *L. flavopunctatus* and *M. natalensis* were exclusively captured during the day time. With the exception of few captures in the *Festuca* grassland, *S. griseicauda* was trapped during the night time. *R. rattus* and *O. typus* were more common during the day time than the night time.

Rodents were captured in all trapping grids characterized with different altitude range and habitat type (Table 2). However, there was variation in the species range of distribution ($p<0.05$). *A. abyssinicus* was the most widely distributed rodent in the study area. It occurred in habitats ranging from the lowland agricultural fields (3200 m asl) to the most elevated moist moorland (3900 m asl). *A. abyssinicus* was not found in the open land and *Erica* forest habitats between 3300 and 3500 m a.s.l. *O. typus* was the second important species in range of distribution. Except open grazing fields at 3300 m a.s.l., it was trapped from crop fields (3200 m a.s.l.) to high altitude grassland habitats (3700 m a.s.l.). Nevertheless, *O. tupus* was not found in habitats of the upper most altitude ranges (3800-3900 m a.s.l.). *S. griseicauda* was limited to habitats above 3600 m a.s.l. *L. flavopunctatus* occurred in habitats between 3500 and 3800 m a.s.l. *M. natalensis* was very common in the human modified lowland habitats (3200-3300 m a.s.l.). The upper altitude range of the species was the forest zone at 3500 m a.s.l. *R. rattus* was confined to the human modified habitats between 3200 and 3300 m a.s.l.

Table 2. Distributional pattern of the rodent species (×= occurrence)

	3900	3800	3700	3600	3500	3300	3200	
Species	HA	HL	FA	EL	Ef	Ol	Fl	Cl
A. abyssinicus	×	×	×	×			×	×
L. flavopunctatus		×	×	×	×			
M. natalensis					×	×	×	×
O. typus			×	×	×		×	×
R. rattus						×	×	×
S. griseicauda	×	×	×	×				

(HA= *Helichrysum* - *Alchemilla* moorland; HL= *Helichrysum* - *Lobelia* shrub; FA=*Festuca* - *Alchemilla* grassland; EL= *Euryops* - *Lobelia* shrub; Ef= *Erica* forest; Ol= Open land; Fl= Fallow land; Cl= Cropland)

3.2. Species abundance and trap success

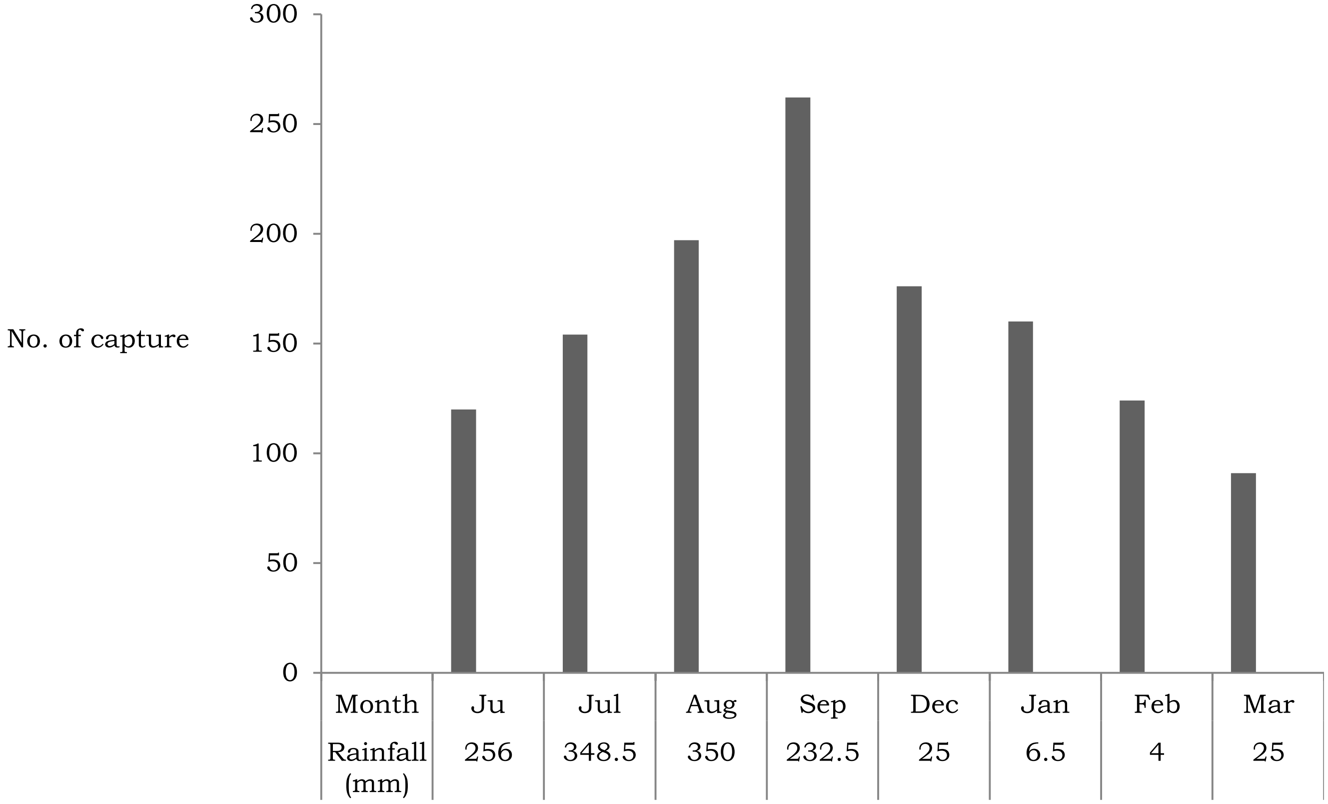
In 12096 trap nights, the total number of captured rodents was 1473. From the total number of captures, the number of live trapped rodents in 8256 trap nights was 1172, of which, 189 were recaptures. The remaining 301 rodents were captured from the removal trapping grids in 3840 trap nights. The over all trap success rate was 10.62%. Trap success in the live trapping was greater (11.91%) than the removal trapping (7.84%).

The relative abundance of species was significantly different (χ^2 = 158.624, $p< 0.001$). Thus, the null hypothesis that assumed all species to occur in equal magnitude was rejected (Table 3). The grass rat, *A. abyssinicus* was the most abundant rodent species (36.99%), followed by *L. flavopunctatus* (17.29%), *M. natalensis* (16.74%). *R. rattus* and *O. typus* consisted of nearly equal relative abundance of 10.05 and 10.44%, respectively. In the study area, the least abundant rodent species was *S. griseicauda* (8.49%).

Table 3. Total catch and relative abundance of rodent species

Species	Total catch	Relative abundance (%)
A. abyssinicus	475	36.99
L. flavopunctatus	222	17.29
M. natalensis	215	16.74
O. typus	129	10.05
R. rattus	134	10.44
S. griseicauda	109	8.49
Total	1284	100.00

Statistically significant ($\chi^2 = 51.418$, $p<0.05$) variation was found in the number of rodents captured during the different months (Fig. 4). The highest rodent capture (n= 262) that accounted 20.40% of all catches was recorded by the end of the wet season, in September. The rainfall distribution recorded during September (232.5 mm) was the least for the wet season, but it was the highest from the dry season records (December-March). The second highest relative abundance (15.34%) was recorded during the peak rain period (350 mm), in August. From all trapping sessions, the least number (n= 91) that comprised 7.09% was recorded in March. The seasonal variation on rodent abundance was statistically significant ($p<0.05$). More number of rodents (n = 733) that accounted 57.09% of the total catch were recorded during the wet season. Whereas during the dry season, the total number of individuals captured was 551, which is 42.91% of all the catch. The variation on trap success during the wet (12.12%) and the dry (9.11%) seasons was significant ($p<0.05$).



Month	Ju	Jul	Aug	Sep	Dec	Jan	Feb	Mar
Rainfall (mm)	256	348.5	350	232.5	25	6.5	4	25

Figure 4. Number of rodent captures against rainfall distribution during the different months

The number of occurrence and relative abundance of the different rodent species showed variation between wet and dry seasons (Table 4). In all species except *O. typus*, more number of captures were recorded during the wet than the dry season. Especially statistically significant variation ($p<0.001$) was found for *S. griseicauda,* with recorded total captures of 77 (70.64%) during wet season and 32 (29.36%) during the dry season. However, the variation between wet and dry season abundance of *R. rattus* (52.99%, 47.01%) and *O. typus* (48.06%, 51.94%) was not statistically significant ($p>0.05$).

Table 4. Variation between wet and dry season captures of the species (the number in bracket shows percentage)

Species	Wet season	Dry season
A. abyssinicus	280 (58.95)	195 (41.05)
L. flavopunctatus	129 (58.11)	93 (41.89)
M. natalensis	114 (53.02)	101 (46.98)
O. typus	62 (48.06)	67 (51.94)
R. rattus	71 (52.99)	63 (47.01)
S. griseicauda	77 (70.64)	32 (29.36)

3.3. Species richness and diversity

Variation on species richness was noted in the different habitats and altitude ranges (Table 5). The highest number of species was four. In the natural habitats, it occurred in *Euryops* - *Lobelia* shrub and *Festuca* grassland of the afroalpine zone between 3600 and 3700 m a.s.l. Similarly, four species was recorded in human modified cropland and fallows of the lowland region (3200 m a.s.l). The rodent communities in the *Erica* forest of the *Erica* belt (3500 m a.s.l.) and *Helichrysum-Lobelia* shrub in the upper mountainous zone at 3800 m a.s.l. were composed of three species. The moist *Helichrysum* - *Alchemilla* moorland in the upper most mountain range (3900 m a.s.l.) and open pastureland habitats of the lowland region (3300 m a.s.l.) consisted two rodent species, which was the least record to the study.

Shannon-Wiener diversity index values of the rodent community at different altitude and habitat types showed variation. High diversity index was recorded in croplands (H'= 1.36) and fallows (H'= 1.314). In the afroalpine zone, diversity index was high in *Euryops* - *Lobelia* shrub (H' = 1.257) at 3600 m a.s.l. and *Festuca* grassland (H' = 0.979) at 3700 m a.s.l. Diversity index of *Erica* forest and *Helichrysum* - *Lobelia* shrub was 0.964 and 0.937, respectively. The diversity index of rodents in the moist moorland (H' = 0.667) and open lands

(H' = 0.691) were the least. Similarly, Simpson's index of diversity was high in cropland (SI= 0.738), fallowland (SI= 0.715) and *Euryops* – *Lobelia* shrub (SI= 0.686) indicating evenness was good in these habitats. In habitats above the *Erica* belt, species diversity decreased with increasing elevation.

Table 5. Shannon-Wiener and Simpson's species diversity index values of rodents at different altitude and vegetation structure

Habitat	Altitude (m a.s.l.)	Richness	Diversity (H')	Simpson's Index (1-D)
Helichrysum-Alchemilla	3900	2	0.667	0.474
Helichrysum -Lobelia	3800	3	0.937	0.553
Festuca - Alchemilla	3700	4	0.979	0.511
Euryops - Lobelia	3600	4	1.257	0.686
Erica forest	3500	3	0.964	0.582
Open land	3300	2	0.691	0.500
Fallow land	3200	4	1.314	0.715
Cropland	3200	4	1.360	0.738

The pair wise measure of rodent community similarity resulted in different values (Table 6). The variation between habitat pairs ranged from absolute dissimilarity (Sij= 0.00) between open land habitats at 3300 m with those afroalpine ranges (3600-3900 m asl) to absolute similarity (Sij= 1.00) between *Euryops* - *Lobelia* (3600 m asl) and *Festuca* grassland (3700 m asl). Similarly, absolute community dissimilarity was found between the *Erica* forest (3500 m asl) and the moist *Helichrysum* - *Alchemilla* moorland (3900 m asl) habitats. The rodent community in the open land habitat (3300 m asl) was more similar to those in fallow land and crop fields at 3200 m asl than the other habitats. Simlarity in rodent species composition was more evident in habitats with comparable elevation.

Table 6. Comparison of rodent community similarity (Jaccard's community similarity coefficient, Sij values) between altitude pairs

Altitude	3900	3800	3700	3600	3500	3300	3200
3900	1.00						
3800	0.66	1.00					
3700	0.50	0.75	1.00				
3600	0.50	0.75	1.00	1.00			
3500	0.00	0.20	0.40	0.40	1.00		
3300	0.00	0.00	0.00	0.00	0.25	1.00	
3200	0.20	0.33	0.40	0.33	0.16	0.50	1.00

Similarly, Distance matrix index or dissimilarity (Dij= 1-Sij) values of the rodent community between altitude pairs varied significantly (Table 7). Remarkable distance matrix index was found between the open land habitat at the lowland (3300 m asl) with the afroalpine ranges above 3600 m asl ($p<0.001$). Including the *Erica* zone (3500 m asl), the species composition among the lowland habitats showed more similarity compared to the upper mountainous habitats (3700-3900 m asl). In the same manner, similarity in species composition was found among habitats of the afroalpine range.

Table 7. Distance matrix index or dissimilarity (Dij= 1-Sij) value of the rodent community between altitude pairs

Altitude	3900	3800	3700	3600	3500	3300	3200
3900	0.00						
3800	0.34	0.00					
3700	0.50	0.25	0.00				
3600	0.50	0.25	0.00	0.00			
3500	1.00	0.80	0.60	0.60	0.00		
3300	1.00	1.00	1.00	1.00	0.75	0.00	
3200	0.80	0.67	0.60	0.67	0.84	0.50	0.00

3.4. Habitat preference and microhabitat association

Rodent abundance varied across habitats (χ^2 = 109.76, $p<0.001$) indicating presence of habitat preference (Table 8). The highest proportion was recorded in *Festuca-Alchemilla* grassland (22.51%) and *Erica* forest (15.89%). There was significant variation with open pastureland ($p=0.0006$), *Helichrysum* - *Alchemilla* moorland ($p<0.05$), *Helichrysum* – *Lobelia* ($p<0.05$ and *Euryops* - *Lobelia* shrub ($p<0.05$). Like wise, rodent trap success rate differed across habitats (χ^2 = 89.46, $p<0.01$). The highest success rate was recorded in *Festuca-Alchemilla* grassland (17.45%), and the least was in open lands (4.47%), which were characterized with open rocky surfaces seasonally covered by assemblage of short herb and grass species. Trap success in human modified habitats of crop fields (15.46%) and fallow lands (14.26%) was also significant following *Festuca-Alchemilla* grassland.

Table 8. Total capture and trap success of rodents in different habitat and altitude

Habitat	Total capture	Relative abundance %	Trap night	Trap success (%)
HA (3900)	126	9.81	1656	7.61
HL (3800)	117	9.11	1656	7.07
FA (3700)	289	22.51	1656	17.45
EL (3600)	153	11.92	1656	9.24
Ef (3500)	204	15.89	1656	12.32
Ol (3300)	74	5.76	1656	4.47
Fl (3200)	154	11.99	1080	14.26
Cl (3200)	167	13.01	1080	15.46
Total	1284	100.00	12096	10.62

(HA = *Helichrysum* - *Alchemilla* moorland; HL = *Helichrysum* - *Lobelia* shrub; FA = *Festuca* -*Alchemilla* grassland; EL= *Euryops* - *Lobelia* shrub; Ef = *Erica* forest; Ol = Open land; Fl = Fallow land; Cl = Cropland)

There was seasonal variation in rodent trap success (Fig. 5). The overall trap success during the wet and dry seasons was 13.87% and 10.48%, respectively. In all habitats except the *Erica* forest and crop fields, the rate of rodent trapping was higher during the wet than the dry season. The variation in crop fields was significant (χ_1^2 = 199.03, p<0.001). Trap success was higher during the dry season (29.8%) than the wet season (6.85%). During the dry season, the open land, *Helichrysum* - *Alchemilla* moorland, *Helichrysum* - *Lobelia* and *Euryops* - *Lobelia* shrub were less important to rodents (p<0.05). Comparatively, rodents used more the fallow land, *Erica* forest and *Festuca* - *Alchemilla* grassland habitats regardless of seasons.

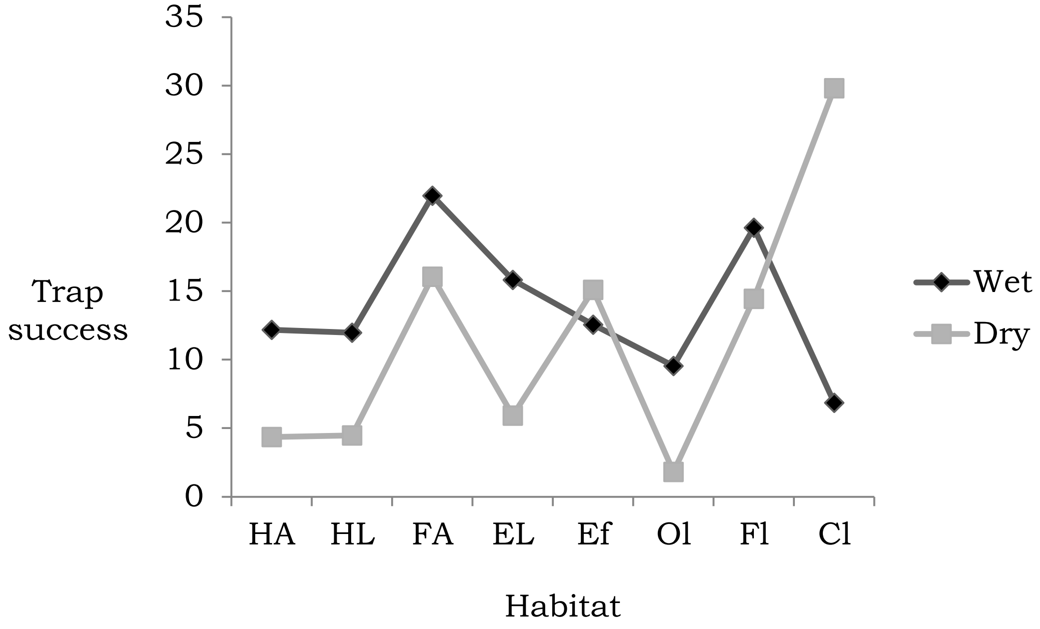


Figure 5. Seasonal variation in trap success based on habitats

(HA = *Helichrysum* - *Alchemilla* moorland; HL = *Helichrysum* - *Lobelia* shrub; FA = *Festuca* - *Alchemilla* grassland; EL = *Euryops* - *Lobelia* shrub; Ef = *Erica* forest; Ol = Open land; Fl = Fallow land; Cl = Cropland)

In all habitats, relative abundance of rodents varied on seasonal basis (Table 9). In most habitats, it was higher during the wet season than the dry season. The variation in fallow land, *Erica* forest and *Festuca* - *Alchemilla* grassland was not significant (p>0.05). Nevertheless, rodents predominantly preferred crop fields more during the dry than the wet season.

Table 9. Wet and dry season relative abundance (%) of rodents in the different habitats (figures in parenthesis are number of captures)

Habitat	Wet	Dry
Helichrysum - Alchemilla moorland	13.23 (97)	5.26 (29)
Helichrysum - Lobelia shrub	12.01 (88)	5.26 (29)
Festuca - Alchemilla grassland	22.65 (166)	22.32 (123)
Euryops- Lobelia shrub	15.96 (117)	6.54 (36)
Erica forest	12.55 (92)	20.33 (112)
Open land	9.00 (66)	1.45 (8)
Fallow land	12.14 (89)	11.80 (65)
Cropland	2.46 (18)	27.04 (149)
Total	100 (733)	100 (551)

The relative abundance and proportion occurrence of each rodent species indicated the presence of variation in habitat preference (Table 10). Each species preferred few habitats among others. *A. abyssinicus* significantly preferred *Festuca - Alchemilla* grassland (χ_5^2 = 86.09, p<0.001) habitat with 66.98% relative abundance and 40.81% proportion of occurrence. The second most preferred habitat by *A. abyssinicus* was the moist *Helichrysum - Alchemilla* moorland, and the recorded relative abundance and proportion of occurrence was 61.31% and 16.25%, respectively. Individuals of *A. abyssinicus* were also periodically common in cultivated fields (9.48%).

Helichrysum - Alchemilla moorland habitat was the most preferred natural habitat to *S. griseicauda* (χ_3^2 = 69.87, p<0.001) that consisted of 40.77% occurrence and 38.69% relative abundance. From afroalpine dry habitats, *S. griseicauda* preferred *Festuca - Alchemilla* grassland with a recorded occurrence of 24.62%. *L. flavopunctatus* inhabit in the afroalpine and *Erica* woodland habitats between 3500 m and 3800 m asl. Nevertheless, the species predominates more in *Erica* forest than others, especially to *Festuca* - *Alchemilla* grassland (χ_1^2= 56.30, p<0.001) and *Helichrysum* - *Lobelia* shrub (χ_1^2= 41.29, p<0.05). From the afroalpine range, it preferred *Euryops* - *Lobelia* shrub with 30.08% occurrence and 42.78% relative abundance.

Table 10. The relative abundance and relative occurrence (in parenthesis) of rodents in each habitat

	Species					
Hab.	A.ab	S.gr	L.fl	M.na	O.ty	R.ra
HA	61.90 (16.42)	38.10 (44.04)	_	_	_	_
HL	64.10 (15.79)	12.82 (13.76)	23.08 (12.16)	_	_	_
FA	69.55 (42.32)	9.00 (23.85)	5.54 (7.21)	_	15.91 (35.66)	_
EL	33.33 (10.74)	13.07 (18.35)	42.49 (29.28)	_	11.11 (13.18)	_
Ef	_	_	55.88 (51.35)	32.35 (30.70)	11.77 (18.60)	_
Ol	_	_	_	52.35 (17.67)	_	48.65 (26.87)
Fl	19.48 (6.32)	_	_	37.66 (26.98)	10.39 (12.40)	32.47 (37.31)
Cl	23.95 (8.41)	_	_	31.74 (24.65)	15.57 (20.16)	28.74 (35.82)

(HA= *Helichrysum* - *Alchemilla* moorland; HL = *Helichrysum* - *Lobelia* shrub; FA = *Festuca* - *Alchemilla* grassland; EL= *Euryops*- *Lobelia* shrub; Ef = *Erica* forest; Ol= Open land; Fl= Fallow land; Cl = Cropland; A.ab = *A. abyssinicus*; S.gr = *S. griseicauda*; L.fl = *L. flavopunctatus*; M.na = *M. natalensis*; O.ty = *O. typus*; R.ra = *R. rattus*)

Including the *Erica* woodland, human modified lowland habitats below 3500 m asl were important habitats to *M. natalensis*. Compared to the open grazing land, the species preferred more *Erica* forest, fallow land and crop land habitats (p<0.05) with preference of 30%, 26% and 24.40%, respectively. In the study area, *O. typus* was the second widely distributed rodent species. However, *Festuca* - *Alchemilla* grassland was the prime habitat preferred by the species (31.45%). In addition, croplands (20.13%) and *Erica* forest (18.87%) were seasonally preferred habitats by *O. typus*. *R. rattus* was exclusively restricted to human modified habitats below 3300 m asl. Significantly, the species preferred more the fallow land (37.27%) and croplands (34.78%) than open grazing fields ($p<0.05$).

Habitat preference of rodent species varied seasonally, although few habitats were more preferred than others regardless of seasons (Table 11). For instance, the population of *A. abyssinicus* did not show significant seasonal variation ($p>0.05$) in preference of *Festuca* - *Alchemilla* grassland habitat. However, this species significantly preferred ($\chi_1^2= 89.66$, $p<0.001$) *Helichrysum* - *Alchemilla* moorland habitat during the wet (21.38%) than the dry (8.92%) season. Contrary to this, *A. abyssinicus* preferred croplands significantly ($\chi_1^2= 101.23$, $p<0.001$) during the dry (19.72%) than the wet (2.30%) seasons. Wet and dry season habitat preference of *S. gresicauda* did not show significant variation ($\chi_1^2= 13.75$, $p>0.05$). Despite the overall significant variation ($\chi_1^2= 38.55$, $p<0.05$) during wet and dry season habitat preference of *L. flavopunctatus*, the variation in the most preferred habitat, *Erica* forest, was insignificant ($\chi_1^2= 11.42$, $p>0.05$).

Table 11. Seasonal variation in habitat preference of the rodent species

Hab.		A.ab	S.gr	L.fl	M.na	O.ty	R.ra
HA	Wet	22.50	44.16	-	-	-	-
	Dry	7.69	43.75	-	-	-	-
HL	Wet	20.36	16.88	15.50	-	-	-
	Dry	9.23	12.50	7.53	-	-	-
FA	Wet	40.71	20.78	7.75	-	41.93	-
	Dry	44.41	31.25	6.45	-	29.85	-
EL	Wet	12.86	18.18	37.98	-	20.97	-
	Dry	5.13	12.50	17.20	-	5.97	-
Ef	Wet	-	-	38.77	30.70	11.29	-
	Dry	-	-	68.82	30.69	25.37	-
Ol	Wet	-	-	-	29.82	-	46.48
	Dry	-	-	-	3.96	-	6.35
Fl	Wet	2.50	-	-	30.70	20.97	47.89
	Dry	13.54	-	-	22.77	4.48	23.81
Cl	Wet	1.07	-	-	8.78	4.84	5.63
	Dry	20.00	-	-	44.55	34.33	69.84

(HA= *Helichrysum* - *Alchemilla* moorland; HL = *Helichrysum* - *Lobelia* shrub; FA = *Festuca* - *Alchemilla* grassland; EL= *Euryops* - *Lobelia* shrub; Ef = *Erica* forest; Ol= Open land; Fl= Fallow land; Cl= Cropland; A.ab = *A. abyssinicus*; S.gr = *S. griseicauda*; L.fl = *L. flavopunctatus*; M.na = *M. natalensis*; O.ty = *O. typus*; R.ra = *R. rattus*)

Mastomys natalensis significantly ($\chi_1^2 = 79.08$, $p<0.001$) used croplands during the dry (41.23%) than the wet seasons (10.29%). However, the variation in *Erica* forest preference was not significant ($p>0.05$). *O. typus* preferred cultivated fields during the dry ($p<0.001$) than the wet season, and fallow lands during the wet ($p<0.05$) than the dry seasons. The variation in *Festuca-Alchemilla* grassland was not significant ($p>0.05$). For *R. rattus,* croplands during the dry ($p<0.001$) and open land habitats during the wet ($p<0.001$) seasons were the most preferred habitats. Fallow land habitats have year round importance to the species ($p>0.05$).

Plant species diversity across the habitats varied significantly ($\chi_7^2 = 28.97$, $p<0.05$). It was high in *Festuca* grassland (H =1.241), fallow land (H = 1.008), and *Euryops-Lobelia* shrub land (H = 0.917) habitats. The least plant species diversity was recorded in the crop field (H = 0.527). Species showed variation in microhabitat selection (Table 12).

Table 12. Microhabitat vegetation variables (% coverage) and rodent species association (number of catches)

Microhabitat variable	A.ab	S.gr	L.fl	M.na	O.ty	R.ra
Dense tree, simple plants and old plant materials under surface (75%)	_	_	14	16	3	_
Dense tree, short herbs under surface (75%)	_	_	48	22	8	_
Less dense tree, tall herbs and grasses under surface (64%)	_	_	62	37	19	_
Dense bush growth (80%)	20	_	_	41	17	24
Less dense bush growth, rocky surface (59%)	15	_	_	24	7	36
Dense shrub, aerial growth (78%)	23	21	21	_	7	_
Dense shrub, short herbs, little aerial growth (80%)	27	15	29	_	3	_
Less dense shrub with short herbs and grasses (72%)	32	25	47	_	13	_
Open rocky, short herbs and grasses (53%)	18	36	13	6	_	_
Dense tall herbs, short grasses (85%)	30	_	-	42	24	35
Dense short herbs, short grasses (87%)	14	_	-	17	8	21
Dense tall grasses and herbs (96%)	85	11	7	_	19	_
Less dense tall grasses and herbs (84%)	34	12	15	_	33	_
Open rocky surface, short grasses (42%)	7	10	_	_	8	_
Dense short grasses (79%)	5	_	_	29	_	30
Less dense short grasses (59%)	-	_	_	16	_	15

(A.ab = *A. abyssinicus*; S.gr = *S. griseicauda*; L.fl = *L. flavopunctatus*; M.na = *M. natalensis*; O.ty = *O. typus*; R.ra = *R. rattus*)

The most preferred microhabitat condition for *A. abyssinicus* (68.29%), *R. rattus* (62.73%), and *O. typus* (54.44%) was tall grasses and herbs. Vegetation density was not significant ($p>0.05$) for *R. rattus* and *O. typus*. Most of the time, *S. griseicauda* was caught in microhabitats of grass and herb assemblage, however the variation with shrub dominated sites was not statistically significant ($p>0.05$). *S. griseicauda* preferred less dense microhabitat conditions. *L. flavopunctatus* ($p<0.001$) and *M. natalensis* ($p<0.05$) significantly occurred in sites dominated with woody vegetation that consisted of short grasses and herbs. However, vegetation density is more important to *M. natalensis* ($p<0.05$) than *L. flavopunctatus* ($p>0.05$).

3.5. Rodents from the live trapping grids

3.5.1. Age and sex distribution

The total number of captured rodents in the live trap grids was 1172. Among this, 189 (16.13%) were recaptures. The number of captures in the different trapping sessions differed significantly ($\chi_7^2 = 45.39$, $p<0.05$). The highest proportion of the captures (21.87%; n= 215) occurred in September. The least (7.22%; n = 71) was recorded in March (Table 13). Most of the captured individuals were males (56.56%); females comprised 43.44%. The rodents were also composed of all age groups (adult, sub-adult and young). However, the number of captures in each age group was significantly different ($\chi_2^2 = 104.65$, $p<0.001$). Adults took the lion share (69.89%; n = 687) and young rodents were the least trapped (8.65%; n = 85).

Table 13. Age and sex distribution of rodents captured in different months

	Jun		Jul		Aug		Sep		Dec		Jan		Feb		Mar		
Age	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	Tot.
Ad	45	30	46	43	60	44	70	59	44	39	48	33	38	32	34	22	687
Sa	0	0	2	0	7	5	35	28	30	18	25	15	21	12	6	7	211
Y	0	2	5	4	11	5	10	13	11	9	7	4	0	2	1	1	85
Tot.	45	32	53	47	78	54	115	100	85	66	80	52	59	46	41	30	983

(Ad = Adult; Sa = Sub-adult; Y = Young; Tot.= Total)

The number of live trapped rodents significantly differed among species (χ_5^2 = 105.73, $p<0.001$). From the total capture, individuals of *A. abyssinicus* were the highest 35.09% (n= 345). The least contribution 8.34% (n= 82) was from individuals of *S. griseicauda* (Table 14). During both seasons, males were more captured than females. The distribution of male and female rodents was 55.53% and 44.67% during the wet, and 57.73% and 42.27% the dry seasons. From the total captured adult rodents (687), more number was collected during the wet 397 (57.79%) than the dry season 290 (42.21%). Except in *O. typus*, the number of adults in all species was more during the wet than the dry seasons.

Table 14. Sex and age distribution of live trapped rodents during the wet and the dry seasons

	Wet							Dry						
	Male			Female				Male			Female			
Sp.	Ad	Sa	Y	Ad	Sa	Y	Total	Ad	Sa	Y	Ad	Sa	Y	Total
A.ab	83	9	7	62	6	10	177	58	26	10	45	21	8	168
L.fl	45	2	7	30	0	8	92	24	21	4	27	15	1	92
M.na	38	8	4	32	6	3	91	25	17	1	17	9	3	72
O.ty	14	8	1	20	10	0	53	17	7	2	20	1	1	48
R.ra	23	5	4	17	5	1	55	30	6	2	9	5	1	53
S.gr	18	12	3	15	6	2	56	10	5	0	8	1	2	26
Total	221	44	26	176	33	24	524	164	82	19	126	52	16	459

(A.ab = *A. abyssinicus*; S.gr = *S. griseicauda*; L.fl = *L. flavopunctatus*; M.na = *M. natalensis*; O.ty = *O. typus*; R.ra = *R. rattus*; Ad = Adult; Sa = Sub-adult; Y = Young)

There was significant variation in the number of sub-adults captured during the wet and the dry seasons ($\chi_1^2 = 107.11$, $p<0.001$). About 63.51% of the total catch occurred during the dry season. In all rodents except *O. typus* and *S. griseicauda,* more number of sub-adults was collected during the dry than the wet seasons. They were captured in all trapping sessions of the dry season. Nevertheless, more number was found in December 35.82% and January 29.85%. Their abundance decreased towards the end of the dry season, in March (9.70%). Sub-adults were rare in the beginning of the main rain season. However, their number showed progress and reached the peak towards the end of the wet season in September (81.82%). *Arvicanthis abyssinicus* (n=62) and *M. natalensis* (n=40) contributed more number of sub-adults.

Young rodents were captured in all trapping sessions (Fig. 6). However, the highest proportion (58.82%; n= 50) was recorded during the wet season. The number of catches increased gradually from June (n= 2) to September (n= 23). Like wise, rainfall distribution showed increasing pattern, and reached peak in August. New recruitment of young rodents decreased from December (n= 21) to March (n= 2) of the dry season trapping sessions. Of all captured young, the highest proportion (41.18%; n = 35) was individuals of *A. abyssinicus*, and the least was for *R. rattus* (9.41%; n= 8).

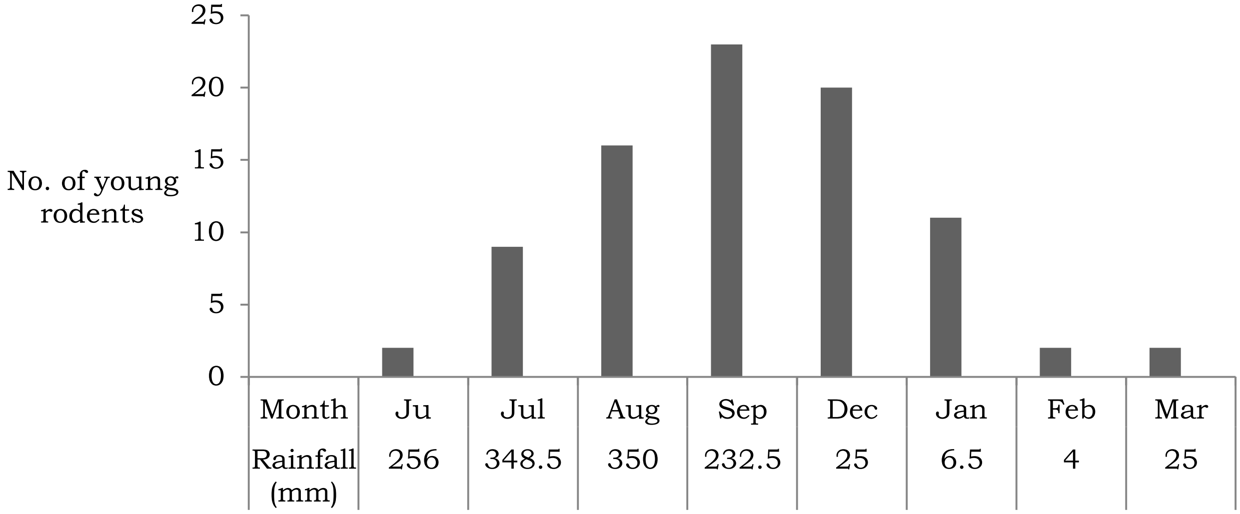
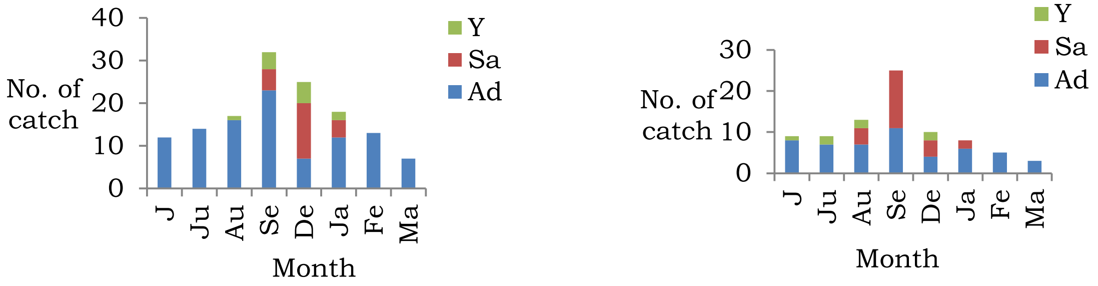


Figure 6. Number of captured young rodents against rainfall distribution in the different months

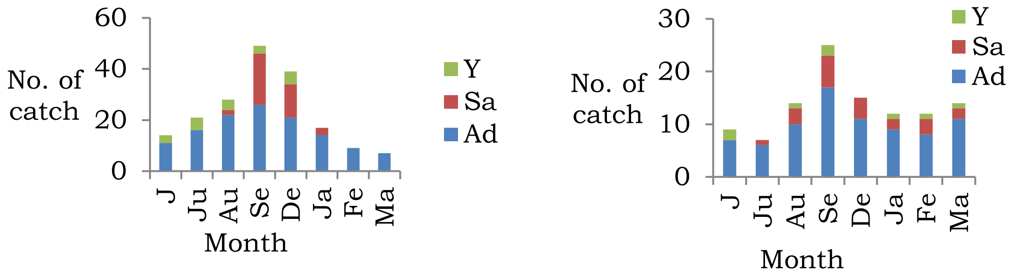
3.5.2. Reproductive activity

Breeding in most rodent species occurred between June and December. However, pregnant individuals of few species were found in March as well. Reproductively active males (raised scrotum) and females (perforated vagina) were caught in all trapping sessions though more notable between June and September. *Arvicanthis abyssinicus* breed between August and December. The first catch of young and sub-adult individuals occurred in August and September, respectively (Fig. 7a). In *S. griseicauda,* breeding begun in June and extend to December. Young individuals were abundant from June to December (Fig. 7b). Similarly, pregnant individuals (swollen belly and large teats covered with hair) and young of *L. flavopunctatus* and *M. natalensis* were caught beginning from June (Fig. 7c,d). Young of *M. natalensis* were found in March, whereas the last catch for *L. flavopunctatus* ccurred in December. The maximum record of sub-adult *L. flavopunctatus* (n = 20) was in September. For *M. natalensis* (n = 12), it was in September and February. Breeding in *O. typus* and *R. rattus* commence in June and extend to March. Young and lactating adults (with big and bare teats) of *O. typus* were caught between July and February, and between June and March for *R. rattus* (Fig. 7e,f).



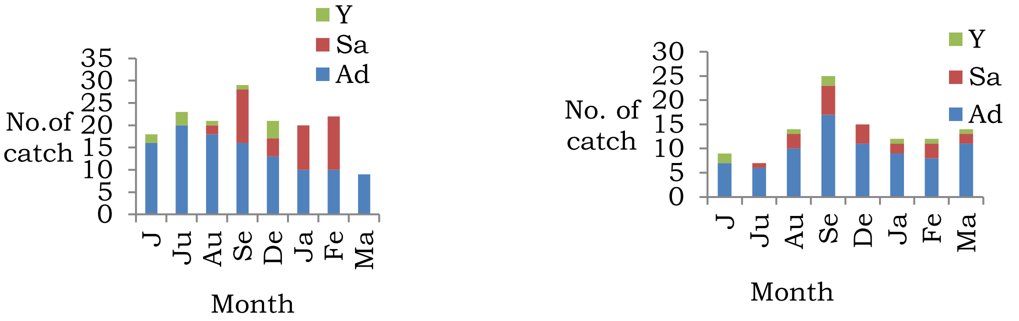
(a) *A. abyssinicus*

(b) *S. griseicauda*



c) *L. flavopunctatus*

(d) *M. natalensis*



(e) *O. typus*

(f) *R. rattus*

Figure 7 (a-f). Number of the different age groups of the rodent species aptured during the different trapping sessions (Ad = Adult; Sa = Sub-adult; Y = Young)

3.5.3. Population estimation and density

The total rodent population in the study grids was estimated to be 2816. The mean population size during each trapping session was 352 (Table 15). Population size in the different grids varied significantly ($\chi_7^2 = 97.81$, $p<0.001$). Mean population size was high in *Festuca* grassland (80.27), followed by *Erica* forest (61.15) and *Euryopys* - *Lobelia* shrub (51.21). The estimated mean population size was lowest in open land (20.2) and *Helichrysum* - *Lobelia* habitats (20.38). The highest estimated mean population for *A. abyssinicus* (46.53), *S. griseicauda* (13) and *O. typus* (16.25) was recorded in *Festuca* - *Alchemilla* grassland. The highest mean population of *L. flavopunctatus* was recorded in *Erica* forest (40.31) and the least was in *Festuca* - *Alchemilla* grassland (4.67). The estimated mean population of *M. natalensis (*16.86) and *R. rattus* (14.6) recorded in croplands was the highest. For both species, the lowest mean population size was recorded in open lands.

Table 15. Mean population size of the rodent species in the different habitats

Habitat	A.ab	S.gr	L.fl	M.na	O.ty	R.ra	Total
HA	23.80	9.60	0.00	0.00	0.00	0.00	33.40
HL	9.33	5.50	5.55	0.00	0.00	0.00	20.38
FA	46.35	13.00	4.67	0.00	16.25	0.00	80.27
EL	23.33	2.17	20.21	0.00	5.50	0.00	51.21
Ef	0.00	0.00	40.31	16.17	4.67	0.00	61.15
Ol	0.00	0.00	0.00	8.20	0.00	12.00	20.20
Fl	5.20	0.00	0.00	13.14	6.80	12.44	37.58
Cl	9.75	0.00	0.00	16.86	6.60	14.60	47.81
Total	117.76	30.27	70.74	54.37	39.82	39.04	352.00

(A.ab = *A. abyssinicus*; S.gr = *S. griseicauda*; L.fl = *L. flavopunctatus*; M.na = *M. natalensis*; O.ty = *O. typus*; R.ra = *R. rattus*; HA= *Helichrysum* - *Alchemilla* moorland; HL = *Helichrysum* - *Lobelia* shrub; FA = *Festuca* - *Alchemilla* grassland; EL= *Euryops* - *Lobelia* shrub; Ef = *Erica* forest; Ol= Open land; Fl= Fallow land; Cl = Cropland)

Population density of rodents was 110.85/ha (Table 16). The variation among habitats was significant ($\chi_7^2 = 106.35$, $p<0.001$). The highest rodent density was recorded in croplands (191.24), followed by *Festuca* grassland (165.82), fallow land (150.32) and *Erica* forest (124.80). Rodent density was lowest in the open land (41.22) and *Helichrysum* - *Lobelia* shrubland (41.59) habitats. Density of rodent species differed significantly ($\chi_5^2= 66.78$, $p<0.05$). The highest record was for *A. abyssinicus* (33.84), followed by *M. natalensis* (21.22), *L. flavopunctatus* (18.05) and *R. rattus* (16.58). Population density of *S. griseicauda* (7.72) and *O. typus* (13.44) was the lowest.

Table 16. Density (ha^{-1}) of rodents in the different habitats

Hab.	A.ab	S.gr	L.fl	M.na	O.ty	R.ra	Total
HA	47.67	19.59	0.00	0.00	0.00	0.00	67.26
HL	19.04	11.22	11.33	0.00	0.00	0.00	41.59
FA	96.60	26.53	9.53	0.00	33.16	0.00	165.82
EL	47.61	4.43	41.24	0.00	11.22	0.00	104.50
Ef	0.00	0.00	82.27	33.00	9.53	0.00	124.80
Ol	0.00	0.00	0.00	16.73	0.00	24.49	41.22
Fl	20.80	0.00	0.00	52.56	27.20	49.76	150.32
Cl	39.00	0.00	0.00	67.44	26.40	58.40	191.24
Tot.	270.72	61.77	144.37	169.73	107.51	132.65	886.75
Mean	33.84	7.72	18.05	21.22	13.44	16.58	110.85

(A.ab = *A. abyssinicus*; S.gr = *S. griseicauda*; L.fl = *L. flavopunctatus*; M.na = *M. natalensis*; O.ty = *O. typus*; R.ra = *R. rattus*; HA= *Helichrysum* - *Alchemilla* moorland; HL = *Helichrysum* - *Lobelia* shrub; FA = *Festuca* - *Alchemilla* grassland; EL= *Euryops*- *Lobelia* shrub; Ef = *Erica* forest; Ol= Open land; Fl= Fallow land; Cl = Cropland)

Density of rodents varied between the wet and the dry seasons. The mean rodent density during the wet and the dry seasons was 119.92 and 99.00, respectively. Seasnal variation in rodent density also occurred on the different habitats (Fig. 8). The variation was significant in *Helichrysum* - *Alchemilla* moorland ($p<0.05$), *Euryops* - *Lobelia* shrubland ($p<0.001$), fallow land ($p<0.001$) and cropland ($p<0.001$) habitats.

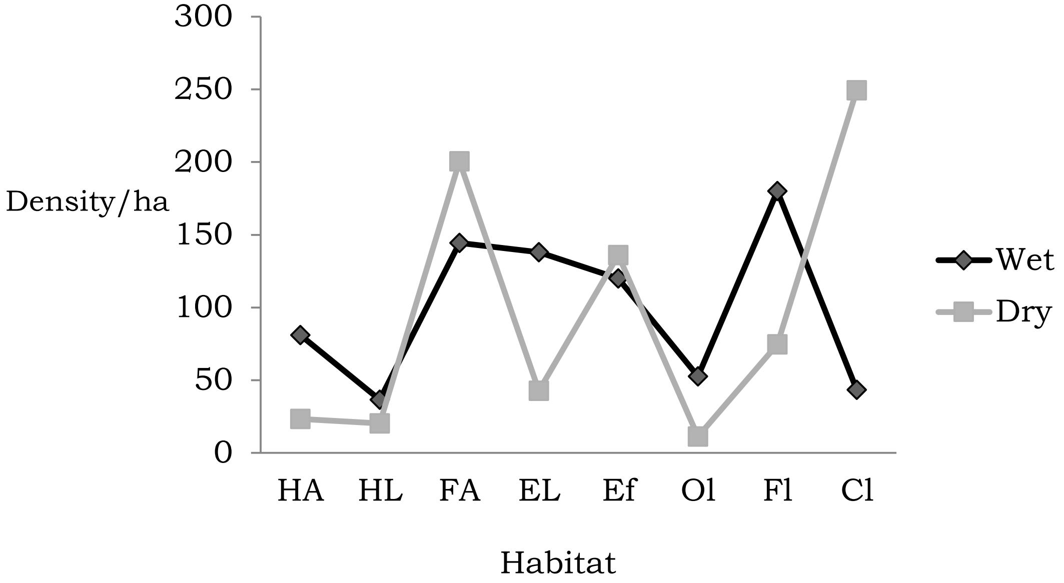


Figure 8. Variation in wet and dry season rodent population density of habitats (HA= *Helichrysum* - *Alchemilla* moorland; HL = *Helichrysum* - *Lobelia* shrub; FA = *Festuca* - *Alchemilla* grassland; EL= *Euryops*- *Lobelia* shrub; Ef = *Erica* forest; Ol= Open land; Fl= Fallow land; Cl = Cropland)

3.5.4. Biomass

The biomass contribution of each rodent species to the total community was calculated for the different habitats (Table 17). The total biomass was estimated as 84,178.99 g. Rodent biomass in the different habitats was significantly different (χ_7^2 = 87.66, $p<0.001$). *Festuca* - *Alchemilla* grassland was the richest habitat that accounted 25.65% of the biomass. The least biomass estimate occurred in open land (5.06%) habitat. Variation on rodent biomass was also noted on seasonal basis.

Table 17. Wet and dry season biomass of rodents in the different habitats

Species/mean weight (g)	Habitat	Wet season	Dry season	Total
A.ab (88.05)	HA	4001.05	1655.01	5656.06
	HL	1954.86	1086.25	3041.11
	FA	7214.45	6782.33	13996.78
	EL	3251.65	1296.10	4547.75
	Fl	460.75	1658.70	2119.45
	Cl	276.45	2856.65	3133.10
	Total	17159.21	15335.04	32494.25
L.fl (57.65)	HL	954.75	318.25	1273.00
	EL	2673.30	954.75	3628.05
	FA	663.85	600.90	1264.75
	Ef	2736.95	3118.85	5855.80
	Total	7028.85	4992.75	12021.6
M.na (55.05)	Ef	1086.25	2091.90	3178.15
	Ol	1431.30	326.20	1757.50
	Fl	1816.31	1076.45	2892.76
	Cl	814.17	3149.60	3963.77
	Total	5148.03	6644.15	11792.18
O.ty (89.64)	FA	1703.16	1613.52	3316.68
	EL	896.40	394.12	1280.52
	Ef	448.20	1075.68	1523.88
	Fl	1496.31	643.22	2139.53
	Cl	471.17	1434.24	1905.41
	Total	5015.24	5160.78	10176.02
R.ra (93.40)	Ol	2031.20	467.00	2498.20
	Fl	520.77	1027.40	3548.17
	Cl	467.00	3082.20	3549.20
	Total	5018.97	4576.60	9595.57
S.gr (95.7)	HA	1570.20	831.67	2401.80
	HL	1025.94	637.10	1663.04
	EL	614.96	402.40	1017.36
	FA	1790.80	1226.30	3017.10
	Total	5001.90	3097.47	8099.37

(A.ab= *A. abyssinicus*; S.gr= *S. griseicauda*; L.fl= *L. flavopunctatus*; M.na= *M. natalensis*; O.ty= *O. typus*; R.ra= *R. rattus;* HA= *Helichrysum - Alchemilla* moorland; HL = *Helichrysum - Lobelia* shrub; FA = *Festuca - Alchemilla* grassland; EL= *Euryops- Lobelia* shrub; Ef = *Erica* forest; Ol= Open land; Fl= Fallow land; Cl = Cropland)

More biomass was recorded during the wet (52.71%) than the dry (47.29%) season. The recorded seasonal variation was significant in open land ($p<0.001$), *Helichrysum* - *Alchemilla* moorland ($p<0.001$), *Euryops* - *Lobelia* shrub ($p<0.001$), fallow land ($p<0.001$) and *Helichrysum* - *Lobelia* shrub ($p<0.05$). In croplands, high biomass was recorded during the dry season ($p<0.001$). The biomass contribution of the rodent species differed significantly ($\chi_5^2 = 101.46$, $p<0.001$). *A. abyssinicus* was the dominant contributor (38.60%) followed by *L. flavopunctatus* (14.28%) and *M. natalensis* (14%). *S. griseicauda* contributed the least (9.62%).

3.6. Rodents from the removal trapping grids

From the removal trapping grids, 301 rodents were caught in 3,840 trap nights. The overall trap success was 7.84%. There was significant variation between wet and dry season catches ($p<0.05$). Higher proportion of rodents were caught during the wet (59.14%; $n = 178$) than the dry season (40. 86%; $n = 123$). The highest number of catches was recorded in the *Festuca* - *Alchemilla* grassland ($n = 60$) habitat, and the least was in the open land ($n = 20$). Individuals of *A. abyssinicus* occupied the highest number ($n = 105$), and the least ($n = 30$) was individuals of *S. griseicauda*.

3.6.1. Body measurement

Body weight and size measurements were undertaken from 172 rodents for taxonomic identification. Rodent species differed in body weight and size (Table 18). *S. gresicauda* was the largest of all in body weight (g) (95.70±6.87) and the smallest was *M. natalensis* (55.05±7.26). *R. rattus* was the largest of all in Head-Body (HB) size (16.80±2.64). The smallest was *L. flavopunctatus* (11.60±0.82).

Table 18. Mean body weight (in g) and size (in cm) of snap trapped rodents (the figure in parenthesis is the number of individuals)

Species	BW	HB	TL	HF	ER
A.ab (28)	88.05±9.65	14.62±0.47	13.87±0.66	2.53±0.23	1.53±2.85
L.fl (28)	57.65±4.04	11.60±0.82	5.96±1.12	1.93±0.61	1.86±0.93
M.na(25)	55.05±7.26	12.78±1.62	11.02±0.30	2.20±0.21	1.60±0.25
O.ty (23)	89.64±4.92	14.26±0.56	6.58±1.52	2.37±0.33	2.21±0.16
R.ra (23)	93.40±6.47	16.80±2.64	18.33±1.45	3.01±0.43	2.10±0.65
S.gr (21)	95.70±6.87	15.02±0.11	14.12±0.65	2.99±0.44	2.41±0.13

(A.ab = *A. abyssinicus*; S.gr = *S. griseicauda*; L.fl = *L. flavopunctatus*; M.na = *M. natalensis*; O.ty = *O. typus*; R.ra = *R. rattus*; BW = Body Weight; HB = Head Body; TL = Tail Length; HF = Hind Foot; ER = Ear)

3.6.2. Embryo count

Embryo count was carried out in 63 pregnant rodents (Table 19). The maximum number of embryo (8–12) occurred in *M. natalensis* during the wet season. The minimum embryo count (1-2) was recorded in *O. typus.*

Table 19. Embryo count of rodents (the figure in parenthesis is the number of pregnant individuals used for embryo count)

Species	Wet	Dry
A. abyssinicus	6-7(12)	5-6 (3)
L. flavopunctatus	3-6 (11)	5 (2)
M. natalensis	8-12 (7)	8-11(4)
O. typus	1-2 (7)	1-2 (4)
R. rattus	4-6 (6)	5 (3)
S. griseicauda	3-5 (3)	3 (1)

3.6.3. Stomach content analysis

Diet components of the rodent species were investigated from the stomach content of 172 snap trapped individuals (Table 20). Plant materials occupied the largest portion in the diet of the rodent species. Regardless of seasons, plant materials covered 62.08% of the food items consumed by the rodents. Leaves and grasses constituted the highest proportion (53.11%) followed by seeds (36.61%) and roots (10.28%). Monocot plants occurred more (61.79%) than dicots (38.21%). Animal matters comprised only 11.08%, of which insects were the most common prey items. These food materials were more frequent during the wet (56.99%) than the dry seasons (43.01%).

Among the rodent species, the use of animal prey differed significantly ($p<0.001$). *L. flvopunctatus* was the most important rodent species that consumed animal components with highest magnitude during both wet (41.26%) and dry (33.42%) seasons. Animal components were least consumed by *O. typus*; 3.35% during the wet and 2.93% during the dry seasons. Following *L. flvopunctatus,* animal matters were important components in the diet of *R. rattus* that on average comprised 15.17% of stomach contents.

Table 20. Diet components (in percent) of rodents (figure in parenthesis is the number of individuals)

		Seeds		Leaves and grass			Animal	Unidentified
Sp.	Season	M.cot	D.cot	M.cot	D.cot	Roots	components	components
A.ab	Wet	8.67	4.25	34.88	27.60	5.26	8.79	10.55
(52)	Dry	22.72	3.76	27.47	15.05	6.89	5.63	18.48
L.fl	Wet	10.83	13.00	12.53	6.41	2.76	41.26	13.21
(28)	Dry	15.40	12.03	10.29	5.38	4.14	33.42	19.34
M.na	Wet	20.68	10.00	26.91	15.28	7.63	10.42	9.08
(25)	Dry	25.02	5.07	16.76	15.03	12.59	8.72	16.81
R.ra	Wet	22.93	9.91	22.18	7.32	6.65	20.08	11.74
(23)	Dry	24.72	9.43	19.86	10.11	6.07	10.25	19.56
O.ty	Wet	6.02	7.03	38.41	26.70	7.49	3.35	11.00
(23)	Dry	7.23	3.72	29.46	27.49	11.83	2.93	17.29
S.gr	Wet	19.88	14.00	21.75	19.77	8.09	6.43	10.08
(21)	Dry	22.37	17.50	11.85	10.29	9.46	7.21	21.32

(M.cot = Monocot; D.cot = Dicot; A.ab = *A. abyssinicus*; S.gr = *S. griseicauda*; L.fl = *L. flavopunctatus*; M.na = *M. natalensis*; O.ty = *O. typus*; R.ra = *R. rattus*)

Leaves and grasses were the most preferred food items of *A. abyssinicus* during the wet (62.48%) and the dry (42.52%) seasons. The use of plant seeds in *A. abyssinicus* significantly differed between seasons ($p<0.05$), the consumption of plant seeds (largely monocots) were high during the dry (26.48%) than the wet (12.92%) season. Leaves and grasses during wet ($p<0.05$) and seeds during dry ($p<0.05$) seasons were preferred food items of *S. griseicauda*.

Leaves, grasses and seeds were important components in the diet of *M. natalensis*. The magnitude of leaves and grasses was higher (42.18%) than seeds (30.68%) during the wet season. During the dry season, both components were found almost in equal magnitude. Like *M. natalensis*, the diet of *R. rattus* was largely composed of leaves, grasses and seeds. These plant materials were invariably consumed during both the wet and the dry seasons. In addition, *R. rattus* supplement animal components significantly during the wet season ($p<0.05$). During both seasons, the diet of *O. typus* was remarkably composed of more leaves and grasses than other food items ($p<0.001$). Animal components were rare in the diet of *O. typus* 3.35% during the wet and 2.93% the dry season.

3.7. Farmer's perception on pest rodents

Barley (*Hordeum vulgare*), 'engido' (*Avena sativa*) and potato (*Solanum tuberosum*) are the foremost crops grown by farmers around the Choke Mountains. Nevertheless, farmers claimed pests as serious threat to crop production in the area. They mentioned rodents, insects and wild pigs as the most troublesome pest species in the vicinity. Most farmers (75.20%), however, prioritize the severity of crop damage and yield loss caused by rodents. Most of the respondents (64%) claimed the vulnerability of all crops to rodent damage. Seed predation during sowing or before seedling stage was rare in engido and barley crops (Fig. 9). Farmers noted serious damage on engido and barley crops during maturity. These crops are also vulnerabe to rodent damage during vegetative and booting stages. There was high damage on potato crop during sowing and maturity.

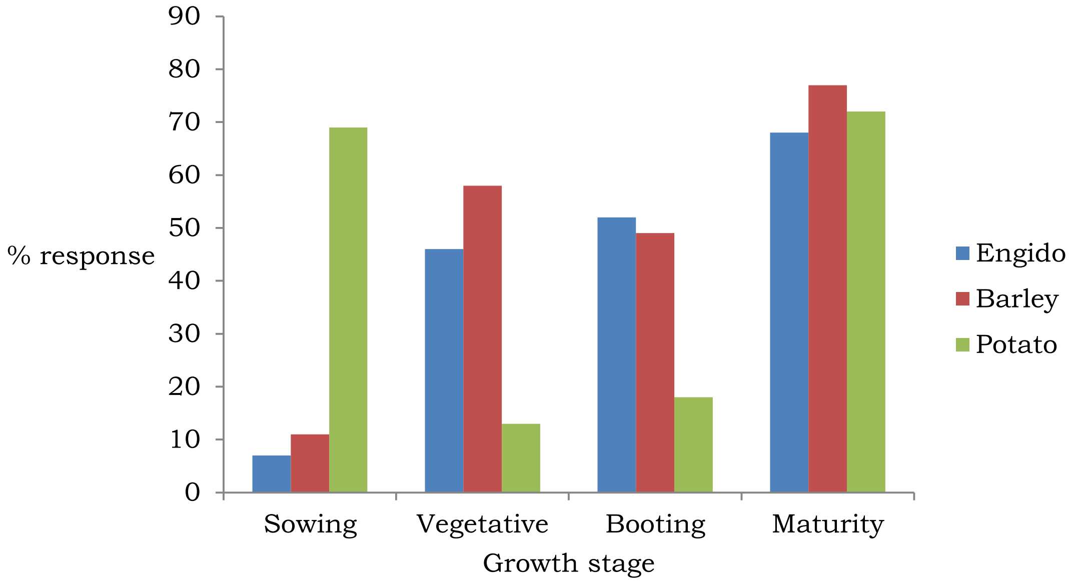


Figure 9. Response of farmers on crop growth stages susceptible to rodent damage

Information on temporal variation in damaging behavior of pest rodents were also collected. Most farmers (69.20%) responded to rodent attack on field crops during both day and night times. Most of the respondents (66%) noted peak rodent abundance and consequently more damage (62%) during the dry than the wet seasons.

On the relation between rodent abundance and intensity of crop damage, all respondents unanimously responded that intensity of crop damage depended on the density of rodents in crop fields. The responses of farmers on the frequency occurrence of rodent pest outbreaks varied significantly (F_{149} = 69.33, $p<0.001$). Most farmers were aware of regular occurrence of rodent outbreaks (every cropping season/year) in their locality (Fig. 10).

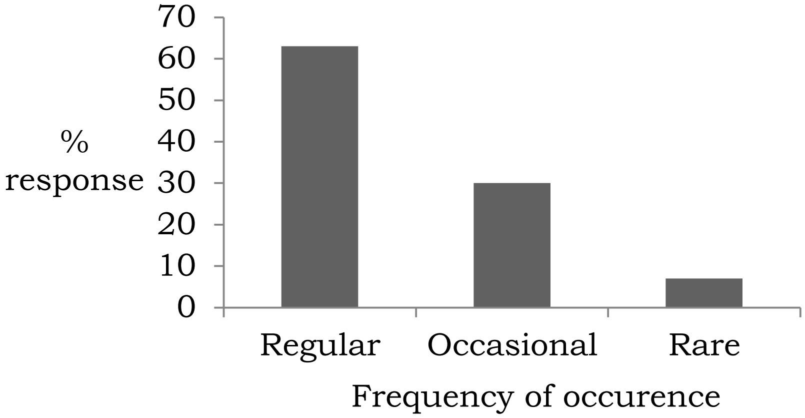


Figure 10. Response on frequency of rodent outbreak

Farmers were asked on the relations between farmland location and intensity of crop damage (Table 21). They noted rodent damage in most of the locations. However, 93.20% of the farmers claimed intense rodent damage on disjointed crop fields situated in a matrix of non-cultivated patches. The variation in number of responses on the damage level in continous monoculture farming system was not significant (F_{149} = 13.02, p>0.05). In any of the cases, farmers never acknowledged low rodent damage.

Table 21. Response on the relation between farmland location and level of damage

Farmland location	Level of crop damage		
	High	Moderate	Low
Close to vegetated natural habitats (forests, bushlands, shrublands and grasslands)	81.60	18.40	0.00
Close to settlement areas	72.40	27.60	0.00
In continuous monoculture field	48.00	52.00	0.00
Disjointed, surrounded with non-cultivated mosaic habitats	93.20	6.80	0.00

Some farmers (46%) recognized crop fields and surrounding hedges as nesting sites of rodent pests. With insignificant variation, 43.2% of the respondents noted the importance of non-cultivated hedges as nesting site for pest rodents. The variation was significant (F_{149} = 59.66, $p<0.001$) to the remaining 10.8% of respondents that granted places within crop fields as nesting sites to rodent pests. Regarding spatial distribution of rodent damage, most respondents (52%) replied high rodent damage in the interior zone of barley fields (Fig. 11). The variation between peripherial and random damage responses was not significant (F_{149} = 10.87, $p>0.05$)

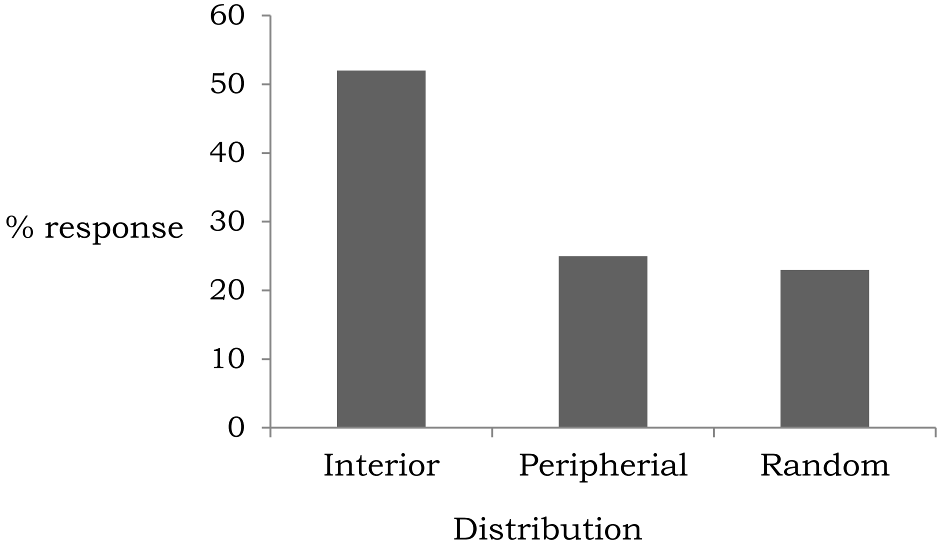


Figure 11. Response on the spatial distribution of rodent damage in barley fields

Most farmers (52%) perform the activity of sowing a particular crop type in a collective manner within a week time. Some of the respondents (32%) use collective trend of sowing practices that could extend up to two weeks. Few respondents (12%) claimed sowing calendar to extend for 3 weeks, and others (4%) for one month. Most respondents (76%) harvest within a month time depending on the seed variety used. The remaining 24% of the respondents noted the completion of harvesting within two-week time. There was variation on farm supervision practices of farmers (Fig. 12). Most farmers supervise farms frequently before harvest, but rarely after harvesting.

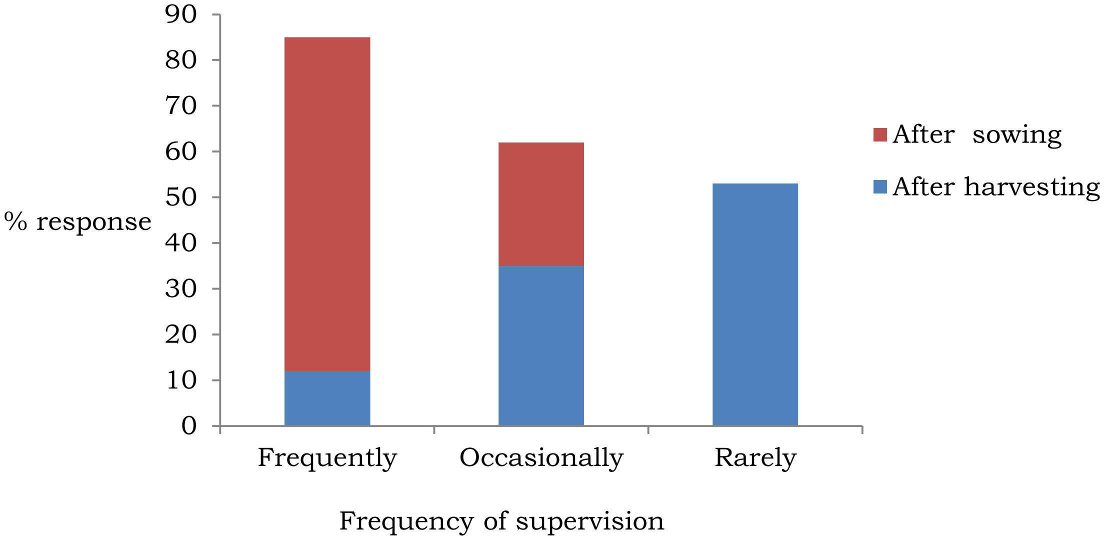


Figure 12. Farmer's response on frequency of farmland supervision

About 52% of the respondents practiced farm clearing (sanitation) from the time of land preparation to harvest. The rest of respondents (48%) practiced farm sanitation only during land preparation time. About 56% of the respondents noted the importance of farm clearing (sanitation) in reducing crop damage caused by rodents (Table 22). Similarly, most respondents (52%) recognized the contribution of early plowing (land preparation) practices in minimizing rodent damage. All the respondents (100%) unanimously claimed increased rodent damage in the presence of stone piles within and around crop fields. Similarly, the majority of respondents (84%) noted increased rodent damage during extended rain period.

Table 22. Responses (%) on the relation between farming practices and rainfall with rodent damage

	Level of crop damage by rodents			
Variables	Increased	Decreased	No relation	Unknown
Farm clearing	0.00	56.00	36.40	7.60
Early plowing	4.00	52.00	40.00	4.00
Stone pile	100.00	0.00	0.00	0.00
Extended rain	84.00	12.00	4.00	0.00
Heavy rain	48.80	51.20	0.00	0.00

Farmers use rodenticides, field sanitation and trapping techniques to control rodent damage (Table 23). About 60.8% of the respondents practice rodenticides, followed by farm sanitation (51.2%) and trapping (38%). Among the respondents, 80.4% prefer rodenticides to its effectiveness. Nevertheless, approaches of multiple techniques were less practiced, and those forms already witnessed by the respondents have poor coverage; rodenticide and trapping (24.40%), rodenticide and sanitation (16.80%).

Table 23. Responses on rodent control techniques practiced by respondents and selection of the most effective specific technique

Rodent control technique	Respondents (%) practicing the technique	The most efficient technique (%)
Trapping	38.00	13.20
Farm sanitation	51.20	6.40
Rodenticide	60.80	80.40
Trapping and sanitation	41.20	0.00
Rodenticide and Trapping	24.40	0.00
Rodenticide and sanitation	16.80	0.00

The majority of respondents (69.2%) apply rodent control techniques during maturity of the barley crop. Some of the respondents (30.8%) practiced rodent control from sowing to harvest. Nevertheless, none of the respondents witnessed application of extended preventive measures after the time of harvest. Respondents estimated an average 50% pre-harvest yield loss due to rodents in barley fields during one crop season. In terms of money, the total economic loss including expenses for rodent control purpose was estimated 1,075 birr (48.50 USD) per household.

3.8. Crop damage and yield loss from experimental barley fields

Rodent species trapped from barley crop fields and the surrounding non-cultivated matrix were composed of *A. abyssinicus, M. natalensis, R. rattus* and *O. typus* (Table 24). Rodent abundance varied in space and time. Rodents trapped in non-cultivated fields (n=435) were higher than barley fields (n=404). In both sites, high number of rodents was captured during the 2015/16 crop season. The variation on wet and dry season rodent abundance was significant (χ_1^2= 126.05, p<0.001). In cultivated fields, rodent abundance was high during the dry season (73.76%), while in non-cultivated fields, it was during the wet season (67.12%). In both habitats, individuals of *M. natalesis* and *R. rattus* were dominant.

Table 24. Rodent abundance in barley fields and adjacent fallow lands (2014/15 and 2015/16)

	Total captures							
	Barley fields				Non cultivated fallow lands			
Species	2014/15	2015/16	Tot.	R.ab	2014/15	2015/16	Tot.	R.ab
A. ab	21	46	67	16.58	48	66	114	26.21
M. na	57	82	139	34.41	55	71	126	28.97
R. ra	55	67	122	30.20	51	69	120	27.59
O. ty	33	43	76	18.81	27	48	75	16.93
Total	166	238	404	100.00	181	254	435	100.00

(A. ab= *A. Abyssinicus*; M. na= *M. natalensis*; R. ra= *R. rattus*; O. ty= *O. typus*; Tot.= Total; R.ab= Relative abundance)

The variation on rodent abundance recorded between barley fields located in a mosaic of non-cultivated fallow ($Bf_{1A,B}$) and in continuous monoculture system ($Bf_{2A,B}$) was significant (χ_1^2= 87.15, p<0.05). The overall rodent abundance in $Bf_{1A,B}$ (62.13%) was higher than $Bf_{2A,B}$ (37.87%). Trap success during 2015/16 crop year (6.61%) was higher than 2014/15 (4.61%). Trap success in different growth stages of barley crop varied significantly for all experimental fields (Table 25). The highest success rate was recorded during maturity. However, success rate differed between the two experimental barley crop fields, and the highest (17.5%) was recorded in $Bf_{1A,B}$ during 2015/16 crop year. The least trap success (0.00%) was recorded at sowing before seedling stage. During the first crop season, the same 0.00% trap success was recorded during seedling stage in $Bf_{2A,B}$. Rodent abundance at booting stage was second following maturity stage.

Table 25. Trap success and relative abundance of rodents during the different growth stages of barley crop

Crop year	Stage	% trap success and Relative abundance (in parantheses)	
		$Bf_{1A,B}$	$Bf_{2A,B}$
2014/15	Land p.	3.33 (8.60)	2.50 (10.53)
	Sowing	0.00 (0.00)	0.00 (0.00)
	Seedling	1.67 (4.30)	0.00 (0.00)
	Vegetative	5.83 (15.00)	2.50 (10.53)
	Booting	10.42 (26.88)	5.42 (22.81)
	Maturity	13.75 (35.48)	8.33 (35.09)
	After harvest	3.75 (9.68)	5.00 (21.05)
2015/16	Land p.	5.42 (9.30)	4.17 (11.90)
	Sowing	2.99 (1.74)	0.00 (0.00)
	Seedling	3.43 (2.00)	1.67 (4.76)
	Vegetative	7.92 (16.52)	3.75 (10.71)
	Booting	11.67 (24.35)	6.25 (17.86)
	Maturity	17.50 (36.52)	10.83 (30.95)
	After harvest	4.58 (9.57)	8.33 (23.81)

($Bf_{1A,B}$= Barley fields situated in matrix of non-cultivated fallow; $Bf_{2A,B}$= Barley fields in continuous monoculture farmland; Land p.= Land preparation)

Rodent damage level varied among the different stages (χ_2^2= 96. 52, p<0.001). High crop damage was recorded during maturity (Table 26). The most vulnerable were barley fields situated in matrix of non-cultivated fallow ($Bf_{1A,B}$). More damage was recorded during 2015/16 crop season (15.31%). In all experimental fields and during the two crop seasons, the least crop damage occurred during sowing, before seedling stage.

Table 26. Rodent damage rate during the different growth stages

		Estimated damage (%) from the treatment (the part open for rodents)					
Year	Type of damage	Bf$_{1A}$	Bf$_{1B}$	Av.	Bf$_{2A}$	Bf$_{2B}$	Av.
2014/15	Seed predation at sowing	0.32	0.35	0.34	0.30	0.29	0.30
	Cut tillers	8.98	8.80	8.89	7.02	7.21	7.12
	Removal at maturity	11.00	10.65	10.83	8.45	8.97	8.71
2015/16	Seed predation at sowing	0.35	0.36	0.35	0.33	0.32	0.32
	Cut tillers	11.25	11.04	11.14	10.64	10.71	10.68
	Removal at maturity	15.58	15.05	15.31	12.17	12.97	12.57

(Bf$_{1A,B}$= Barley fields situated in matrix of non-cultivated fallow; Bf$_{2A,B}$ = Barley fields in continuous monoculture farmland; Av.= Average)

Yield variation between the control and the treatment plots was considered as loss due to rodent pests (Table 27). On average, 23.50% yield loss was found in a barley field. More yield loss (28.57%) was recorded from the barley fields in matrix of non-cultivated fallow (Bf1). There was inter-annual variation of yield loss. The recorded 29.95% that occurred during the 2015/16 crop season was more devastating than the 2014/15 crop season (17.04%).

Table 27. Estimated pre-harvest yield loss of barley crop

	% barley yield loss		
Experimental field	2014/2015	2015/2016	Average
Bf$_{1A,B}$	19.57	37.57	28.57
Bf$_{2A,B}$	14.51	23.34	18.43
Average	17.04	29.95	23.50

(Bf$_{1A,B}$= Barley fields situated in matrix of non-cultivated fallow; Bf$_{2A,B}$ = Barley fields in continuous monoculture farmland)

Additional information on species diversity, similarity index, yield variation, species photo and sampling of rodent damage is given from Appendix 1-6.

4. Discussion

Ethiopian highlands support about 60% of the rodent fauna in the country. Several endemic species were recorded in northwestern, central and southeastern highland plateaus (Yalden and Largen, 1992). Eight rodent species were identified in the current study from the Choke Mountains region. This is about 10% of the total rodent species in the country. Early studies have reported variation in rodent species richness among Ethiopian highlands. More number of rodent species than the Choke Mountains was recorded in southeastern highlands, Bale Mountains (n=15) (Yalden, 1988b), and Chilalo-Galama Mountains (n=14) (Mohammed Kasso *et al.,* 2010).

In principle, species richness has strong link with habitat heterogeneity (Cramer and Willig, 2002). Large and heterogeneous habitats support distinct populations. In Ethiopia, richly vegetated habitats of the southern highlands avail more niches for several species of rodents (Rosenzweig and Winakur, 1969). Modification of the characterstic highland vegetations like montane forests noticeable in Choke Mountains could have a subsequent impact on the rodent species composition of the region. The Montane woodland in Chilalo-Galama is among the habitats most preferred by rodent species like *Stenocephalemys albipes, Arvicanthis dembeensis* and *Mus mahomet* (Mohammed Kasso *et al.,* 2010).

The rodent species recorded in the current study were also reported from other highlands in the country. Interms of species richness, it is more comparable to Guassa Mountains of central highlands (Zelalem Tefera *et al.,* 2012) and Simien Mountains National Park of northwestern highlands (Mesele Yihunie and Afework Bekele, 2012). The Choke Mountains region supports three of the rodent species endemic to Ethiopian highlands (*A. abyssinicus, O. typus* and *S. griseicauda*). Among the Ethiopian highlands, rodent species endemicity in the Choke Mountains is more comparable to Guassa Mountains (Zelalem Tefera *et* *al.,* 2012) and Simien Mountains National Park (Mesele Yihunie and Afework Bekele, 2012).

Variation in diurnal activity pattern of rodents was widely reported (Sillero-Zubiri, *et al.,* 1995; Zelalem Tefera, 2001; Mesele Yihunie and Afework Bekele, 2012). In the study area, most of the rodent species (*A. abyssinicus*, *L. flavopunctatus* and *M. natalensis*) were captured during day time. Most likely, this is an adaptation to cope up the extreme cold temperature in high altitude mountain landscapes (Zelalem Tefera, 2001). Though few individuals were captured during the night time, individuals of *R. rattus* and *O. typus* predominate during the day time. Most activity of *S. griseicauda* was restricted during the night time, eventhough few individuals from *Festuca* grassland were captured during the day time. The species may develop this behaviour in response to the day time predation risks. Individuals of this species were mostly trapped in less dense and open habitats. As noted by Zelalem Tefera (2001), thermoregulation in this species is maintained through reduced metabolism.

Along a landscape, altitudinal gradients give rise to vegetation zonation. Accordingly, rodent species exhibit distributional pattern in a mountain landscape (Clausnitzer and Kityo, 2001). In the study area, most of the rodent species were found in habitats of wide altitudinal range. Such strategy may maximiz resource use and consequently the species ecological fitness. Among recorded rodents, *A. abyssinicus* was the most widely distributed species. Individuals of this species were trapped in six habitats, from agricultural fields in the lowland to high altitude moorland (between 3200 and 3900 m a.s.l.). Similarly, a study in Simien Mountains National Park reported wide range of distribution for this species (Mesele Yihunie and Afework Bekele, 2012).

Otomys typus is the second most widely distributed species, trapped from five habitats. It was trapped from crop fields at 3200 m a.s.l. to high altitude afroalpnie grassland habitat (3700 m asl). Likewise, *O. ytpus* is reported in similar habitat features from Mount Kenya (Coe and Foster, 1972). Nevertheless, unlike *A. abyssinicus, O. typus*, was not found in the upper most moist moorland. This species may not go well with the extreme coldness and poor vegetation structure that characterize moorlands. These altitude ranges were better explored by *S. griseicauda*. The species was restricted to afroalpine habitats (between 3600 and 3900 m a.s.l.). *S. griseicauda* inhabit in similar altitudinal ranges from Bale Mountains (Yalden, 1988b; Sillero-Zubiri *et al.*, 1995).

In East Africa, *L. flavopunctatus* is reported in wide range of montane and highland habitats. The species in Ethiopia was recorded between 1500-4000 m asl (Yalden and Largen, 1992). In Choke Mountains, the distribution of *L. flavopunctatus* was exclusively limited to natural habitats between 3500 m and 3800 m asl. The current observation is in line with the reported distribution of the species in Mount Elgon (Clausnitzer and Kityo, 2001). The restriction of *L. flavopunctatus* to high altitude mountain ranges may be due to problem of habitat loss following the intensive land cover change to crop fields that occurred below 3500 m asl, which instead favoured opportunistic species.

The most known rodent pest, *M. natalensis* dominated the lower elevation human modified crop fields, fallow areas, hedge grows, and edges of the *Erica* forest. This opportunistic behaviour of the species is widely reported in other parts of the country (Yalden and Largen, 1992; Lovrechenko *et al.,* 1998; Venturi *et al.,* 2003; Tadesse Habtamu and Afework Bekele, 2008). Similarly, *R. rattus,* was restricted in distribution to human modified habitats, coexisting with *M. natalensis*. A very restricted distribution of this species was also reported in a mosaic field of farmlands, grasslands and forests (Iwala *et al.,* 1980). In the Chilalo-Galama Mountains, *R. rattus* was confined to altitude ranges between 2500 and 2800 m asl (Mohammed Kasso *et al.,* 2010).

Intruder species like *R. rattus* are opportunistic, which benefit from anthropogenic land cover changes. Agricultural activities expanded to high altitude mountain landscapes might have opened the opportunity for this commensal species further to extend its range of distribution away from human habitations.

Different authors have reported strong link between species richness and altitude. For example, Krebs, *et al.* (1998) reported decreasing vertebrate richness with elevation. While, Yalden (1988b) and Sillero-Zubiri *et al.* (1995) reported increased species richness with increasing altitude from the Bale Mountains. In Choke Mountains, more number of rodent species was recorded above the *Erica* belt in the afroalpine range between 3600 and 3700 m asl. It gradually diminished in the upper landscapes between 3700 and 3900 m asl. Hence, the current findings are support the reported negative correlation between species richness and altitude by Krebs *et al.* (1998). Nevertheless, rodent species richness along altitudinal gradients is also a function of habitat complexity and heterogeneity, not exclusively of elevation (Bond *et al.,* 1980; Happold and Happold, 1989). In Mount Elgon, Clausnitzer and Kityo (2001) reported that altitude itself is not the ultimate determinant of rodent diversity. The most important are vegetation type and habitat structure, which depend to some extent on elevation, but also on the degree of disturbance.

In principle, habitats with related vegetation and, consequently, related characteristics of food and shelter are expected to consist the same rodent communities. In the present study, the comparison between pairs of habitats resulted variation in degree of rodent community similarity, which varied from absolute similarity (100%) or community overlap to absolute dissimilarity (0%). Perfect community overlap was recorded only between *Festuca* grassland and *Euryops lobelia* shrub, which actually differed in plant species composition and level of disturbance. Thus, community similarity in the current situation is not only a function of similarity in resource characteristics, but also the distance and presence of convenient dispersal routes between habitats. In addition, despite fluctuations in abundance and within habitat distribution, the rodent species composition in each habitat has not been altered even at times of critical resource shortage. The noticeable coexistence among rodent species may come from strategies of controlled reproduction rate and changes in space and resource use.

In 12,096 total trap nights, 1,473 individual rodents were captured, of which 189 were recaptures. Regardless of seasons, the combined trap success was 10.62%. Success rates more higher than the present study have been recorded in different parts of the country: 19% in highlands of south Goba (Yalden *et al.,* 1996) and 18.7% in Harenna Forest (Yalden, 1988a). The variation in the recorded success rate may originate from differences in habitat quality and level of management. Habitat quality in Choke Mountains has been under progressive trend of degradation due to livestock grazing pressure. A study from Hunkolo, southeast Ethiopia reported rodent abundance affected by livestock grazing pressure (Zerihun Girma *et al.,* 2012).

In this study, rodent species differed in relative abundance. The grass rat, *A. abyssinicus* was the most abundant of all rodent species. It was the most adaptable rodent species that fits and exploits resources from most habitats, including crop fields at times of critical resource shortage. The adaptive flexibility to confine in most habitats of different management levels is an important survival strategy that enhanced the abundance of the species. Following *A. abyssinicus*, *L. flavopunctatus* and *M. natalensis* were the important rodent species in abundance. Similarly, *L. flavopunctatus* was the most abundant species in Chilalo-Galama Mountains (Mohammed Kasso *et al.,* 2010). The population of *L. flavopunctatus* is highly concentrated in the *Erica* forest. It prefers humid habitats, and may benefit from the minimum predation stress and rich insect preys in forest habitats.

Temporal and spatial fluctuations in the rodent populations was noted in the current study. Rodent abundance and trap success rate were highest during the wet season. Similar trend of rodent abundance was reported in Simien Mountain National Park (Mesele Yihunie and Afework Bekele, 2012). As reported by Oguge (1995) and Martin (1998), seasonal change in availability of food and cover might have resulted in periodic fluctuation on rodent abundance. Spatial variation in rodent abundance indicates variability in quality and degree of disturbance among habitats. The rodent species in the study area remarkably preferred few potential habitats among others. This is related with the inherent strong link between rodent species abundance and habitat quality, provision of sufficient food and cover (Lin and Batzli, 2001; Pusenius and Schmidt, 2002). Likewise, in most habitats, there was significant variation on wet and dry season abundance of rodents that indicated seasonality to access for substantial food and cover.

In Choke Mountains, grassland habitats dominated by tall *Festuca* grass were the most preferred habitats with the highest record of rodent population. This strengthens previous reports in the Simien Mountain National Park (Mesele Yihunie and Afework Bekele, 2012) and in Mount Klilimanjaro (Mulung *et al.,* 2008). Furthermore, *Festuca* grassland was one of the most important habitats in rodent species richness. Different studies have noted the positive correlation between availability of food resources and cover with abundance of rodent species (Tadesse Habtamu and Afework Bekele 2008; Marcello *et al.,* 2008). In the current situation, *Festuca* grassland mountains are well protected from livestock grazing and any other form of resource exploitation, thus the year round availability of forage and dense cover were important qualities that rodents demand and already access. Relative abundance and species diversity was very low in open grazing fields. Vegetation growth and cover in this habitat is highly suppressed through grazing pressure, which made the place less comfortable to rodents in securing forage and potential cover from predators. Following the *Festuca* grassland habitat, rodent population abundance was highest in the *Erica* forest. Like *Festuca* grasslands, the *Erica* forest is protected from any form of human use, thus it contributed a significant role in maintaining high and stable rodent population.

Forests are among the most important habitats in rodent species assemblage and diversity associated with the diverse microhabitat conditions apparent in rich forests (Pereyra *et al.,* 2003). However, the *Erica* forest in the current study area was not good in terms of rodent species diversity. The rodent community in this forest has limitations in both species richness and evenness components of diversity. Potentially, this habitat provides promising aerial cover for rodents, however, the entire forest is dominated by *Erica arborea* and associated simple plants, with minor grass and herb assemblage underneath, which resulted in less heterogeneous environment for rodents. In species rich forests of Arbaminch (Demeke Datiko *et al.,* 2007) and Alatish National Park (Tadesse Habtamu and Afework Bekele, 2008), rodent species diversity was high. Despite the need for detailed investigations, it is likely to speculate local extinction of forest specialist rodents following the past destruction on montane woodland and *Erica* forests.

Crop fields were resource source to a large population of pest rodents on seasonal basis. Rodent abundance in crop fields was peak during the dry season when crop fields possessed with quality food and promising cover from predators (Demeke Datiko and Afework Bekele, 2013). Moreover, this could be related with the dry season coincidence in availability of quality food from crop fields and resource exhaustion in most wild habitats. Nevertheless, the importance of crop fields decreased and rodent abundance gradually declined after harvest due to predation pressure (Hansson, 1999; Meheretu Yonas *et al.,* 2014). As reported by Workneh Gebresilassie *et al.* (2004), farmlands provide essential resources better than grasslands before harvest.

According to Guttinger *et al.* (1998), grazing has a detrimental effect on rodent community through food competition, destruction of shelters, and increasing predation risk. The findings in the current study are in line with this fact. Habitats under livestock exploitation (open land, *Helichrysum* - *Alchemilla* moorland, *Helichrysum* - *Lobelia* and *Euryops* - *Lobelia* shrubland) were less important to rodents especially during the dry season. This is a response to habitat quality degradation and increased resource compeitition pressure (Olson and Brewer, 2003). As noted by Makundi *et al.* (2009), population size of small mammal species fluctuates greatly because of change in quality and quantity of resources in the environment. Therefore, uncontrolled livestock grazing could aggravate resource depletion there by affecting rodent population abundance. Similar observations were reported in livestock dominated habitats (Ryan, 1999; Viall *et al.,* 2011). Rodent species abundance in this study was a matter of habitat quality, which is related to resource abundance and level of disturbance.

In Choke Mountains, following human modified crop fields and fallows, high altitude afroalpine grassland and shrubland habitats were good in rodent species diversity. For instance, the rodent community in the afroalpine *Euryops-Lobelia* shrub was composed of 66.66% of the total rodent species. Rodent diversity, evenness and plant species diversity was good. Despite intense livestock pressure, rodent species composition has not been altered in this habitat. Nevertheless, in terms of rodent abundance, afroalpine shrubs were not appreciated as discussed above. Instead of species diversity, there was strong link between rodent abundance and level of habitat disturbance. The result corresponds with previous findings from fragmented highland landscape of Isthmus, Mexico (Barragan *et al.,* 2010). The authors noted strong link of rodent diversity with the level of landscape heterogeneity, but not with level of disturbance. However, the distribution of habitats on the landscape, the presence of plant corridors and the differing displacement capacity of the animals allowed for the presence of generalist and specialist species in most landscapes units. This resulted in similar abundances among units and the presence of rare species.

At macrohabitat level, species richness is maintained by the presence of different habitats that satisfy specific requirements. The relative abundance and proportion occurrence of rodent species indicated preference of few potential habitats among others. The recorded trap successes similarly reflected differential macrohabitat use by rodent species, for it directly depends on local rodent densities (Traba *et al.,* 2010). Accordingly, *Festuca* grassland was the most preferred habitat by *A. abyssinicus*. Above all, the population of *A. abyssinicus* did not show significant seasonal crash in this habitat. The second most preferred habitat by *A. abyssinicus* was the moist *Helichrysum* - *Alchemilla* moorland. However, the population of *A. abyssinicus* declined significantly in *Helichrysum* - *Alchemilla* moorland during the dry season. Even though mountain grassland and herbs were the ideal natural habitats, population of *A. abyssinicus* were seasonally common in human modified habitats, mainly in crop fields. At microhabitat level, the most preferred microhabitat condition by *A. abyssinicus* was tall grasses and herbs.

Stenocephalemys griseicauda was exclusively confined to high altitude afroalpine grasses, shrubs and moorland. It is an afroalpine specialist similarly reported in Chilalo-Galama Mountains (Mohammed Kasso *et al.,* 2010). The upper moistt *Helichrysum* - *Alchemilla* moorland was the most preferred habitat by *S. griseicauda*. The species also occurred more in *Festuca* grassland than *Helichrysum* - *Lobelia* shrubland. The use of both *Helichrysum* - *Alchemilla* and *Festuca* grassland habitats did not show significant variation on seasonal basis. Most frequently, *S. griseicauda* was caught in microhabitats of grass and herb assemblage; however, the variation with open shrubs was not statistically significant. *S. griseicauda* preferred less dense vegetation with aerial cover.

The populations of *L. flavopunctatus* inhabit both afroalpine and *Erica* forest habitats. Nevertheless, the relative occurrence of this species predominates more in the forest than the afroalpine shrubs and grassland environments. *L. flavopunctatus* may benefit from the rich insect prey and trustworthy shelter in the *Erica* forest. In fact, following the forest habitat, the species preferred *Euryops* - *Lobelia* shrubland. Including the *Erica* forest, human modified low elevation habitats were important habitats to *M. natalensis*. However, compared to the open livestock dominated grazing land, the species preferred *Erica* forest, fallowland and crop fields. *M. natalensis* significantly used cropland during the dry than the wet seasons. However, the variation in *Erica* forest preference was not significant. *L. flavopunctatus* and *M. natalensis* significantly occurred in microhabitats of woody vegetation with moderate density and ground cover of short grasses and herbs.

Members of the genus *Otomys* are highly adapted herbivores, living exclusively on grass and herbs (Perrin and Curtis, 1980). In this study, *Festuca* grassland was the prime habitat preferred by *O. typus* with recorded population almost stable during both wet and dry seasons. The result corresponds with previous studies in Simien Mountain National Park (Mesele Yihunie and Afework Bekele, 2012) and Mount Kenya (Coe and Foster, 1972). Croplands, fallow lands and the *Erica* forest were seasonally preferred habitats. The population used croplands during the dry and fallowlands during the wet seasons. *O. typus* preferred microhabitat features of tall grasses and herbs. *R.rattus* was exclusively restricted to human modified habitats. Significantly, the species preferred more fallowland and croplands than the open pastureland. Fallowland habitats have year round importance to the species. Nevertheless, it predominantly used croplands during the dry and open land habitats during wet season. Most frequently, *R. rattus* was trapped in microhabitats of grasses and herbs of moderate density.

In this study, the total number of live trapped rodents was 1172. Among this, 16.13% were recaptures. The highest of all catches was recorded during the wet season trapping session in September, and the least was during the dry season in March. The population was male biased in sex distribution. Such type of observation was recorded in previous studies (Manyingerew Shenkute *et al.,* 2006; Mesele Yihune and Afework Bekele, 2012). Variation in range of field exploration between male and female rodents as reported by Odhiambo and Oguge (2003) and the intersexual variation in parental investment recognized in mammals could affect the chance of trappablity in adult female rodents. For instance, females have restricted movement for activities related to lactation and nursing (Delany, 1986). Despite the dominance of adults, populations of live trapped rodents comprised of all age groups. Juveniles were the least trapped. Almost similar percent composition of the different age groups was reported from Chebera-Churchura National Park (Demeke Datiko and Afework Bekele, 2013). According to Workineh Gebresilassie *et al.* (2006), unlike juveniles, adults and sub-adults have wider home ranges, thus increased chance of trappability.

Reproductively active male (scrotal testes) and female (perforated vagina) adults were caught in all trapping sessions even though the magnitude increased between June and September. Nevertheless, reproductive activity was triggered by the onset of the long rain season and the subsequent move in the abundance of quality food resources. In Nechisar National Park, Sintayehu Workeneh *et al.* (2011) reported similar observations. As reported by Whitman and Haugse (1972), compared to spring precipitation, summer precipitation better predicts total forage production. As a result, young rodents occurred in all wet season trapping sessions, and their number showed progressive increment from June to September, but new recruitment decreased from

December to March. Demeke Datiko *et al.* (2007) reported similar result from Arba Minch forest and farmlands. This periodic change in rodent population structure between June and December was signal to hot breeding activities, though limited number of pregnant individuals was found in March indicating extended breeding period in few. This observation corresponds with previous findings (Afework Bekele, 1996a; Marcello *et al.,* 2008).

The first juveniles and sub-adults of *A. abyssinicus* were caught in August and September, respectively, and extend to January. Breeding activity commences late in August and most likely extend to December. More number of pregnant individuals of *L. flavopunctatus, M. natalensis* and *S. griseicauda,* were captured in June, indicating breeding activity that begun following the rain early in June. Similarly, breeding that commenced following the rain in June extend to March in *O. typus* and *R. rattus*. In general, new recruitments in the population increased from June to December, which indicated reproduction driven seasonal rodent population growth. Therefore, density independent factors were critical for the population. On the other hand, reduced reproductive effort during the dry season reduced the cost of reproduction and at the same time increased the probability of individual survived over the coming breeding season. In such less stable ecosystem, rodents were able to control population pressure and consequently ecological problems linked with density dependent factors by altering reproduction rate.

The minimum number estimate of rodents from all trapping sessions was 2816. The mean record of rodent population number was high in *Festuca* grassland, *Erica* forest and *Euryopys-Lobelia* shrub. The overall rodent population density in the study area was 110.84 individuals/ha. This is very high when compared to the report of 21 ha^{-1} by Sintayehu Workeneh *et al.* (2011). Very higher records were reported from different studies in Africa. Dieterlen (1967) found 236–361 individuals ha^{-1} in Congo, and Delany and Kansiimeruhanga (1970) recorded 160 individuals ha^{-1} in Uganda. Rodent population density was significantly high in cropland, *Festuca* grassland, fallow land and *Erica* forest. In population ecology, this can be explained as response to the apparent local variation in resource distribution and abundance among habitats.

In habitats open for ungulates, rodent population density was very low indicating negative interaction between the grazing communities. This is an implication for the presence of exploitation competition, which emanated from diet overlap and limited supply of shared resources (Tokeshi, 1999). In this study, progressive enrichment on rodent population densities was recorded following the wet season. Such temporal density changes may come from the usual trend of periodic improvement in abundance of food resources and subsequent enhancement in rodent population activities. Likewise, increase in population density with increased food abundance was evident from different studies (Smith, 1971; Hansen and Batzli, 1978; Marcello *et al.,* 2008).

Animal biomass has strong link with population density and community production at different levels. It is an important parameter to evaluate both primary and secondary production of a community. In this study, the estimated rodent community biomass was 84178.99 g. The highest contribution was from *Festuca* grassland habitat. As noted by Happold (1974), this is due to the rich food resources from grasslands. In the study area, *Festuca* grassland is the most resourceful and stable habitat for the grazing rodent community especially secluded from competing ungulates. The overall rodent biomass was better during the wet than the dry season, and corresponds to previous reports in different parts of the country (Demeke Datiko *et al.* 2007; Habtamu Tadesse and Afework Bekele, 2008). From the current observations, primary production of habitats was one of the ecological factors that affect rodent community biomass, either directly through an increase in seeds, fruits, or indirectly through insects. The reduced rodent biomass in most habitats coupled with the apparent seasonal crash might have influenced the richness and abundance of specialist predators, which are very common in most of the Ethiopian highlands.

The stomach contents of 172 snap trapped rodents were examined for diet study. The bulk of the diet in the study area was composed of plant materials (leaves, grasses, seeds and stem). Regardless of seasons, they occupied the largest part of contents in the stomach. The result supports the report of Iwala *et al.* (1980) following a study on diet and foraging ecology of African rodents. The use of animal food components in most rodent species was less frequent, and insects were the only prey items identified. As noted by Booth (1960), rodents generally prefer plant matter to any other category of food. Leaves and grasses were the most preferred food items for *A. abyssinicus* during both wet and dry seasons. In *A. abyssinicus*, the tendency of seed predation (largely monocots) was higher during the dry than the wet seasons. Leaves, grasses and seeds dominated the diet of *S. griseicauda*. Nevertheless, the use of these diet sources varied on seasonal basis; leaves and grasses during the wet and seeds during the dry seasons.

Animal components were rare in the diet of *O. typus*, during both seasons. The diet of *O. typus* was composed of leaves and grasses compared to other food items. On Mount Elgon, *O. typus* preferred most shoots and leaves of *Festuca pilgeri* (Clausnitzer, 2000). Leaves, grasses and seeds were important components in the diet of *M. natalensis*. During the wet season, the use of leaves and grasses was more frequent than seeds, but both components were used almost in equal magnitude during the dry season. Like *M. natalensis*, the diet of *R. rattus* was largely composed of leaves, grasses and seeds. The species used these plant materials invariably during both wet and dry seasons. In the diet of *R. rattus,* insect preys were significant during the wet season. Similarly, Fall *et al.* (1971) observed the diet of *R. rattus* predominated with plant food although varieties of insects were used. Among species, variation in resource use has great ecological significance, thus some of the observed resource use differences could enhance coexistence among rodent species. In addition, seed predation by rodents witnessed in the current study magnifies their ecological roles in diversification and dispersion of the afroalpnie plant species. Nevertheless, inclusion of crop seeds observed in the diet of few rodent species is a signal to the presence of conflict with humans.

In relation to this, further evidences were collected through attitude survey and experimental studies in crop fields. People in Choke Mountains vitally depend on crop production for livelihood. They grow barley, wheat and potato in plot of land. Nevertheless, crop production accrording to farmes is under serious challenge by field pests. Crop fields often harbour variety of wildlife species, which results in crop damage (Wywialowski, 1994). In the study area, farmers particularly ranked rodents as number one pest in crop fields. Similar perception was reported in central Ethiopia (Makundi *et al.,* 1999) and northern Ethiopia (Meheretu Yonas *et al.,* 2010).

Globally, different rodent species are recorded as crop pests, which result in substantial agricultural losses each year (Witmer *et al.*, 1995). In its 2002 report, FAO notified vulnerability of cereal crops to many rodent pest species, which constitute the largest part of the total area used for agriculture in the world. Farmers in the study area reported variety of rodents in crop fields, which they claim of different morphology from those in residential areas. During the actual field study, *M. natalensis*, *A. abyssinicus*, *O. typus* and *R. rattus* were recorded from experimental crop fields. An earlier study reported species of *Arvicanthis* and *Mastomys* from maize fields in central Ethiopia (Afework Bekele and Leirs, 1997) and in wheat and barley fields in northern Ethiopia (Meheretu Yonas *et al.,* 2014). In this study, *M. natalensis* and *R. rattus* are the dominant rodent pest in barley fields with highest relative abundance. Relative abundance of *A. abyssinicus* was the least of all. This is consistent with the reported abundance of *M. natalensis* and *A. abyssinicus* from farmlands in Alleltu, Ethiopia (Manyingerew Shenkute *et al.,* 2006). More indivisuals of *A. abyssinicus* were recorded in adjacent non-cultivated area, suggesting its great reliance on natural habitats.

Most respondents recognized temporal variation in rodent abundance from crop fields. They marked increased rodent abundance and consequently high crop damage during the dry season, when crops mature. The same situation was recorded in the field study. In all experimental fields, rodent damage follows crop phenology. Highest damage was recorded during maturity of a barley crop. At the same time, it was at this stage where the highest trap success was found. This is consistent with a study in farmlands of Alleltu Woreda, Ethiopia (Manyingerew Shenkute *et al.,* 2006). At this stage, rodents were attracted to crop fields to benefit from easilly accessible ripened barley seeds. Barley crops reach maturity early in the dry season where food resources in surrounding natural fields are in short supply to rodents. Makundi *et al.* (1999) reported damage during maturity of maize crop by *M. natalensis* in Tanzania. In maize fields from Ziway, Ethiopia, Afework Bekele *et al.* (2003) reported significant rodent damage after seedling stage. Similarly, in this study, vegetative and booting stages were also susceptible to rodent damage. However, seed predation at sowing was rare. Probably, rodents in the current situation preferred growth stages that provide substantial cover besides food source. Thus, seed predation at sowing has least effect on final yield loss.

Rodent outbreak according to most respondents is a regular event in the locality. This is consistent with the reponse of farmers in Tanzania (Makundi *et al.,* 2009). Afework Bekele and Leirs (1997) noticed rodent outbreaks driven by climatic fluctuations and environmental variations. Inter-annual variability in rodent abundance was recorded from experimental crop fields. Rodent abundance and crop damage were more during 2015/16 crop season. Extended rain period that was evident during the crop year could increase survivors during the dry season, and at the same time may favour reproductively active rodents to produce more young ones. Farmers in the locality also witness high crop damage during years of unusually extended rain period. Favourable conditions would lead to high populations that escape the normal density dependent regulation leading to population eruption (Pech *et al.*, 1999).

Most respondents recognized no spatial variation in rodent damage intensity. They report high rodent damage regardless of crop field locations. In experimental fields, rodent damage was recorded more from crop fields located in a mosaic of natural grass fields and fallows than those located in continous monoculture fields. Large monocultures in Tanzania experienced less rodent damage than small fields that are interspersed with fallowland (Myllymäki, 1987). Capture rates were higher in the surrounding permanent grass areas than the crop fields, suggesting that these grassy areas serve as refugia for rodents. Similarly, Key (1990) and Redhead and Saunders (1980) reported a strong correlation between rodent damage caused to maize and sugar cane and the presence of uncultivated land. Permanent vegetation close to crop fields could host more number of rodents, which seasonally invade crop fields and potentially cause severe damage.

Respondents reported variability in spatial distribution of rodent damage in a crop field. In experimental fields of continous monoculture system, rodent damage predominates in the interior zone. While in crop fields situated adjacent to fallow area, rodent damage was not localized, it occurred in all parts including edges. Farmland supervision is practiced inconsistently, and only during preharvest period. Limitations in farm supervision and rodent survey may create good opportunity for eruption of rodent pests in crop fields.

Many pest problems can arise under no-till farming system; however, the system is not common in the current situation. Most respondents know that farm clearing (sanitation) and early plowing (land preparation) practices reduce crop damage that can be caused by rodents. In fact, some of the respondents lacked awareness on the relations. Plowing fields disrupt burrows and remove gound cover. When the ground is not plowed and crop residues were maintained, the potential for substantial increase populations is high with subsequent crop damage (Johnson, 1987; Bourne, 1999). All the respondents recognized increased rodent damage in the presence of stone bunds in and around crop fields. In the study area, stone bunds are very common in crop fields and adjacent to non-cultivated landscapes for soil and water conservation purposes. Nevertheless, as noted by farmers, they became important sheltering sites to rodents. Farmers were aware on the relations between rodent abundance and rainfall intensity and seasonality. Most of the respondents have observations of reduced rodent abundance during heavy rain and outbreaks during extended rain season. Probably, high flooding could abandon burrows of rodents and kill less active juveniles subsequently affecting rodent population density.

Most respondents perceived crop damage by rodents is uncontrollable, even with application of different control techniques. In North America, herbicides and clean farming practices were reported to be effective (Hines and Hygnstrom, 2000). Field sanitation using herbicides, plowing, and burning prevent fields from developing vegetative cover that rodents need for year-round food and shelter. Of all techniques, rodenticide chemicals are more prefered by farmers for their effectiveness. Nevertheless, they noted the economic cost of rodenticide chemicals as a major constraint. Similarly, earlier study by Makundi *et al.* (1999) reported that rodent control by farmers in Ethiopia and Tanzania is based on economic reasons. In Tanzania, however, farmers receive free supplies of rodenticides from the government during outbreaks. Therefore, economic cost for rodent control techniques may discourage farmers, and could be the major source for their desperate perception towards rodent control.

In general, limitations were observed in rodent control strategies by farmers. Despite a range of control techniques, application of multiple techniques were less practiced, and those witnessed by respondents had poor coverage. Simultaneous use of more than one control techniques in a crop field is a more preferred approach. Further more, application of rodent control techniques is undertaken at individual level and mainly during maturity of barley crop. The problem with farm sanitation practices is that it is an activity restricted by most during land preparation period. Only few respondents practiced farm clearing as year round activity. Pest species can get sufficient shelter if shrubs and outcrops are not cleared around farmlands (Manyingerew Shenkut *et al.,* 2006), subsequently enhancing attractiveness and accessibility of the fields for rodents (Brown *et al.,* 2001). Rodent control activities are more effective when practiced in a collective way and a consistent manner. None of the respondents practiced preventive measures after harvest. Nevertheless, application of control measures before planting reduced rodent infestation (Makundi *et al.,* 1999).

Farmers reported 50% pre-harvest yield loss of barley crop due to rodent pest. In the highlands of Tigray, farmers estimated 8.9-44% preharvest loss in annual cereal production (Meheretu Yonas *et al.,* 2010). In terms of money, the total economic loss including rodent control expenses is more than 1,075 birr per household annually. In experimental fields, on average 23.5% barley loss was recorded annually. The damage level is comparable with 20% (Goodyear, 1976) and 20-26% (Afework Bekele *et al.,* 2003) annual yield loss recorded in Ethiopia. The highest (29.95%) damage record during 2015/16 crop year was comparable with 34% loss of barley reported in western Kenya following an outbreak (Taylor, 1968).

People in this highland are small landholders, and above all suffer declined land productivity due to problem of soil degradation. Therefore, the estimated annual economic loss caused by rodents is a huge disaster for a householder where crop production is the sole source for livelihood. According to Makundi *et al.* (1999), the damage to crops by rodents and the subsequent yield losses at harvest is economically significant since farmers in Ethiopia are small landholders with little alternative income.

5. Conclusion and Recommendations

In this study, rodent species composition, diversity and abundance in Choke Mountains were found to be comparable with other studies. However, in species richness and diversity, it was less comparable to those rich highlands in south and southeast regions of the country. Choke Mountains has suffered huge biodiversity crisis due to uncontrolled anthropogenic resource exploitation and land cover change Currently, problems of habitat loss and fragmentation, resource competition by grazing ungulates, are major threat to rodents. Irregularities in distributional patterns of species, demographic flactuations and conflict with humans noticed currently are reflections to the apparent disturbance pressure and ecosystem degradation.

Absence of large and medium sized mammals symbolic to afroalpine systems might be due to local extinction caused by previous vegetation distruction. Aside from maintaining endemicity, protection of the existing rodent species has immense ecological importance including restoration of the characterstic highland vegetations. Nevertheless, if things keep on with no reservations, the crisis in the future will be much worst, follwoing inevitable human population growth and subsequent demand for more farmland and other resources. Globally, agricultural intensification is one of the greatest anthropogenic risks to animal conservation (Krebs *et al.,* 1999; Chamberlain *et al.,* 2000). More than half of the recorded rodent species were found as serious crop pest, which cause great damage on field crops. The recorded 23.5% yield loss together with economic expenses for rodent control is catastrophic to people with less alternative income source.

From the findings, the researcher has come up with a set of recommendations that may reduce problems of biodiversity crisis and crop damage in Choke

Mountains. Therefore, to concerned stakeholders (Administrators, Agricalturalists, Conservationists and Environmentalists) the researcher recommends the following:

- Protection and rehabilitation activities are critical to rescue existing biodiversity and maintain the ecosystem.
- Protection of grasslands already practiced in few mountain landscapes should be expanded as they are ideal habitats to endemic rodent species.
- Reduction of grazing livestock density would enhance restoration, and at the same time reduce human-rodent conflict.
- Farming should be in a continuous monoculture system, instead of isolated small patch.
- Farming close to wild areas should be minimized.
- Rodent control activities should be carried out in a collective manner
- Multiple rodent control techniques should be practiced widely.
- Includig fallows and hedges, farm clearing or sanitation activities should be consistent beginning after a harvest crop residue.
- Collective rodent control campaign between February and May would substantially diminish reproductively active rodents during the coming rain season.
- Technical experts should get involved in selection and application of rodenticides
- Application of rodenticides should also include non-cultivated rodent sheltering habitats adjacent to crop fields.
- To maximize success and minimize economic expens, application of rodenticides should be during high rodent population density.
- Before application of rodenticides, pre-test on rodent density and location are very important.
- Planting trees along edges of crop fields would enhance rodent predation by birds.

- Applying traditional rodent trapping technique, “Difit”, which is very common in Menz area is also important.

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7. Appendix

Appendix 1. Equipment and chemicals that were used both in field and in the laboratory were the following:

- Sherman's live traps
- Snap traps
- Spring balance
- Polythene bag
- Dissecting kit
- Formalin
- Dissecting microscope
- Peanut butter
- Scissors

Petridish
Tent
Matress
Sleeping bag
GPS
Wire mesh
Wooden and metal peg
Paper card
Scotch tape

Ink
Rolling meter
Specimen tube
Glove
Data sheet
Camera

Appendix 2. Shannon-Wiener species diversity index at different altitude

Altitude	Species	No.	p_i	$\ln p_i$	$p_i \ln p_i$
3200	A. ab	35	0.190	1.660	0.316
(Fl)	M. na	65	0.350	1.050	0.367
	O. ty	24	0.130	2.040	0.265
	R. ra	60	0.326	1.109	0.366
					∑ = 1.314
3200	A. ab	49	0.247	1.398	0.345
(Cl)	M. na	61	0.308	1.178	0.363
	O. ty	32	0.162	1.820	0.295
	R. ra	56	0.283	1.262	0.357
					∑= 1.360
3300	M. na	49	0.521	0.652	0.339
	R. ra	45	0.479	0.736	0.352
					∑= 0.691
3500	L. fl	124	0.541	0.614	0.332
	M. na	75	0.328	1.114	0.366
	O. ty	30	0.131	2.032	0.266
					∑= 0.964
3600	A. ab	56	0.311	1.168	0.363
	S. gr	24	0.133	2.017	0.268
	L. fl	77	0.428	0.849	0.363
	O. ty	23	0.128	2.056	0.263
					∑= 1.257
3700	A. ab	211	0.670	0.400	0.268
	S. gr	32	0.102	2.282	0.233
	L. fl	22	0.070	2.659	0.186
	O. ty	50	0.159	1.839	0.292
					∑= 0.979
3800	A. ab	82	0.603	0.506	0.305
	S. gr	21	0.154	1.871	0.288
	L. fl	33	0.243	1.415	0.344
					∑= 0.937
3900	A. ab	84	0.613	0.489	0.300
	S. gr	53	0.387	0.949	0.367
					∑= 0.667

Appendix 3. Simpson's species similarity index at different altitude

Altitude/Hab.	Species	No	pi	pi^2	$\sum pi^2$	1-D
3200 (Fl)	A. ab	35	0.190	0.036	0.285	0.715
	M. na	65	0.350	0.123		
	O. ty	24	0.130	0.017		
	R. ra	60	0.330	0.109		
3200 (Cl)	A. ab	49	0.247	0.061	0.262	0.738
	M. na	61	0.308	0.095		
	O. ty	32	0.162	0.026		
	R. ra	56	0.283	0.080		
3300	M. na	49	0.521	0.271	0.500	0.500
	R. ra	45	0.479	0.229		
3500	L. fl	124	0.541	0.293	0.418	0.582
	M. na	75	0.328	0.108		
	O. ty	30	0.131	0.017		
3600	A. ab	56	0.311	0.097	0.314	0.686
	S. gr	24	0.133	0.018		
	L. fl	77	0.428	0.183		
	O. ty	23	0.128	0.016		
3700	A. ab	211	0.670	0.449	0.489	0.511
	S. gr	32	0.102	0.010		
	L. fl	22	0.070	0.005		
	O. ty	50	0.159	0.025		
3800	A. ab	82	0.603	0.364	0.447	0.553
	S. gr	21	0.154	0.024		
	L. fl	33	0.243	0.059		
3900	A. ab	84	0.613	0.376	0.526	0.474
	S. gr	53	0.387	0.150		

Appendix 4. Barley yield variation between the control and treatment plots during the two crop seasons

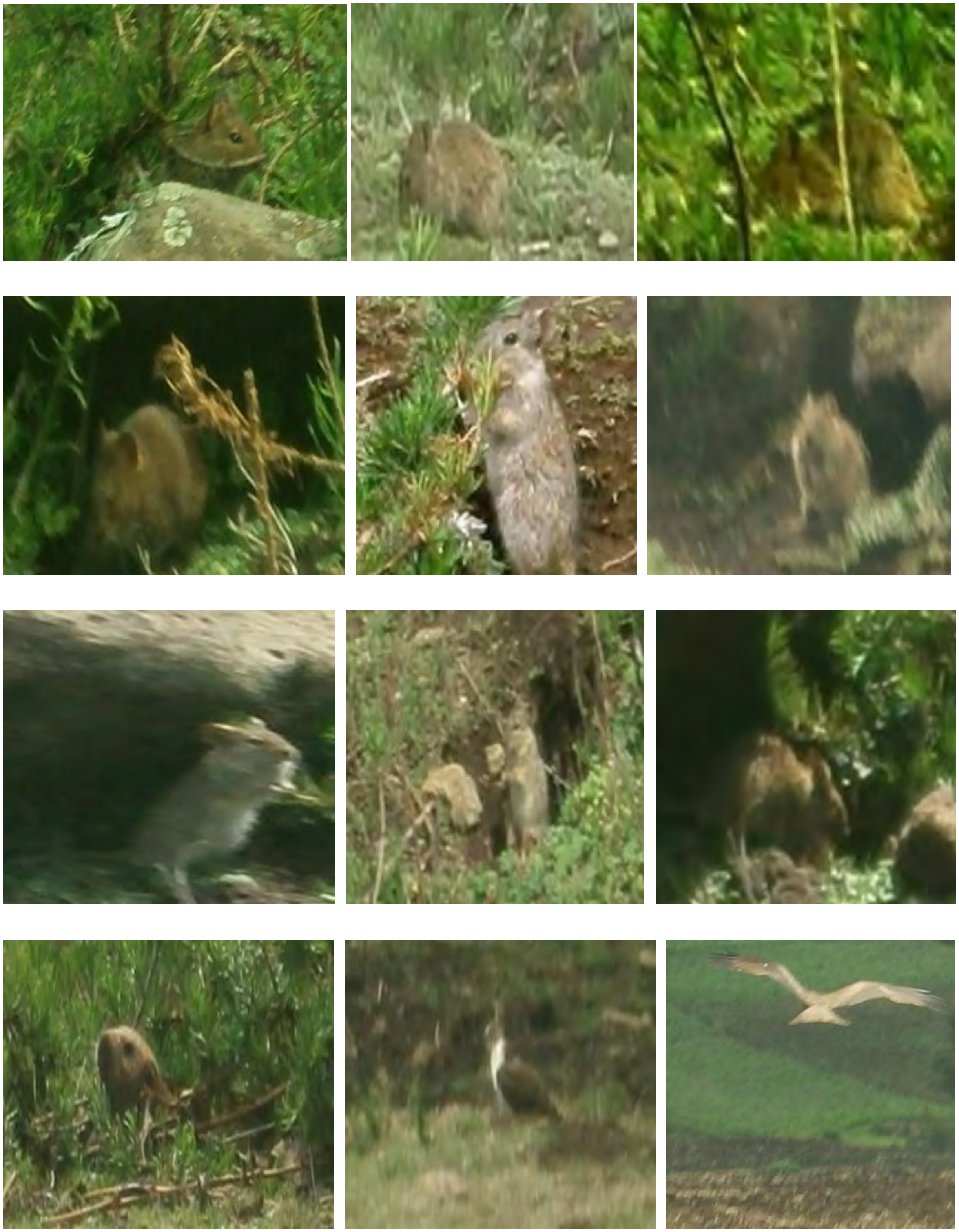
Barley crop plots	Average barley yield (kg/m^2) 2014/15	2015/16	Variation
Pl_{1A}			
Control units (4m^2)	0.500	0.513	+0.013
Treatment units (4m^2)	0.400	0.320	-0.080
Variation	0.100	0.193	+0.093
Pl_{1B}			
Control units (4m^2)	0.502	0.509	+0.007
Treatment units (4m^2)	0.406	0.320	-0.086
Variation	0.096	0.189	+0.093
Pl_{2A}			
Control units (4m^2)	0.507	0.505	-0.002
Treatment units (4m^2)	0.430	0.397	-0.033
Variation	0.077	0.108	+0.031
Pl_{2B}			
Control units (4m^2)	0.499	0.519	+0.020
Treatment units (4m^2)	0.430	0.398	-0.032
Variation	0.069	0.121	+0.052

Appendix 5. Photograph of rodent species in Choke Mountains (snap trapped)

a) *L. flavopunctatus* b) *A. abyssinicus* c) *S. griseicauda*

d) *O. typus* e) *R. rattus* f) *M. natalensis*

Appendix 6. Photograph of live rodents and a predator bird



Appendix 7. Photograph of rodent damage, burrows and hoarding

DECLARATION

This PhD thesis is my original work, and was not presented in any university for similar specialization or other purposes. Sources of the reference materials used in the thesis are duly acknowledged.

Name: Getachew Simeneh Signature: __________

Date: _______________