WEATHER - BASED FACTORS THAT INFLUENCE POPULATION DISTRIBUTION OF MYOMORPH RODENT PESTS IN CEREAL FARMS OF UNIVERSITY OF ELDORET, KENYA.

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DECLARATION

Declaration by the Candidate

This thesis is my original work and has not been presented for a degree award in any other university. No part of this thesis may be reproduced without the prior written permission of the author and /or University of Eldoret.

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DEDICATION

This work is dedicated to my husband Professor Bernard Kibeti Nassiuma, Sons Kevin Cheng`et and Bill Nassiuma and my daughter Purity Luseno for being there for me at all times.

ABSTRACT

In Kenya, rodents are pests of concern because they cause damage to cereal crops before and after harvest, posing a threat to both food availability and safety. However, information about the ecology of myomorph rodent pests and the infestation of cereals in Kenya is limited. The objective of the research was to identify myomorph rodent species, assess population abundance and determine how weather -based ecological factors of rainfall, relative humidity and temperature influence rodent populations, species richness and distribution of male and female rodents in University of Eldoret farms. Two habitats (Maize and wheat farms) were selected where a 70mx70m grid crop cutting was done in commercial fields for the study. The grid was subdivided into four quarters each with four Sherman's live traps and four locally woven live traps resulting in 32 trapping points with trap spacing being 10m apart. Peanut butter and sun-dried fish (*Rastrineobola argentea*) were used as baits. The rodents captured were identified to species level using keys for classifying rodents. Chi square test, independent sample t-test, Poisson, binary logistic and multinomial regression were used to establish the relationship between nominal response variable given one or more predictors. Autoregressive Integrated Moving Average (ARIMA) [1, 1, 1] [2, 0, 0] Time series model was used. Three myomorph rodent species *Mastomys natalensis*, *Arvicanthis niloticus* and *Lemniscomys striatus* were captured during the study period. A total of 924 myomorph rodents were captured with 50.97%, 19.48% and 29.54% captured in year one, two and three, respectively. *M. natalensis* represented the highest captures (60.61%), then *A. niloticus* (38.42%) and *L. striatus* (0.97%). There was a significant variation in infestation in year one (P = 0.001) and no significant variation in year two (P = 0.499) and three *(*P = 0.127). Species displayed variation in distribution. There was a significant difference in distribution of gender in second year of study (t = -2.625, P = 0.009) and overall, no significant variation in distribution of gender (t = 0.525, P = 0.600) in the two habitats. ARIMA (1, 1, 1) model predicted a higher abundance of rodents between the months of March and July with decline in November to January of the forecasted year with minimal variation. The findings indicate statistically significant difference in species distribution of rodents in maize and wheat fields (t = 3.523, P = 0.001) and weak positive correlation between rainfall and gender distribution (r = 0.171, P = 0.001), a weak positive correlation between relative humidity and gender (r = 0.198, P =0.001) that was statistically significantly different. Rainfall and relative humidity had an effect on distribution of gender. However, there was a weak positive correlation between temperature and gender distribution in year one and two (r = 0.056, P = 0.225; r =0.093 P = 0.214) and weak negative correlation in year three (r = -0.046, P = 0.449 with no statistically significant effect of temperature on gender distribution (P > 0.001). Pearson correlations between ecological factors of rainfall, relative humidity and temperature showed a linear weak correlation with species distribution (r =-0.001, P=0.986).Rainfall and relative humidity were shown to influence species distribution, but temperature did not have notable influence on species distribution in this study. Rainfall, relative humidity and temperature could predict the changes in population, species and gender. Changes in temperature had inverse relationship with gender and species abundance. In conclusion, there existed variation in infestation of myomorph rodents, the type of species identified did not vary and weather-based ecological factors of rainfall, relative humidity and temperature do not have consistent in influence on myomorph rodent pest population, species and gender disparity in cereal farms in the three cropping years.

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ACRONYMS AND ABBREVIATIONS

ANOVA	Analysis of variance
A. niloticus	*Arvicanthis niloticus*
ARIMA	Auto-Regressive Integrated Moving Average
FAO	Food and Agriculture Organization.
G	Grams
H	Habitat
Ha	hectares
L. striatus	*Lemniscomys striatus*
M	Metres
Mm	Millimetres
M. natalensis	*Mastomys natalensis*
NACOSTI-K	National Commission for Science Technology and Innovation-Kenya
RH	Relative humidity
Sex	sex
SP	Species
UoE	University of Eldoret
WHO	World Health Organization

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CHAPTER ONE

INTRODUCTION

1.1 Background information

Rodents (class Mammalia and order Rodentia) are the most diverse and abundant groups of mammals accounting for over 2200 species known to science, with new species being described every year (Monadjem *et al*., 2015). The order Rodentia comprises three suborders namely Hystricomorpha, Sciuromorpha and Myomorpha (Vaughan *et al*., 2000). Some rodents are acknowledged as the most significant crop pests from an ecological perspective. Rodents are widespread in terrestrial habitats and play a crucial role in the ecosystem functioning (Fischer *et al.*, 2017; Mayamba, 2020). Rodents are also of biogeographic, systematic and conservation interest (Happold, 2013; Monadjem *et al.*, 2015). According to Royer *et al.* (2016) rodent immigrations and emigrations, take place that results in new regional populations being established in order to occupy the fundamental niche that is a potential role that could be filled. This is affected by among other factors the ability of individual organism to disperse, their tolerance to different environmental conditions and how the organism interact with other species.

Rodents are small to medium sized mammals (40 mm to 1300 mm). Some rodents weigh less than 100 g possessing only two incisor teeth positioned in the upper and lower jaws (Orr, 1975). Rodents differ from Pikas, rabbits and hares (Order Lagomorpha) by having a single pair of upper incisors while lagomorphs have two pairs of upper incisors, one directly behind the other, with second incisor being smaller and lacking a cutting edge. Rodents differ from insectivorous species such as the shrews and hedgehogs in that they possess an elongated snout and primitive teeth lacking the enamel (Vaughan, 1986). In suborder Myomorpha infra orbital canal is enlarged for transmitting medial masseter muscle while in Sciuromorpha (squirrel like) rodents the infra orbital canal is exceedingly small. In suborder Hystricomorpha (porcupine like) rodents the infra orbital canal is greatly enlarged for transmitting medial masseter muscles. This study was concerned with mouse like rodents (Myomorpha) *per se.*

The habitat and behaviour of rodents are highly diversified. (Kingdon, 1997; Nowak, 1999). Rodents are highly intelligent, and with the right conditioning, they can learn even simple tasks. They have acute hearing, taste, smell, and touch senses. Rodents are extremely social creatures that communicate using a variety of senses. According to (Nowak, 1999) rodent's behaviour is highly adaptable. They have high reproductive rates, ability to invade varied habitats and therefore they are able to spread and multiply very quickly. The rats begin to search for food and water shortly after sunset. The signs of rats are tracks; rub marks, droppings, gnawing and burrows (Aplin *et al*., 2003) and therefore the need to investigate their populations in the study area by trapping the rodents both during the day and night.

Rodents exhibits irregular population dynamics with occasional out breaks, typically occurring over extensive areas and are among the most destructive vertebrate pests (Leir *et al*., 1996; Singleton *et al.*, 1999). The rodents breed throughout the year. They shift from one suitable site to another according to Zeese *et al.* (1989). The control measures on rodent population growth includes: habitat modifications such as removing weeds, shrubs and trash, habitat protection like the breeding and resting sites of the predators, habitat manipulation like crop rotation, rodent proofing of storage buildings and biological methods like supporting natural enemies and competitors of rats (Zeese *et al*., 1989). Some of the rodent control means include, use of mechanical control such as the use of snap traps and live traps, chemical control using multi- dose anticoagulant, poisoned bait in houses and fields multi-dose anticoagulant tracking powder in highly attractive crops and animal farms, multidose anticoagulant liquid-bait in stores and animal farms and acute poison in wasteland. Handwerk, (1998) reported that the potential enemies or predators of rats and mice are jackals (*Canis aureos*), foxes (*Vulpes vulpes*), owls (*Athene noctual*), Krestels (*Falcon tinnunculus*), black shouldered kites (*Mustela nivalis*) and snakes, among others. The various control elements include surveillance, community education, special baiting, law enforcement, special clean-ups, and community participation in clean-ups. It has been demonstrated that the distribution of rodents varies both temporally and geographically and is controlled by ecological variables such as land use, cover, soil characteristics, and climate (Chidodo *et al*. 2019).

An ecological study is an observational study defined by the level at which data are analysed at group level than individual level. Lorraine *et al.* (2014) defines ecological studies, as studies in which the unit of observation is a group not separate individuals. It involves grouping individuals with similar characteristics in a group and coded (Nowak, 1999). An ecological study focuses on groups rather than individuals such that the variables may be aggregate measures, environmental or global measures. The purpose of ecological studies is to make inferences about effects on groups not individuals. The ecological study design can be exploratory, descriptive, or analytic study whose aim is to establish spatial patterns; it can be multiple group study where subjects are grouped by place and time (time –trend study time series) to show rate over time. Time series data are used to forecast future trends or rate of an incidence or place and time study. Numerous categories may be used to classify ecological factors, including topographic, biotic, edaphic, and climatic categories. Temperature, precipitation, light, wind, water, and relative humidity are examples of climatic factors. They are elements that the organisms must have in the ideal quantities in order to develop and function properly.

Kumar, (2008) defines an ecological factor, an environmental factor or eco factor as any factor, abiotic or biotic that influences living organisms. Biotic factors include other organisms, competition, parasitism, predation, and symbiosis while abiotic factors are physiographic factors including altitude effect of steepness, climatic factors that include temperature, rainfall, sunlight, atmospheric pressure, humidity of the air, radiation and ionisation of air, chemical composition of water and atmosphere. Edaphic includes soil type, soil pH, soil temperature, soil moisture, organic carbon and nitrogen content and heavy metal content (Kumar, 2020). In the present study climatic factors of rainfall, relative humidity and temperatures were considered because they are alleged and have been suggested to influence the population of rodents. These factors were related to rodent infestation in the study fields of maize and wheat to establish relationship between myomorph rodent pest population and ecological factors, then formulate predictive models that can be adopted that can minimise, mitigate the loss by rodents and predict or forecast rodent out breaks.

Anthropogenic environmental changes have been shown to be crucial determining factor in the increase of rodent’s ubiquity through time when rodents are attracted to food in villages and fields (Dean, 2005). Dean (2005) also observed that kangaroo rat population increased due to the weedy annuals around human habitation. Different species of rodents vary in their ecology and behaviour, in the type of damage they cause and in their response to various control measures according to Oguge *et al.* (1983). In China, where climate patterns are changing, there are more severe droughts, and during warmer winters, rodents become more plentiful and have widespread outbreaks, infesting 24.9% of arable land and 14% of grassland annually, rodent pests have been reported as a serious problem for agricultural production (Zhi-Bin Zhang, 1999). Furthermore, Zhi-Bin Zhang (1999) found that the dynamics of the rodent population and management tactics differed widely and were influenced by the species and its ecosystem. The population grew throughout the rainy season's seed ripening phase and the dry season's milky stage. The majority of field pest rodents also exhibit erratic population breakouts, which can cause extremely detrimental damage to standing crops. The irregular population outbreaks may be due to animals being residents or passer-by. Mulungu (2017) and Kasso (2013) described rodents as pests that substantially cause damage to agricultural crops, household goods, and human health through mechanisms like feeding, discomfort, contaminating food, mechanical damage, and disease transmission. Rodents infest areas or land that offers them a place to live and damage in the field is either random or regular. Rats usually feed on embryo part of the grain because of the lipid content that is easier to digest and provides energy for the rodents instead of starchy carbohydrates that are left as waste not fit for human consumption. The grains leftovers are not palatable and are easily prone to infection by aflatoxins. High populations of rodents with their wasteful, destructive eating cause loss in production of maize and wheat. In general, rodents prefer seeds with a low carbohydrate, high protein, and low-fat content to grains with the same characteristics (Asran *et al*., 2014). Rodents are a substantial cause of pre- and post-harvest losses among other pests, especially to grain crops in East African countries (Mayamba *et al*., 2019; Mulungu *et al*., 2010; Makundi *et al*., 2006; Leir *et al.*, 1997). This study was to investigate the type of pests that infested maize and wheat farms in the study area.

1.2 Statement of the Problem

Micro- climatic shift may affect the consistency of weather-based ecological factors thereby altering conditions in a given habitat. Rodents are the largest group of mammals and are important components of all terrestrial ecosystems. Rodents are herbivores that aerate soils by burrowing activities and are important vectors or reservoirs of numerous diseases that affect humans, domestic animals and other wildlife species. Some rodents form major pests of agricultural crops causing damage to cereal crops before and after harvest (Wondifraw *et al*., 2021). In Kenya, save for a few studies (e.g., Taylor, 1968; Oguge *et al*., 1983; Oguge, 2003; Odhiambo *et al*., 2008; Ognakossan, 2017; Ochilo *et al.*, 2018), information on rodent population dynamics is very limited. Information on population dynamics, habitat use and factors that limit breeding, reduce survival and influence dispersal of rodent species is essential for development of effective economic and sustainable management program (Tripathi and Chaudhary, 2005). Rodent population dynamics have been studied based on biotic factors such as food availability, reproductive ability, nature of vegetation, natural enemies like prey- predator relationships and parasites -vector host relationship (Taylor and Green, 1976; Oguge, 1995; Mayamba *et al*., 2020). Although the environmental factors and many combinations of predictor and outcome variables have been used to explain and predict rodent distribution by Ashcroft *et al*.(2011), rodents remain animals of great concern depending on the species involved, the kind of environment where the problem may occur, the nature of problems and the value of anticipated damage. The rodent destructive behaviour to human livelihood through their competition for food and other animals leads to need for control and management of their population growth and distribution within the habitat they occupy.

The University of Eldoret farms that were chosen as the study site produces maize and wheat on large commercial scale. The measures used on the farms such as pest surveillance, use of biocide such as herbicides for weed control, rodenticide for rodent pest control and mechanized farming system practiced to improve on the commercial production of maize and wheat may not reduce rodent pest population or comprehensively address the rodent pest population dynamics. Although no rodent population explosion and major damage has been reported in University of Eldoret farms, it is necessary to investigate possible rodent population explosion, which could lead to extensive damage to the crops. University of Eldoret environment is conducive for infestation by myomorph rodent pests due to supply of food and climatic factors being favourable like in other regions where extensive studies have been carried out (Mayamba *et al*., 2020; Ognakossan, 2017). Weather-based ecological factors are some of the factors, which could influence rodent pest population and therefore these calls for investigation on their influence on myomorph rodent populations, species and gender in order to contribute to possible strategies on rodent pest management and control without necessarily causing ecological imbalance.

The era of eradication of rodent through killing alone is not appropriate and development of management option is necessary. Development of genetic resistance to anticoagulants and chemical poison is a call to ecologists to think on how to outwit rodent pests. Much is required to be done to understand and outsmart the rodents. Several factors influence rodent population dynamics. Rodent pest distribution in various ecological habitats is one of the important factors that have effects on humans, other animals and the environment in general. Singleton and Petch, (1994) reported that agricultural fields serve as highly productive habitat for rodents whereby changes in agricultural practices such as increasing number of crops produced per year or increasing amount of arable land in a region can lead to marked increases in the magnitude of rodent problems. Weather- based ecological factors have been reported to be one of the important factors that influence rodent distribution and hence the need for this study in order to establish their role in distribution of rodents in maize and wheat farms at University of Eldoret. The data obtained will not only contribute to establishing the role of rainfall, relative humidity and temperature on myomorph rodent population, species and gender abundance and distribution but can be extrapolated to other regions with similar environmental conditions and agricultural practice.

1.3 Purpose of the Study

Some rodent species are known to be major pests of agricultural crops in various parts of the world. Even though no alarm had been raised about rodent pest outbreak in the study area, the purpose of this study was to generate information on the identity of rodent species and establish whether weather-based ecological factors had influence on the abundance of myomorph rodents at the farms of the University of Eldoret. In the University of Eldoret, maize and wheat are grown and produced on commercial large scale. The study also sought to establish whether there is potential rodent populations that could cause crop destruction and loss. The findings of the study add to research output on the influence of weather-based ecological factors on myomorph rodent pests in Kenya and East African region at large.

1.4 Research Objectives

1.4.1 General Objective

To investigate the influence of weather -based ecological factors on the abundance and species diversity of myomorph rodents that infest maize and wheat farms of the University of Eldoret (UoE).

1.4.2 Specific Objectives

i. To assess the variations in distribution of myomorph rodent pest populations among three cropping years in maize and wheat farms.
ii. To determine the rodent species abundance in maize and wheat fields.
iii. To determine the gender (male and female) distribution of each identified species of myomorph rodent pest in both maize and wheat farms.
iv. To determine the influence of rainfall, relative humidity, and temperature on the population of rodent pests, species and gender in maize and wheat fields.

1.5. Research Hypotheses

i. H_{01}: There is no significant variation in rodent pest population between the cropping years and its infestation in maize and wheat fields.

ii. H_{02}: There is no statistically significant difference in the abundance of rodent pest species between maize and wheat fields.

iii. H_{03}: There is no statistically significant difference between male and female abundance of identified species of myomorph rodent pests in maize and wheat farms.

iv. H_{04}: There is no statistically significant influence of rainfall, relative humidity and temperature on the abundance of rodent pest population, species, and gender in maize and wheat fields.

1.6 Justification and Significance of Study

It is universally accepted that rodent pests occupy almost every region of the world. Unique circumstances that determine rodent population dynamics in tropics may be different from temperate regions. Weather-based ecological factors that influence population dynamics have not been exhaustively studied. Findings from different researchers give conflicting results on the same. While some studies report food as the main driving factor for population changes (e.g. Odhiambo *et al.* 2008; Monadjem *et al*. 2015; Ognakossan, 2017), other researchers state that climatic ecological factors are important (Royer *et al*.2016; Ochillo *et al*. 2018; Mayamba *et al*. 2020). According to Jurisic *et al.* (2022), methods of reproduction, constant availability of sufficient amounts of food, favourable climatic factors and rodent hibernation in tunnels during winter helps create suitable microclimate that can lead to overpopulation, disruption of natural balance and occasional calamities due to high population density. Although the rodent pest infestation has hither to not been documented at the University of Eldoret (UoE) Uasin

Gishu county and its environs, there is a possibility of their presence and possibility of problem arising in future, if it is not investigated. If prevailing factors would lead to an increase in rodent pest populations, they would lead to crop destruction not only the study area but also the surrounding, which would make it difficult to manage rodent pest population, which in turn would affect crop production.

The study on weather-based ecological factors population dynamics and species that inhabit study area and neighbouring areas would provide critical information on rodent species and gender distribution in the maize and wheat farms of the UoE. This information is important as a scientific basis for laying strategies on rodent management for better crop yields without destabilizing ecological balance. The significance of this study is based on rodents being pests of concern. Rodents are primary consumers of grains and herbage, increased rodent population lead to intraspecific and interspecific competition that would cause damage to crop before and after harvest. The damage is likely to lead to reduced crop yields. There is therefore need to establish possible rodent pest species that inhabit or infest the farms and their response to environmental factors because different species may exhibit different destructive abilities, fecundity, and survival (Oguge, 1995; Jurisic *et al.*2022). Weather- based ecological factors determine the state of crop development, food availability and population change of rodents. There is therefore need to understand the ecological biology of myomorph rodent pests in order to set pest management strategies to minimize destruction of crops during both pre harvesting and post-harvest period and also minimize occurrence of ecological imbalance due to either population explosion or decline in numbers and species of myomorph rodents.

A systematic review of rodent pest research in smallholder farming systems in Afro-Malagasy (including several countries like Ethiopia, Eritrea, Lesotho, Madagascar and Uganda) showed that there is a disparity in number of research studies conducted in Kenya on rodents. In the review, Kenya accounted for 8% out of 51% of research (Mulungu, 2017). Mulungu (2017) further showed that there is an in depth of studies on rodent abundance and effectiveness of various management actions on rodent pest damage in the region. therefore need to carry out this study in order to compliment the findings on studies carried out earlier in addition to establishing how the environmental conditions would influence the infestation pattern of given habitats.

1.7 Scope of the Study

The scope of the study was zoology animal ecology. The study investigated myomorph rodent species identity, population, abundance, species and gender distribution and the influence of weather -based ecological factors of rainfall, relative humidity, and temperature on rodent populations, species and gender distribution in maize and wheat farms. The study was undertaken at the University of Eldoret maize and wheat farms in Uasin Gishu County for a period of three years. It was a quantitative, longitudinal, and observational research based on capture recapture method.

1.8 Limitations of the Study

This research confined itself to myomorph rodents that infested maize and wheat fields at University of Eldoret farms and the findings have to be seen in light of some limitations. The consistency in monitoring and use of mechanization was a limitation because it interfered with monitoring consistency of population dynamics of rodent pests based on influence of weather -based ecological factors. The habitat modification through use of machinery could interfere with establishment of new rodent populations.

CHAPTER TWO

LITERATURE REVIEW

2.1 Description and biology of Rodents

2.1.1 Distribution and behavioural characteristics of rodents

Rodents belong to order rodentia of class Mammalia. A pair of very sharp chisel shaped ever-growing incisors in each jaw characterizes these small mammals. The incisors grow at a rate of about 0.4mm / day. The canine teeth are absent leaving a wide gap between incisors and grinding teeth called diastema. They are omnivorous and cannibalistic and highly adaptive, very secretive mostly nocturnal and have well-developed sense of smell, hearing, and touch (Tripathi and Singh, 2011).

Most rodents are squat, compact with short limbs and a tail. They are distinguished from other mammals by a pair of chisel -like front incisor teeth, lack of canine teeth, and few molars on each side of the jaw and a toothless gap diastema between incisors and the premolars. The incisor continues to grow throughout the lifetime but is worn down by routine gnawing. Rodentia is the most inadequately understood order taxonomically (Kingdon, 1997). Classification has been based on the use of shape and size of infra orbital canal or the phylogeny of the order but because of the fossorial habits of the rodents and the anatomical modifications and resulting modifications of key characters the two approaches rarely agree. Based mostly on the jaw muscles and accompanying skull anatomy, rodents are divided into three suborders, namely, Sciuromorpha (squirrel-like), Myomorpha (rat-like), and Hystricomorpha (porcupine-like). Twenty-nine extant families, 426 genera, and 2,000 species make up these sub-orders.

Therefore, among all the animal orders, rodents are the most diverse (Nowak, 1999). Two-thirds of all rodents belong to a single family, the Muridae, and the majority of the rodent species among them are members of the sub-order Myomorpha. As new methods of recognizing siblings and cryptic species are developed, the number of rodent species continues to increase (Happold, 2013).

With over 2200 known species, comprising of more than 40% of all mammals, rodents are the world's most diverse and most prevalent group of mammals. They include beavers, chipmunks, hamsters, mice, porcupines, rats, squirrels, and voles (Kingdon, 1997). According to Sinclair in (1976), the Muridae are the biggest rodent family (rats and mice). A third of all rodent species or 1,011 species belong to the family Muridae. Scuiridae (squirrels) is the second-most numerous family. Rodents were around more than 58 million years ago, according to archaeological evidence, but between 54 and 38 million years ago, these animals are thought to have evolved into jumping, sprinting, and burrowing species. According to Nowak (1991) and Nowak (2018), rodents are the group of mammals with the greatest diversity and number of species, making up over half of all known mammalian species. They also account for about 28% of mammalian species in East Africa.

2.1.2 Rodents as pests

Rodents are recognised ecologically as one of the most destructive pests. The rodents cause great economic loss to farmers by damaging growing crops, stored products, poultry, and animal farms. They damage structure and fabric of buildings because they gnaw through almost every object to obtain food and shelter (Desoky, 2018). Rodentia, which is the most important mammalian order with greatest number of rodents, have their effect on environment directly through feeding and foraging habits. They are primary consumers feeding on grains and vegetation there by reducing potential production of grains or indirectly through their position in the food chain whereby they are preyed on by predators including reptiles like snakes, birds, cats, and jackals.

Rodents are known to be important in that some species constitute pests that cause damage to a variety of crops before and after harvest. Odhiambo and Oguge, (2003) reported a 90% loss of crops due to rodents in Kwale County in Kenya. Rodent species reported by Oguge *et al*., (1983) included *Arvicanthis niloticus* (Demarest), *Pumilio natalensis* (Smith), *Rhabdomys pumilio* (Smith), *Lemniscomys striatus* (Linnaeus), *Rattus rattus* (L) and *Mus* species. All the species are pests of stored cereal and grains as reported by Vaughan, (1986). Taylor (1968) had also reported rat outbreaks in Kenya, and he recorded eight species the most serious pests being, *Mastomys natalensis*, *Arvicanthis niloticus* and *Rhabdomys pumilio.* Taylor, (1968) found that the species targeted wheat, maize, and barley among other crops. *Arvicanthis niloticus* has been reported to infest and feed on both the lodging and standing maize plants, they cause damage to stalk and spikes of cereal plants. They cause more damage to seed bearing heads or spikes of cereal plants and grains, (Desoky, 2018; Meheretu *et al*., 2013) identified and cited rodents as pests of agricultural crops in central Ethiopia whereby out of 34 recorded species, 12 were rodents that cause damage to crop both as pre harvest and post-harvest pests. In diverse crop production, damage estimate was 6% to cereals, 3% to pulse, 4-26% to groundnuts, and 4-20% to vegetables and 7 to 8 species of rodents were pests out of which 3 to 4 species were reported to inflict economic damage at any particular cropping system or habitat (Tripathi and Choudhary, 2017).

Kamwaga *et al*. (2016) have identified rodents as pests of wheat and *Rattus species* is identified for being a menace especially during post-harvest and storage stage. The sign of rodent infestation is presence of droppings and nesting sites, scattered grains, round droppings or footprints, unconsumed grain contaminated with urine and droppings and partially consumed. Rodents feed on endosperm part of the seed that has highly concentrated and localized nutrient source of lipids than other parts of the plants, starchy carbohydrate part is left behind as left overs and presence of dirty marks in places through which they pass in diverse crop production.

According to Singleton (2003), the majority of rodents consume both invertebrates and a variety of plant materials, making them one of the most significant pests in ecology. Some of them exhibit cannibalism and others are specialized carnivores. They devour anything, severely damaging field crops, grains kept in warehouses, and other goods (Tripathi and Singh, 2011). The majority of rodent species live with people in homes or as commensals, such as the house rat (*Rattus rattus*) and house mouse (*Mus muscularis*), although certain species, are pests in food storage and agricultural crops. The common rat, roof rat, and house mouse are the three primary rodent pests to humans. They could destroy plant crops or devour stored food to pollute it.

The damage produced by rodent pests is comparable to or greater than that caused by insect pests in many countries (Gwinner *et al*., 1996; Ognakossan, 2017). Rats and mice are rodents that are major grain pests (family of Muridae). The four most prevalent species are the natal multimammate mouse (*Mastomys natalensis*), the house mouse (*Mus musculus*), and the black rat or roof rat (*Rattus rattus*) Makundi *et al*., 1999). *R. rattus*, *M. musculus*, and *M. natalensis* are thought to be the main rodent species in East Africa that cause post-harvest crop damage, according to Makundi *et al*. (1999). These animals, often known as commensal rodents, typically coexist closely with humans (Fall, 2011). In addition to causing bodily harm and crop loss, rats contaminate food with their droppings, which can result in illnesses brought on by rats. By destroying agricultural goods, they pollute the environment and taint food with microbiological diseases that cause human and animal allergies. Additionally, they disperse toxic fungus as well as physical impurities like hair, urine, and faeces, including faecal pellets. According to Meerburg and Kijlstra (2007) and Soveig Vibe-Peterson *et al*. (1999), the multimammate rat *M. natalensis* is a widespread and significant pest species in sub-Saharan Africa, and rodenticides are the primary method for their management. Many carnivorous animals, birds, and reptiles eat rodents as an essential component of their diets.

For maize farmers' rats not only cause serious damage after harvest but they are also responsible for causing serious damage while the maize stands in the fields, Mulungu (2017). According Mulungu (2017), farmers are aware of the losses resulting from rodents, particularly at the planting stage when maize seeds and seedlings are at their most vulnerable stages. Rodents cause great economic loss to farmers damaging growing crops, stored products, poultry, animal farms and indirectly loss to food manufacturers because they damage structures and fabric of buildings. They gnaw through almost every object in their way to obtain food and shelter, such that they destroy directly through feeding habits and indirectly on environment by themselves being stable food item for many predators in the food chain this is according to Desoky, (2018). Rodents are capable of destroying crops, trees, damage structural property and transmit diseases.

According to Tripathi and Singh (2011), 103species and 16 families were reported as pests in arid region out of which three families, Scuiridae, Hydricidae and Muridae constitutes pests. Tripathi and Singh (2011) encountered 18 species in arid zone of which only about 7 to 8 species are considered as pests in agriculture. They further reported that rodents inflict economic damage in any particular crop per cropping system and the damage range between 2-5% with maximum loss when maize is harvested, heaped in fields, and followed the cobs. Wheat experienced 11 to 21% loss; Mustard experienced 22.9 to 43.5% reduction in plant stand, groundnuts 30 to 50% loss, tomatoes, carrots, and radish 16 to 30% loss to squirrels and 60 to 80% loss of forest desert acacia to desert gerbils. Hair footed gerbils also dig out sown seed and feed on them almost to the roots of fodder. Therefore, rodents being herbivorous are always a potential threat to various production systems agriculture, horticulture, forestry, and rangelands. Farming system make rodent problem aggravated because annual and perennial crop components in any system provides food and shelter to native rodent species on regular basis. Rodents can infest areas throughout the year especially where they can meet their basic needs unlike insect pests that are seasonal. Rodents are highly mobile, and an individual can cause damage to several plants.

Small rodents, whose distribution and abundance vary across landscapes, are becoming increasingly significant as agricultural pests (Mayamba *et al*., 2020). According to Ochilo *et al*. (2018), agriculture is the most significant industry in the majority of African nations, and low agricultural production worsens poverty, food insecurity, and malnutrition. In East Africa, rodent pests are by far the biggest issue. They are in charge of causing significant damage to buildings, industrial, household, and food and cash crop property. More than 25 species of rodents have been identified as pests in agriculture, resulting in a variety of losses and damages to crops like cotton, sugarcane, cottonseed, and root crops as well as cereals, legumes, and vegetables. Pest species can be found in farmed fields, urban settings, and home settings, among other habitats. They contribute to crop damage, but they are also zoonotic disease reservoirs and carriers that in some parts of East Africa have taken a lot of lives (Makundi *et al*., 1999).

2.2 Rodent pest species in agricultural production of maize and wheat

Only a small number of the more than 2000 species of rodents that exist are pests to agriculture. According to Aplin *et al*. (2003), there are roughly 381 species in Africa, 77 of which are pests that harm agriculture, and 12 to 20 of these species are significant in cropping systems. The Muridae family of rodents, which includes 12 species of mice known as the most infamous pests in East Africa, contains the most dangerous rodents. *Arvicanthis* and *Mastomys* species are major maize pests with a wide geographic distribution across Ethiopia, according to study by Bekele and Leirs (1997). Rodent damage to crops is highly common, according to Shenkut *et al* (2006).'s investigation on the species diversity, distribution pattern, relative abundance, and biomass of rats in Ethiopian farmlands. In areas growing cereal grains, which made up the majority of the world's agricultural land, many rodents are common (FAO, 2001). The dynamics of rodent pest populations in agriculture can exhibit at least three distinct basic patterns, including relatively stable populations, populations that fluctuate irregularly, populations that exhibit strong seasonality, like *M. natalensis*, or populations that erupt with irregular peak years alternated with periods of lower populations, like *Mus domesticus*. Agricultural fields are homogenous landscape, and the vegetation is dominated by one or few crop species and therefore many rodents are common in such fields especially with cereals. Agronomic pests significantly affect pre-harvest and post-harvest yield loss. One of the main pests of agricultural crops are rodents. About 10% of the rodent species together have an impact on agriculture. Out of the 395 rodent species found in Africa, 77 are pests. More than 6 out of 91 species of rodents in Ethiopia were found to be serious agricultural pests. In Africa, species from the genera *Mastomys* and *Arvicanthis* are particularly prevalent crop pests. In Africa, 50% pest rodents are reported by four countries; Tanzania (24.69%), Nigeria (8.64%), Ethiopia (8.64%), and Kenya (8.02%)(Wondifraw *et al*., 2021).

According to Mulungu *et al*. (2003), rodents have a substantial influence on food security at all sizes, from the household to the regional, and in Tanzania, losses of up to 80% have been documented. According to Massawe *et al*. (2011), the two main pest species are *Mastomys* and *Arvicanthis*. Desoky, (2018) revealed that the only species that persisted and was in charge of maize damage was the *Arvicanthis niloticus* field rat, also known as the Nile grass rat. Furthermore, it has been noted that rodent damage is rarely consistent over time. It follows crop phenology, for instance in rice field rat's damage paddy more severely at certain stages than at others and destroy planted maize seeds, although they are less harmful during maize growth until the crops begin to maturity (Makundi *et al*, 1999). Rodent damage is more persistent but varies in perennial crops to correspond with fruiting. Depending on the crops, crop stage, agro-ecological location, availability of food, and physical surroundings, estimates of rat damage to crops might vary greatly.

2.3 Rodent population dynamics and relative abundance

The most numerous and significant mammalian order, the rodentia, has a significant impact on the ecosystem both directly through destructive eating habits and indirectly by serving as a reliable food source for several predators in the food chain. According to Mulungu (2018), changes in the agro ecosystem have a significant impact on the distribution and population density of field rats. Taylor and Green (1976) demonstrated that rainfall is the primary cause of variation in rodent density. Populations of *M. natalensis* typically exhibit seasonal trends related to variation in rainfall, peaking near the end of the rainy season when food resources are abundant and breeding decreasing toward dry months. Additionally, it has been demonstrated that rodents reproduce year-round, depending on the species and the availability of food. They may produce 1 to 22 litters, 800 to 1200 offspring per couple annually, exhibit promiscuous mating behaviours, and have lifespans of 1 to 4 years (Tripathi, 2014) adding that rats brought over by immigrants not only multiply but also cause damage. Rain encourages grass germination, which causes sub adult females to mature and produce a high number of young in a short amount of time, which causes population breakouts in multimammate mice. These mice have tight breeding seasonality that is strongly tied to rainfall (Bekele and Leir 1997, Shenkut *et al*., 2006).

Climate change and other environmental changes influence rodent populations. According to reports, rodent population dynamics follow seasonality in connection to changes in rainfall and peak at the conclusion of the rainy season when resource supplies are plentiful (Feliciano *et al*., 2002; Massawe *et al*., 2006). The ultimate cause of change in rodent density is rainfall, which inhibits breeding during the dry months (Caro, 2002). According to reports, temperature and humidity are important factors in affecting mouse activity (Cheeseman, 1977). Alemayehu and Bekele, (2013) and Odhiambo *et al*. (2008) also reported on the seasonal variation of rodent populations, noting that the peak population size in agricultural fields was seen at a period when the crops were fully grown and prepared for harvest. Rodents from the surrounding area can move to the agricultural fields during the attractive stage of the crop when food resources are available and plenty.

In addition to climate and season having an impact on rat populations independently of reproduction, Michelle *et al*. (2016) found a correlation between higher rat numbers in metropolitan locations and the availability of food and harbourage. Rat population density is influenced by the availability of food supplies, and infestation is linked to the presence of domestic animals like cats, dogs, and livestock in homes, gardens, or city blocks. Michelle *et al*. (2016) discovered that harbourage influences whether or not a population is established, with easily accessible or abandoned structures acting as the source of the population. Rat infestations are linked to factors that make refuge accessible, such as rat holes, gaps in walls, ceilings, and building foundations, as well as sewer systems.

2.4 Rodent population, ecological factors and factors influencing habitation

Ecological factors as categorized by Kumar, (2020) are biotic factors that includes such factors as predation, availability of other organisms for food, predator and prey that have evolved together or new predators from another ecosystem and diseases. When organisms are introduced into a new ecosystem, they often bring new pathogens and intraspecific and interspecific competition for resources such as food, water and mates affects how a species is distributed.

Abiotic factors include non-living variables that can influence where organisms can live. They are climatic temperatures, light intensity, moisture content humidity and rainfall. Edaphic abiotic ecological factors include soil properties like moisture content, pH, texture, and soil profile. In the present study, the ecological factors of rainfall, relative humidity, and temperature influence on rodent pest population, species and gender were investigated.

CHAPTER THREE

METHODOLOGY

3.1 The Study area

3.1.1 Study location

This study was undertaken on maize and wheat farms of the University of Eldoret (UoE) that is located in Uasin Gishu County, in Kenya's Great Rift Valley (Figure 1). The County borders Kakamega County to the northwest, Kericho County to the southeast, Elgeyo Marakwet County to the east, TransNzoia County to the north, and Nandi County to the south (County Integrated Development Plan CIDP, 2018).

The University of Eldoret is situated 9 km to the north of Eldoret town at latitude 0^0 34'36" N and longitude $35^0$18' 20" E along Eldoret - Ziwa road off Iten road in Moiben sub-County.

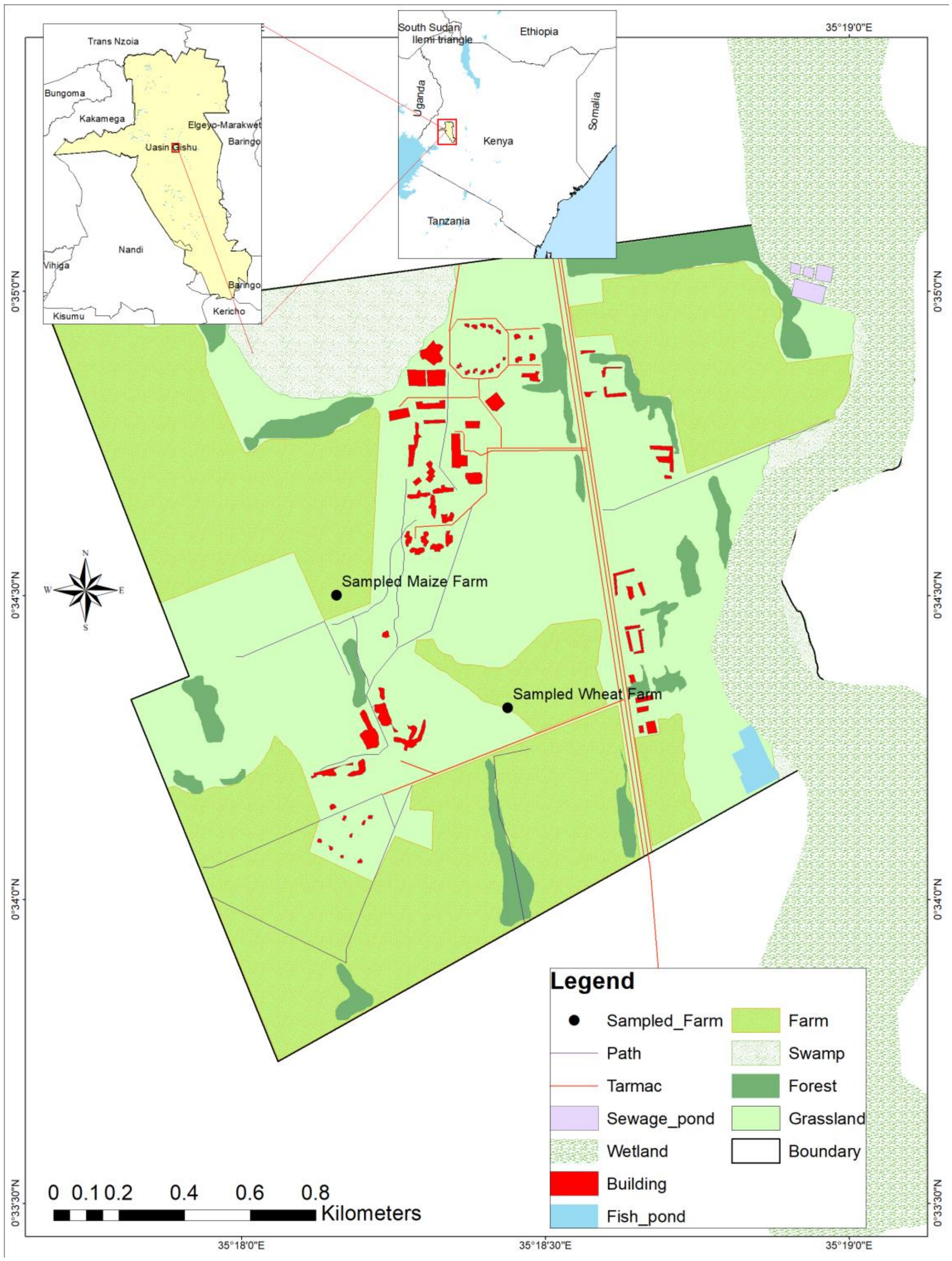

Figure 1: A map showing the location of sampled maize and wheat farms at UoE. Inset shows the study area location in Uasin Gishu County and Kenya.

3.1.2 Climate and land use of study area

The Uasin Gishu District environmental action plan (DEAP) of 2009-2013 indicates that agriculture remains one of the most important sectors in Kenyan economy contributing about 26% of gross Domestic product (GDP) and about 80% of the human population lives in rural areas and depends on agriculture for their livelihood. Uasin Gishu County is referred to as cereal and grain production area of Kenya. The primary agricultural production system in the County is small-scale mixed farming, in which farmers grow a variety of crops and keep cattle on the same piece of land.

The county receives high and consistent rainfall. Consequently, a few large-scale farmers practice huge scale maize and wheat farming for commercial purposes. The County's primary crops include maize, which grown on 102733 hectares, as well as wheat, beans, Irish potatoes, and beekeeping. The County produces about 200 million kilograms of milk and about 2.5 million kilograms of meat annually from its livestock, which includes dairy farming, beef cattle, chickens, sheep, goats, and pigs, as well as beekeeping, rabbit farming, and fish farming (CIDP, 2018). The two main agricultural methods are mixed farming of commercial crops and dairy cows, and mixed farming of subsistence food crops and animals. From small-scale, low-input farming (2 to 10 hectares) to highly automated, large-scale farming (over 50 hectares), with a high degree of input utilization, production varies across the County. With a population of 336122 dairy cattle, 40270 beef cattle, 83856 meat goats and 470 dairy goats, 129692 sheep, 707903 chickens, and 23266 beehives, beekeeping is also considered as part of the major livestock that is managed (CIDP,2018).

Uasin Gishu County is categorized into three main distinct agro-ecological zones (AEZs) namely, lower highlands (LH), Upper midlands (UM) and upper highlands (UH). Lower highlands constitute LH2, LH3 and LH4, upper midlands have UM3, UM4 and upper highlands is represented by UH1 and UH2 (MoALF- 2017). According to MoALF, (2017), the Lower Highlands (LH2) have an annual average precipitation of 1150 - 1220 mm, annual mean temperatures of 15.1^0C - 15.7^0C and at an altitude of 2350 - 2450 m. Areas under lower highland, LH3 have an annual precipitation of 900-1300 mm and annual mean temperatures of 15.10^0C - 18.0^0C with altitude ranging between 1950-2450 m above sea level. The areas under lower highland, LH4 have an annual precipitation of 900-1100 mm and annual temperatures of 16.3^0C - 18.0^0C with altitude ranging between 1950-2250 m above sea level. Upper Midlands is represented by (UM4) have an annual precipitation of 1000-1400 mm and annual mean temperatures of 18.0^0C - 20.5^0C with an altitude ranging between 1550 and 1950 m above sea level. The remaining areas of the County fall under Upper Highlands (UH2), which have an annual precipitation of 1150-1400 mm and annual mean temperatures of 13.0^0C - 15.0^0C. UH3 areas have an annual precipitation of 1100-1200 mm and annual temperatures of 13.0^0C - 15.0^0C at an Altitude ranging between 2350-2750 m above sea level.

The University of Eldoret occupies 414.8 hectares at an altitude of 2140M above sea level.The area experiences one long rainy season from March to September with two peaks in March and August. The mean daily temperature is about 18^0C (range 9^0C - 25^0C). Usually the highest and lowest temperature occur in February and July, respectively which can be categorised under low highland agro- ecological zone LH4 (MoALF, 2017).

3.1.3 Maize and wheat farming in study area.

As a major producer of maize and wheat, Uasin Gishu County is a bread basket for Kenya. Investigating the abundance and species richness of rodent pests that infest crop farms in the study area may lead to better management of rodent pest problems in case of rodent outbreak and reduce crop loss.

The University of Eldoret farms are used for commercial production of maize and wheat crops used for both food and research. Research has led to production of improved wheat seed variety, quality seed that is high yeilding and resistant to pests and diseases. Pest management is intensified on the farms but the possibility of rodent immigrations from sorrounding bushes and from neighbouring land beyond the University fence may lead to presence and incidences of rodent infestation.

University of Eldoret is a learning institution where students are engaged in learning and research that has led to development of wheat variety resistant to wheat rust. The university farms are used as research experimental plots.The maize variety grown is not only for food but large scale maize production on farms are utilized for production of silage and maize stalks used to feed the cattle. The institution keeps livestock for dairy. Although pest managenent is intense on University of Eldoret farms, the farms were appropriate study site on ecology of myomorph rodent pests because incidences of rodent pests from the areas bordering the farms may form hiding sites which can facilitate rodent movements. Availability of large quantity of feed on the farms as a result of highly improved means of production could influence the feeding and movement of various rodent species.

3.2 Research Design

A longitudinal, correlational non-experimental (observational) quantitative research design was employed in this study. Repeated numerical primary data from selected maize and wheat fields were collected over a period of three years. The data was analysed and averages used to predict trends and establish the influence of independent variables of rainfall, relative humidity and temperature on dependent variable of population abundance, species, and gender on the density distribution of myomorph rodent pests. Discrete variables of rodent abundance, type of species and abundance of each gender (males and females) were used to investigate their variation across maize and wheat farms during the three years of study. The longitudinal research design aimed at identifying the changes in rodent abundance over a period of three cropping period and provide insights into the causes of changes in abundances, species and gender across the two maize and wheat farms. Environmental variables of mean monthly rainfall, temperature and relative humidity were recorded and compared to rodent species recorded each month and mean percentages calculated. The study was based on empirical field data collected through observation during the study period as per Pandey and Pandey, (2015) who stated that both data observation and experimental procedures are used for reporting research.

3.3 Materials

Materials used in this study included traps, data sheets, tape measure, waterproof markers, field notebooks, leather gloves and surgical gloves, trap baits and animal field guides. Tools used to obtain data on weather - based ecological factors included standard rain gauges, dry and wet bulb thermometers and ordinary Mercury minimum and maximum thermometers found at the Eldoret international airport meteorology station.

3.3.1 Traps

Different traps exist for capturing small mammals. It is necessary to select a trap type and trap size that would maximize the trapping efficiency of the target species because no single type of trap can capture all species, sexes, or age classes of animals within a community with an equal probability. For instance, fossorial and non –fossorial species require different trap types. Museum-specific traps, Mouse, Rat, Longworth, Havahart, Tomahawk, Conibear, Pitfall, and Sherman traps are among the sorts of traps used to catch small mammals (SERAS, 2003). In this study, Sherman traps were used because they are lightweight compact box traps made of aluminium. They are designed to capture animals alive, which means the animals may be released back into population leaving them unaffected by the experiment. Sherman traps are particularly helpful in exploratory research intended to identify the species present in an area. Additionally, Sherman traps are collapsible, foldable, portable, and therefore easy to transport.

Trap checks were conducted two times a day at dawn and late afternoon to minimize stress to captured animals. To prevent the internal gloves from being shredded on the sharp surfaces of the traps and as personal protection equipment to avoid contact with the animals, the researcher or the research assistant wore surgical hand gloves underneath an outside pair of leather gloves when checking the traps. A marking pen, a field notebook, new bait for re-baiting the traps were brought along at each trap check. Information recorded included species, sex and numbers of each trapped rodents. If a trap shows signs of use but no rodent is visible, such as if the bait has been consumed, urine or droppings are apparent, or the trap has sprung, the trap was re-baited and reset.

3.3.2 Baits

To catch rodents, one must rely on baits. Traditional types of baits include cheese, peanut butter, bacon, cereals, and meat. Smells and odours attract rats and mice instantly and any potential food like nuts, fish and mouldy cheese can actually attract rats. In this study peanut butter and fish, Omena (*Rastrineobola argentea*) were used as baits. Peanut butter has been shown to be the most irresistible bait for most small rodent species, although roasted oats have also been used and recommended (Mayamba *et al*.,2019; SERAS,2003). In some incidences, peanut butter attracts ants during the day but cotton wool soaked in peanut butter was put around the bait where ants could stick to it to prevent damage and spoilage of the baits.

The peanut butter bait was kept in a closed airtight container with a coverlid while Sun dried fish *Omena*, were kept in a closed polythene bag and put in a locked clean cool dry laboratory cabinet for storage. Laboratory cabinets were labelled with a warning of not to be interfered with and only accessed by the research team to avoid contamination of the baits. The Omena was sun dried on regular basis to avoid their spoilage. Although Mayamba,(2020) reported that mouldy fish attract some species of rodents, it was important to maintain the quality of the bait since it is not clear which rodent species was going to be attracted to the mouldy Omena. The Omena was sun dried to maintain its quality so that they do not become a factor that would affect the catchability of the rodents. For each trap, equal amount of peanut butter weighing 10 grams and 4 pieces of whole Omena was used as bait because amount of bait varies very widely depending on rodent population density and other species, like ants, which may eat the bait. About 10 grams of bait was weighed using a Smart Weigh Gem 20 digital portable milligram (Gemini-20 model, American weigh scales) scale that has a cap lid calibrated to measure precise weights.

3.4. Methods of rodent data collection.

3.4.1 Live trapping of rodents

The methods of live trapping and trap placements was determined by a number of factors based on the habitat, the selected target species, and the study objectives. They include grid method, pace line method and sign method (SERAS, 2003).

Modified grid approach with standard operating procedures for small animal collection and processing (SERAS, 2003) was employed in the current investigation. With the assistance of the university farm manager, permanent trapping grounds for the study were selected in the commercial fields of wheat and maize farms. Using random numbers written on pieces of paper and picked randomly, a 70 m x 70 m grid crop cutting was randomly selected for placement of traps. Sherman live-trap (7.5 x 9.0 x 23.5 cm, HB Sherman Trap Inc., Tallahassee, USA; Figure.2) and locally woven live traps (Figure. 3) bought from municipal market in Eldoret town were used. The Sherman live traps are light aluminium box traps and are designed to capture live animals. They are collapsible and easy to transport.

The 70 m x 70 m grid crop cutting was subdivided into four quarters (quadrats). In each quadrat, randomization was done to identify the specific site of trap placement. To ensure population parameters are unbiased and the sample represent the rodent population, same type of traps were used in different quadrats multiple observations done. At the site, the traps were counted, marked with waterproof ink marker, and labelled as traps 1 to 4 per quarter. This was crucial for keeping track of the number of traps set and recovered as well as maintaining a trap inventory. The locations of these areas were noted in a field notebook. In the grids, traps were spaced 20 metres apart and 1metre between the two types of traps, distance measured using a measuring tape. The study employed a modified trapping design known as the standard grid, developed by Linzey and Kesner in (1997). A trapping grid was built in each quarter and marked with sticks along two lines spaced 20 metres apart. In the existing maize and wheat grids, 32 traps were deployed; a set of four Sherman's traps and four locally woven traps were randomly positioned 1m apart in each quadrat. Omena (*Rastrineobola argentea*) and peanut butter used as bait in the traps to attract rodent pests for capture.

Figure 2. Locally woven trap and Sherman trap in maize farms.

Source: Author, 2022

Figure 3. Sherman traps and locally woven trap in wheat farms

Source: Author, 2022

To maintain uniformity in data collection by both traps and identify any variations in trap catches, the traps were examined twice a day, early in the morning before 10.00h and late in the afternoon before 18.00h. Rodents are known to be active early evening before and at dawn so the traps were checked in the morning for those captured at night to be recorded and evening for those that could be caught during the day to be recorded. Each trapped rodent was marked on the ear with a unique number and colour using permanent ink marker after shaving, identified and released, modified (Linzey and Kesner, 1997) for future recapture data. In addition, data of sex, species, and farms where the rodents were captured were recorded. In all cases, trapped rodent numbers were recorded based on the species type. In order to get specimen for confirmation of identity, Snap traps with bait were used once to capture rodents in the demarcated grids. Snap -trapped rodents were retained as voucher specimens and deposited at the National Museums of Kenya to both facilitate and document identifications; identifications and nomenclature followed Kingdon, (1997); and Nowak, (1999). The techniques recommended by Cavia *et al*. (2012) of using live traps and non-toxic baits were also used in present study to estimate abundance of rodents.

To prevent neophobia in the event of trap familiarity and trap shyness, both types of traps were distributed at random inside each quadrat. Based on physical variations, caught rodents were divided into groups using characteristics such hair colour and texture, body size and shape, size and form of the mouth, and number of rodents recorded. The capture-recapture method was employed to gauge rodent population levels. The number of caught rodents was utilized to estimate the rodent abundance and species richness.

3.4.2 Investigation of variation of rodent pest population between the cropping years In maize and wheat fields

The population of each species was determined from the total myomorph rodents captured during the study period. The numbers of each species captured each month were coded and identified to species level.

3.4.3 The rodent species distribution in maize and wheat field in University of Eldoret

The rodent species captured from each field of maize and wheat were counted, identified to species level and their percentage calculated.

3.4.4. The gender distribution of each identified rodent species in maize and wheat fields of University of Eldoret

To investigate species distribution in maize and wheat fields per gender, all captured rodents were sorted out and grouped into male and females and their numbers recorded. Each species captured and gender were expressed as a percentage means then independent t-test was used to compare the abundance.

3.4.5 Determination of the relationship between the weather - based ecological factors and species abundance in study area

The influence of weather-based ecological factors on the relative abundance of myomorph rodent pests was investigated. Rainfall data was obtained using a standard rain gauge. In addition, tilting syphon rainfall recorder and tipping -bucket rain gauge tools are used to measure the intensity and duration of rainfall. In this study amount of rainfall received, each month was obtained from the ordinary standard rain gauge (Figures 4 and 5).

Ordinary rain gauge Tilting syphon Tipping bucket rain gauge

Figures 4: The ordinary rain gauge, tilting syphon rain recorder and tipping bucket rain gauge used to measure rainfall parameter.

Source: Author, 2022

Figure 5: The ordinary rain gauge used to collect amount of rainfall per month.

Source: Author, 2022

The relative humidity, which is the amount of water vapour actually in air data, was measured using standard tool, a hygrometer. The Hygrometer consists of dry and wet bulb thermometers. The difference between readings of the depression of the dry- bulb temperatures and wet -bulb temperatures were keyed into a relative humidity rule gadget to obtain relative humidity measurements, which is moisture in the air. The two sets of thermometers are kept in a Stevenson screen (Figure 6). The Stevenson screen commonly referred to as weather instrument shelter, holds instruments that include thermometers, ordinary mercury maximum and minimum thermometers, hygrometer, a Psychrometer, dew cell, a barometer and thermograph. Temperature measurements were obtained by use of weather thermometers (Figure7).

Figure 6: Stevenson screen contains four thermometers (Maximum, Minimum, dry bulb thermometer and Wet bulb thermometer).

Source: Author, 2022

A. dry bulb b. wet bulb c. Maximum d. Minimum thermometer.

Figure 7: Researcher taking data from Maximum, Minimum, dry bulb thermometer and Wet bulb thermometers in Stevenson screen

Source: Author, 2022

The climatic weather data from the Eldoret International Airport were used. Meteorological station in liaison with meteorology station staff provided accurate standard data to avoid inconsistency in data collected. Regular visits to the airport station when data records were being taken ensured my participation in data collection. The Eldoret international Airport meteorology station data provided consistency of data collected since there were more than one equipment for determine the same type of measurement this accuracy is important in order to avoid giving of erroneous data for it is necessary for control of aerospace to minimise the risks that would arise in aeroplane movement. Data from Eldoret International Airport station applies to environment covering areas beyond the airport.

3.4.6 Population and sample size estimation

The total population samples were taken to be the number of captures from experimental fields during the study period.

3.5 Data processing, analysis, and interpretation

3.5.1 Data processing

Data from two agro-habitats were pooled together to give total Myomorph rodents captured. Data processing began with the organising data for analysis, which included editing, coding, and classification. Means, standard deviations, and percentages of the population were utilized as descriptive statistics. In order to assess the association between certain variables (rainfall, relative humidity, temperature, farms, and sex) and relative abundance for each rodent species, correlation analysis, Poisson regression model and binary logistic regression analysis were conducted. Autoregressive time series model was employed to determine the future rodent population and predict future rodent outbreak. These data were analyzed using SPSS 20.0 (SPSS, USA). After statistical analysis, interpretation was done as per Gupta (2000). Interpretation of regression models output, and results of data analysis were done according to guides of reporting regression by (Jain and Chetty, 2014; Dhakal, 2018; Zach, 2021; Egunjobi, 2022).

3.5.2 Data analysis and interpretation of rodent relative abundance and population changes

The effect of weather - based ecological factors on myomorph rodent pest distribution and abundance over time were analysed. Modified Stenseth *et al*. (1996) Autoregressive Model and Spatial autocorrelation model and time series analysis were used to analyse the population change over period of study. Time series analysis refers to a sequence of data points measured at successive time and spaced at time intervals. Time series was employed in forecasting the future values or the population distribution of the rodent pests for the next one year. Autoregressive Integrated Moving Average (ARIMA) [1, 1, 1] [2, 0, 0] model was selected among the time series models in determining the possible future outbreak of the rodent pest population. ARIMA [p, d, q] model where p is autoregressive order, d is degree of differencing, q is moving average orders with random errors independently and identically distributed with a constant variance. The Auto regression parameter estimate and moving average parameter estimate stationary time series to look for line of best fit. Models of correlations and regression were used to test variance and relationships among the independent variables (year of study, ecological factors of rainfall, relative humidity, and temperatures) and dependent variables (gender, rodent abundance and species types).The ARIMA Model formula being

ARIMA Model

$$Z_t = (X_t - X_{t-1}) - (X_{t-1} - X_{t-2})$$

Where

Z_t = Linear function of the values of X

X_t = Past values of X

The monthly captures were counted and recorded then analysed to test for significance difference in frequency of captures as percentages. The mean monthly captures were also calculated to establish the infestation level in each field.

The species relative abundance was calculated using the formula:

Relative abundance = n/Nx100

Where

n =total number of captures of a species

N =total rodent population captured each year.

Relative abundance expressed as a percentage composition of a particular kind relative to the total number of the organism in an area. It shows how common or rare an organism is (Singleton *et al.*, 2003).

Chi-Square test (χ^2) was used to test the association between the relative abundance of each species in maize and wheat farms during the three years of study. Chi-Square test (χ^2) tested whether there was a statistic significance difference in the relative abundance of rodents captured during year1, year2 and year3 in maize and wheat fields with the formula

Chi-square

$$\chi^2 = \sum \frac{(O_i - E_i)^2}{E_i}$$

Where

χ^2 = Chi-squared value

O_i = Observed value

E_i = Expected value

In addition, the following assumptions were made:

i. Abundance is nominal with distribution in three years such that each year has its own abundance.

ii. The category of relative abundance is exclusive such that each sample belongs to each year.

From the above assumptions, the null hypothesis is that there is no statistically significant difference in relative abundance among the three years of study.

Independent t - test was used to compare rodent abundance in the two agro-habitats, with the following formula and assumptions,

T-test

$$t = \frac{\overline{X_1} - \overline{X_2}}{\sqrt{\left(\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}\right)}}$$

Where

t = t statistic

$\overline{X_1}$ = mean of the first group

$\overline{X_2}$ = mean of the second group

S_1^2= variance of the first group

S_2^2= variance of the second group

n_1= number of observations in the first group

n_2 = number of observations in the second group

i. The species are discrete dependent variable whose means were compared in maize and wheat fields during the three years of study.
ii. There is no connection between observations in the two fields during the years of study.
iii. The various species of rodents are normally distributed during the three years of study.

The totals and means of abundance of each species captured were used to show level of infestations and distribution in maize and wheat fields during the period of study. Independent samples t -test as described by Baran and Warry, (2008) was used to establish if there was significant difference in abundance and distribution of males and females in maize and wheat fields over the three years of study with the following assumptions being made:

i. That male and female are discrete dependent variables whose means were compared in maize and wheat fields during the three years of study.
ii. There is no connection between observation in the two groups males and females
iii. The males and females are normally distributed in maize and wheat during the three years of study
iv. There is homogeneity of variance of the two groups.

To obtain monthly relative humidity dew point hygrometer readings were taken at four synoptic hours being 0.00, 0.600, 12.00 and 18.00hrs and divided by four to get average for the day. Sum of the daily mean temperatures obtained was divided by number of days per month to get relative humidity for that particular month. Though not used in the study a Psychrometer can also be used to measure air temperature, vapour pressure and relative humidity. Using a psychrometer where two readings were done in a day at 0.600hr and 1200hrs add the two readings divide by two to get day's relative humidity. For monthly relative humidity, mean daily readings were divided by number of days in a month.

Temperature measurements were obtained by use of weather thermometers. Mercury Maximum and Minimum thermometers where two readings maximum daily temperature and minimum daily temperature were read, and the average obtained is the daily mean temperature. To get the temperature at any given time, dry bulb thermometer can be used such that daily mean temperature can be calculated by taking maximum reading plus minimum reading divide by two. The summation of mean daily temperature over the number of days in a month gave us the mean monthly records. Weather thermometers are tools used to measure ambient air temperature in degrees Celsius.

To find out how climatic weather data impact rodent distribution in the habitats of maize and wheat, the climatic ecological parameters of rainfall, relative humidity, and temperatures were compared to total rodent capture, species, and gender for each cropping year. The strength of the link between ecological parameters such as rainfall, relative humidity, and temperatures and populations of species and gender was measured using the Pearson correlation coefficient, as interpreted by Schober *et al*. (2018). While species collected and gender were dependent variables (y), the ecological factors of rainfall, relative humidity, and temperatures were independent variables (x). CRAMER'S V

Pearson product moment correlation formula given as follows:

$$r = \frac{n(\sum xy) - (\sum x)(\sum y)}{\sqrt{[n\sum x^2 - (\sum x)^2][n\sum y^2 - (\sum y)^2]}}$$

Where.

r = Pearson correlation coefficient

n = Number of observations

$\sum xy$ = Sum of the product of x and y values

$\sum x$ = Sum of x values

$\sum y$ = Sum of y values

$\sum x^2$ = Sum of the squared x values

$\sum y^2$ = Sum of the squared y values

Correlation coefficient (r) being a measure of linear relationship or association was used to describe the strength of the association (Pandey and Pandey, 2015; Taylor, 1990), correlation coefficient ranges between negative 1 to positive 1. According to guide by Schober *et al*. (2018) a value range of 0.00 to 0.19 is described as very weak, 0.20 to 0.39 weak, 0.40 to 0.59 moderate, 0.60 to 0.79 strong and 0.80 to 1.0 is very strong.

Poisson regression is a technique utilized in predicting a dependent variable that contains count data with one or more independent variables. The ecological factors in this case were used to predict rodent abundance. Poisson regression analysis was employed to determine how unit change in ecological factors of rainfall, relative humidity and temperature would predict change in response variable rodent relative abundance for the three cropping years.

Poisson regression

$\log \lambda_i = \beta_0 + \beta_1 X_{i1} + \cdots + \beta_n X_{in}$

Where

λ = Dependent variable

$\beta_0 - \beta_n$= Regression coefficients

X_i = Independent variables

The binary logistic regression was utilized in predicting the probability that an observation would be in either of the two categories of a response variable given one or more predictors. In this case, gender was used as the dependent variable and ecological factors that include rain, relative humidity and temperatures as the predictors.

Binary logistic regression formula being,

$$P = \frac{1}{1 + e^{-(\beta_0 + \beta_1 x_1 + \cdots + \beta_n x_n)}}$$

Where

P = Probability of the dependent variable

$\beta_0 - \beta_n$= Parameter estimates

X_i = Independent variables

The multinomial logistic regression was used to establish the relationship between nominal response variable given one or more predictors. In this case, the dependent variable was species given the ecological factors that include rain, relative humidity and temperatures

Multinomial regression formula

$$P(Y = n) = \frac{e^{\beta_n X_i}}{1 + \sum_{n=1}^{n} e^{\beta_n X_i}}$$

Where

P = Probability of the dependent variable

$\beta_0 - \beta_n$= Parameter estimates

X$_i$ = Independent variables

3.6 Accuracy and equipment reliability.

This study used instruments to collect data on weather based ecological factors of rainfall, relative humidity and temperatures that meet international standards. They have been found to give accurate and precise measurements in order to obtain reliable and valid measurements. The Eldoret international airport meteorology provided data that can be verifiable and dependable. The techniques and standard operating procedures for small mammal sampling were used. The Sherman traps have been tested to be efficient and dependable in trapping rodents they are acceptable for capture recapture methods of rodent population studies and many researchers have used and tested their efficiency and are dependable in different contexts many times.

3.7 Ethical considerations

The ethical considerations in the execution of the study included, trap monitoring such that none of the animals captured spent more than 10 hours inside such that animals captured were freed after marking. Humane procedure of handling rodents was done. The study did not expose university of Eldoret farm community to risks of any kind in terms of disposal of research materials used. Hygienic manner of disposal of expendable materials was observed, they were placed in garbage bin then transported to a common collecting point to be disposed by university rubbish collecting department caution was exercised to avoid spillage of waste emanating from refuse e.g., hand gloves. The mode of disposal of waste research material did not expose University of Eldoret farm animals to any form of risk. No plagiarized materials were used. The traps used met the expected standards and requirements for trapping rodent pest species and was approved by institutional research committee for animal research.

CHAPTER FOUR

RESULTS

4.1 Population distribution of myomorph rodent pest among cropping year in Maize and wheat farms in University of Eldoret

Three species of myomorph rodent pests were captured during the study period in maize and wheat fields. These were the Natal Multimammate mouse (*Mastomys natalensis)*, the Nile Rat (*Arvicanthis niloticus)*, and the Typical Striped Grass Mouse (Lemniscomys *striatus.* (Figures 8, 9 and 10). *M. natalensis* was captured throughout the three cropping years in both fields followed by *A.niloticus* and *L. striatus*

Figure 8: Photograph showing *Mastomys natalensis* captured during the study period.

Source: Author, 2022

Figure 9: Photograph showing *Arvicanthis niloticus* captured during the study Period.

Source: Author, 2022

Figure 10: Photograph showing *Lemniscomys striatus* captured during the study period.

Source: Author, 2022

Presented in Tables 1 findings of variation in distribution of myomorph rodents. The numbers of captures for the three species not only varied from year to year but also between maize and wheat farms. The total captures were 924 myomorph rodents, which entailed 57.68 % and 42.32% in maize and wheat farms respectively. The total captures also comprised of 50.97% captures in year one of study, 19.48% representing captures for year two and 29.55% for year three. Presented in Table 2 and 3 is the population and relative abundance of myomorph species for each farm during cropping period.

Table 1: Myomorph rodent population percentage in maize and wheat fields during study period

Habitat	Year1	Year2	Year3	Totals captures	Percentage %
Maize	288(31.17%)	99(10.71%)	146(15.80%)	533	57.68
Wheat	183(19.80%)	81(8.77%)	127(13.74%)	391	42.32
Total captures	471(50.97%)	180(19.48%)	273(29.55%)	924	100

Table 2 : Myomorph rodent population cross tabulation for Habitat * Species * Cropping Years

		Mastomys natalensis	*Arvicanthis niloticus*	*Lemniscomys striatus*	
Year one	Maize	136	149	3	288
	Wheat	122	58	3	183
	Total	258	207	6	471
Year two	Maize	72	27	0	99
	Wheat	57	21	3	81
	Total	129	48	3	180
Year three	Maize	87	59	0	146
	Wheat	88	39	0	127
	Total	175	98	0	273
Total	Maize	295	235	3	533
	Wheat	267	118	6	391
	Total	562	353	9	924

Table 3: Myomorph rodent captures at UoE farms during- the three cropping years

Species	Total rodents captured (924)											
	Maize (533)						Wheat (391)					
	Year 1		Year 2		Year 3		Year 1		Year 2		Year 3	
	T.c	R.a (%)	T.c	R.a (%)	T.c	R.a (%)	T.c	R.a (%)	T.c	R.a (%)	T.c	R.a (%)
M. natalensis	136	47.22	71	71.72	87	59.59	122	66.67	57	70.37	87	68.50
A. niloticus	149	51.74	28	28.28	59	40.41	58	31.69	21	25.93	40	31.50
L. striatus	3	1.04	0.00	0.00	0.00	0.00	3	1.64	3	3.70	0.00	0.00
Total	288	100	99	100	146	100	183	100	81	100	127	100
Total (%)	31.70		10.71		15.80		19.80		8.77		13.74	

T.c = Total captured; R.a = Relative abundance

There was a statistically significant variation in population distribution and relative abundance between the two farms for year one (χ^2 =18.265, df = 2, P = 0.001). The second and third year showed no statistically significant variation in rodent population distribution between the two farms for the three cropping years. The results further revealed there was statistically significant variation in population distribution between the two farms (maize and wheat) for the three cropping years (χ^2 = 19.820, df = 2, P =0.001) as shown in Table 4. Levine test to determine the equality of variances showed that the variances are not significantly different from each other (P= 0.127) and thus homogeneity assumption was met. There was no statistically significant difference in rodent abundance between maize and wheat farms (t =1.722, P= 0.078, df = 168) as shown in table 5.

Table 4: Chi- Square tests for the rodent pest population in three cropping years

Years		Value	df	Sign (2-sided)
Year one	Pearson Chi-Square	18.265[b]	2	0.001
	Likelihood Ratio	18.559	2	0.001
	Linear-by-Linear Association	14.462	1	0.001
	N of Valid Cases	471		
Year two	Pearson Chi-Square	3.732[c]	2	0.155
	Likelihood Ratio	4.856	2	0.088
	Linear-by-Linear Association	0.669	1	0.413
	N of Valid Cases	180		
Year three	Pearson Chi-Square	2.778[d]	1	0.096
	Continuity Correction[e]	2.373	1	0.123
	Likelihood Ratio	2.793	1	0.095
	Fisher's Exact Test			
	Linear-by-Linear Association	2.768	1	0.096
	N of Valid Cases	273		
Total	Pearson Chi-Square	19.820[a]	2	0.001
	Likelihood Ratio	20.028	2	0.001
	Linear-by-Linear Association	12.421	1	0.001
	N of Valid Cases	924		

Table 5 : Homogeneity of variance, Independent t-test for rodent abundance between maize and wheat farms

		F	P-value.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
Rodent abundance	Equal variances assumed	5.010	0.127	1.772	168	0.078	1.241	0.700
	Equal variances not assumed			1.808	134.935	0.073	1.241	0.687

The findings depicted that there was statistically significant difference in rodent abundance among the three cropping years (F = 8.894, P = 0.001, df = 2) as presented in Table 6. The results revealed that there was no statistically significant variation in rodent abundance between the three rodent species (F = 1.047, P =0.353, df = 2) as presented in Table 7.

Table 6: ANOVA for rodent abundance between the three cropping years

	Sum of Squares	df	Mean Square	F	P-value.
Between Groups	343.055	2	171.528	8.894	0.001
Within Groups	3220.733	167	19.286		
Total	3563.788	169			

Table 7: ANOVA for rodent abundance between the three species

Sum of Squares	df	Mean Square	F	P-value
44.143	2	22.071	1.047	0.353
3519.646	167	21.076		
3563.788	169			

The trend analysis and forecasting with time series model depicted that there was abundance of rodent pests between the months of March to May, declining between May to July, then increasing from September to November and finally declining to January during the three-year circle. The model predicted that there would be a higher abundance of rodents between the months of May and July and declining to November (Figures 11 and 12). The population trends vary from year to year over the three years.

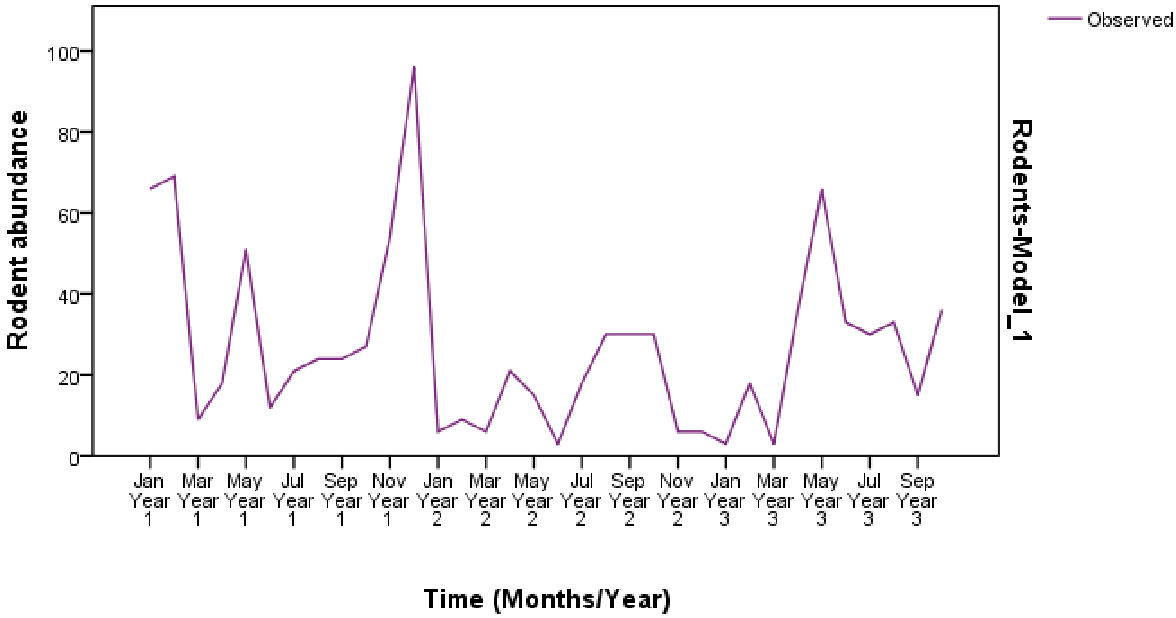

Figure 11: Trend analysis for rodent abundance versus time during the three cropping years

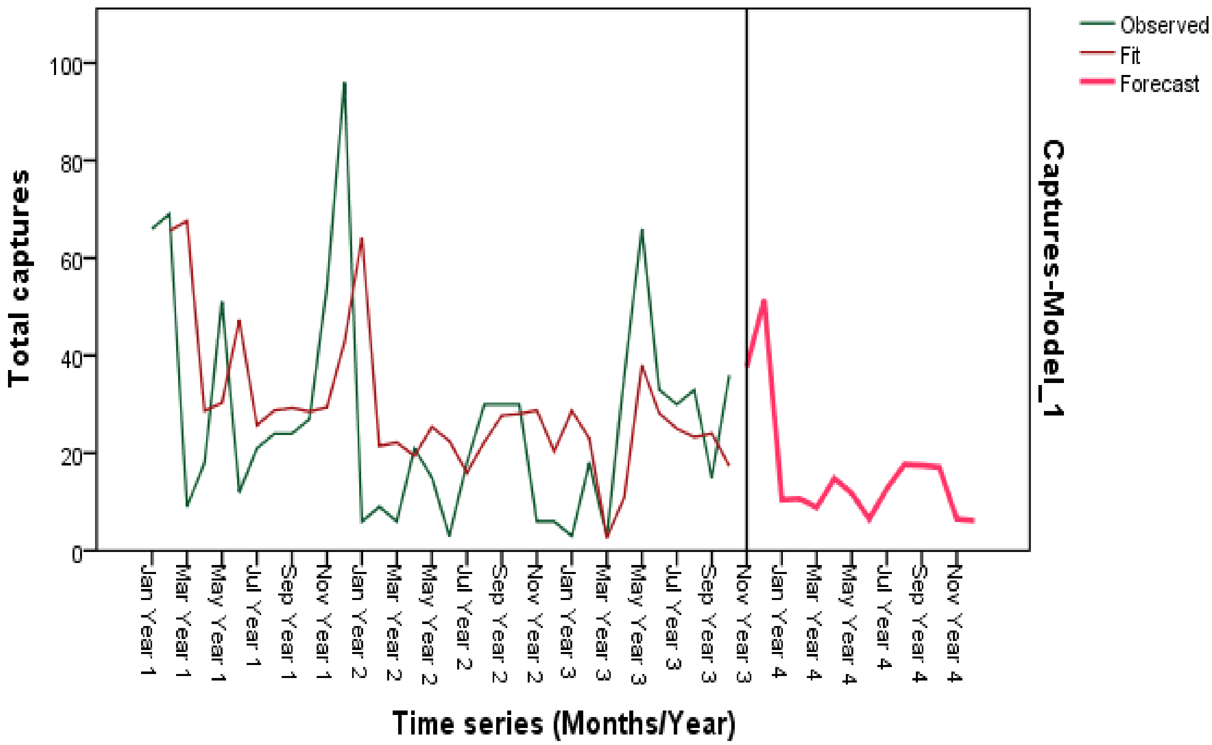

Figure 12: One year forecast using regression model with ARIMA (1, 1, 1) (2, 0, 0) for the rodent population

4.2 The myomorph rodent species distribution in Maize and Wheat fields

The findings to determine myomorph rodent species distribution in maize and wheat fields are presented in Table 8. The number of captures for the three species varied from year to year and between the two fields.

The most dominant rodent species trapped was *Mastomys natalensis*, which was higher in maize fields than wheat fields, followed by *Arvicanthis niloticus* and then *Lemniscomys striatus* being a rare species during this particular period of study. The myomorph rodents were randomly distributed in the two fields. *Mastomys natalensis* with a 55.16% dispersion in maize and 68.03% in wheat making 60.61% of rodents captured during the study period. *Arvicanthis niloticus* showed a 44.28% dispersion in maize and 30.43% in wheat accounting for 38.42% of total rodents captured. The least captured rodent was *L. striatus* at 0.56% in maize and 1.54% wheat accounting for only 0.97% of total population captured. There were more incidences of *M. natalensis* than *A. niloticus* and *L. striatus* in maize than in wheat fields. *Lemniscomys striatus* was a rare species compared to the other two species where it was only captured once in maize and wheat fields in year one and year two and once in wheat during the study period. The results depicted that only *Arvicanthis niloticus* species turned out to be independent of cropping year and crop type (χ^2 = 6.805, df = 2, P = 0.033) as shown in Tables 9 and 10.There was no consistency in the trend of rodent population distribution in the two fields of maize and wheat as shown in Figures 13 and 14.

Table 8: Myomorph rodent species in maize and wheat fields (agro-habitats)

Species	Habitat					
	Maize		Wheat		Total	
	Count	Row N %	Count	Row N %	Count	Row N %
M. natalensis	295	55.16	267	68.03	560	60.61
A. niloticus	236	44.28	118	30.43	355	38.42
L. striatus	3	0.56	6	1.54	9	0.97
Total	533	100	391	100	924	100

Table 9: Cross tabulation for Species* Habitat * Cropping Years

		Year one	Year two	Year three	Total
M. natalensis	Maize	136	72	87	295
	Wheat	122	57	88	267
	Total	258	129	175	562
A. niloticus	Maize	149	27	59	235
	Wheat	58	21	39	118
	Total	207	48	98	353
L. striatus	Maize	3	0	0	3
	Wheat	3	3	0	6
	Total	6	3	0	9
Total	Maize	288	99	146	533
	Wheat	183	81	127	391
	Total	471	180	273	924

Table 10: Chi-Square tests between species, habitat and cropping years.

Species		Value	df	Sign. (2-sided)
Mastomys natalensis	Pearson Chi-Square	1.117[b]	2	0.572
	Likelihood Ratio	1.118	2	0.572
	Linear-by-Linear Association	0.281	1	0.596
	N of Valid Cases	0562		
Arvicanthis niloticus	Pearson Chi-Square	6.805[c]	2	0.033
	Likelihood Ratio	6.745	2	0.034
	Linear-by-Linear Association	5.021	1	0.025
	N of Valid Cases	353		
Lemniscomys striatus	Pearson Chi-Square	2.250[d]	1	0.134
	Continuity Correction[e]	.563	1	0.453
	Likelihood Ratio	3.139	1	0.076
	Fisher's Exact Test			
	Linear-by-Linear Association	2.000	1	0.157
	N of Valid Cases	9		
Total	Pearson Chi-Square	4.821[a]	2	0.090
	Likelihood Ratio	4.823	2	0.090
	Linear-by-Linear Association	4.503	1	0.034
	N of Valid Cases	924		

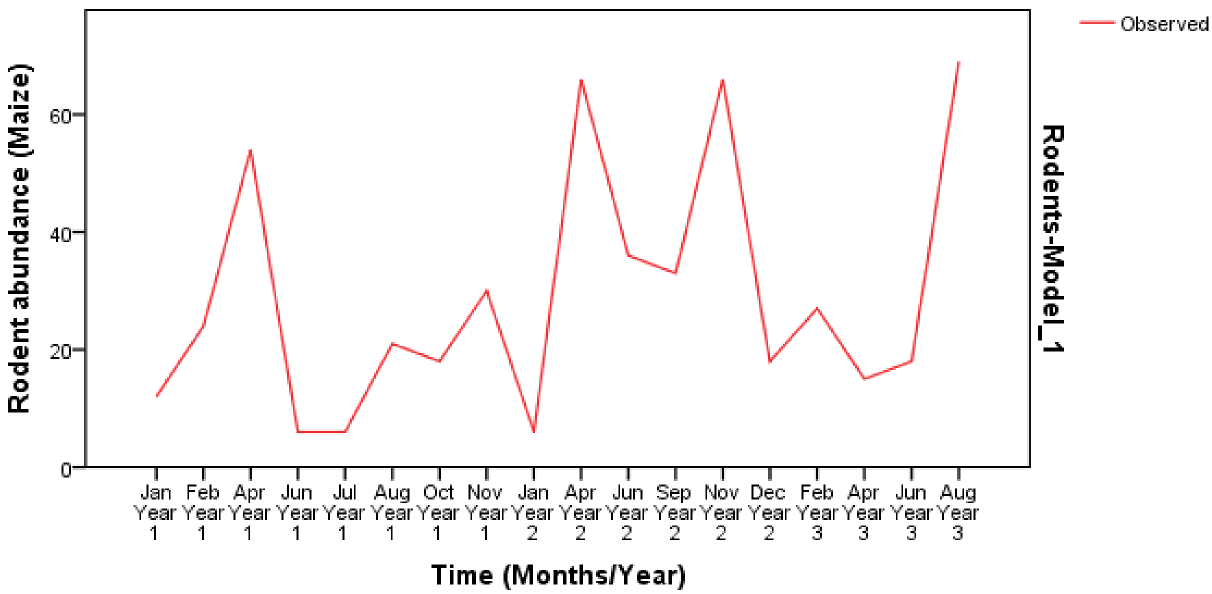

Figure13: Trend analysis for myomorph rodent abundance in maize farms versus time

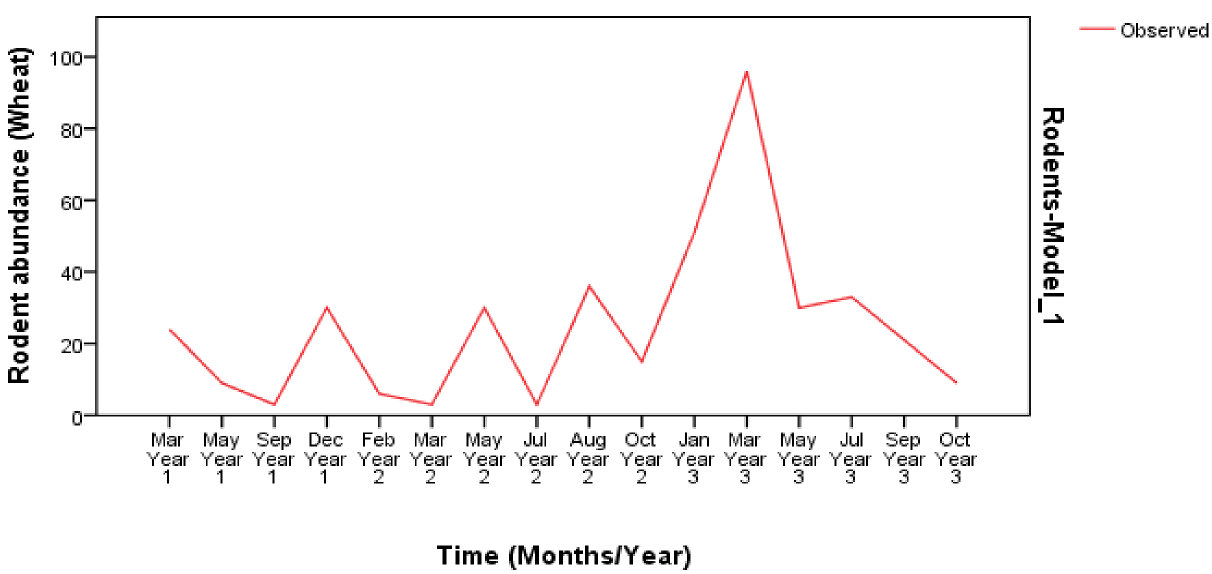

Figure14: Trend analysis for myomorph rodent abundance in wheat farms versus time

There was no consistency in distribution of each identified species captured in maize and wheat fields over the study period as shown in Figures 15, 16, and 17.

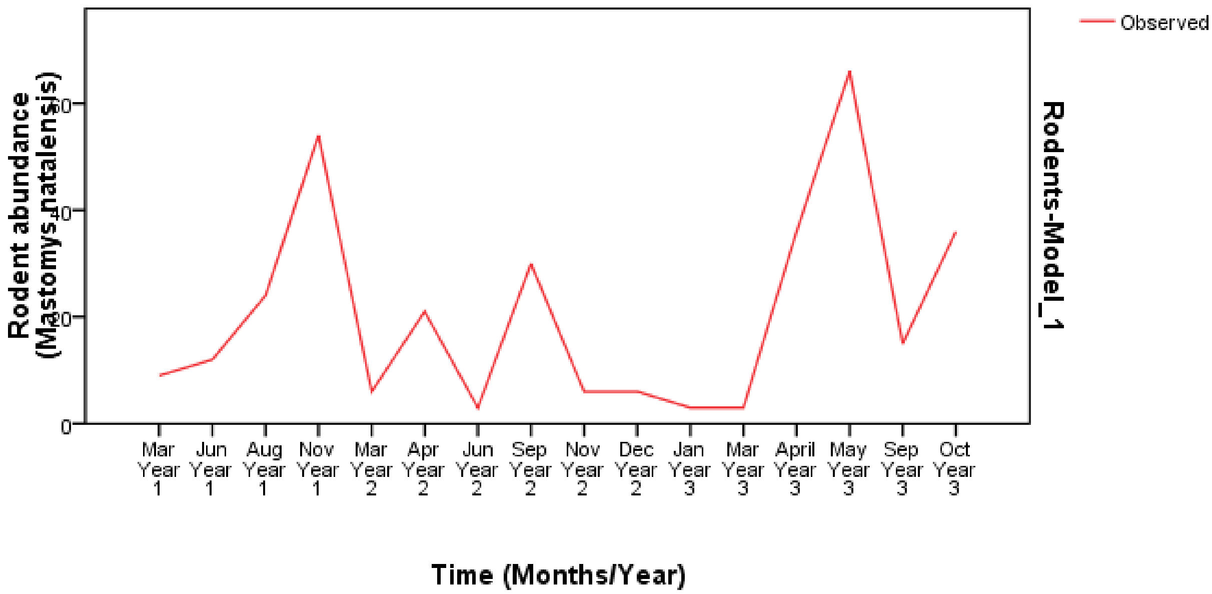

Figure15: Trend analysis for *Mastomys natalensis* abundance versus time

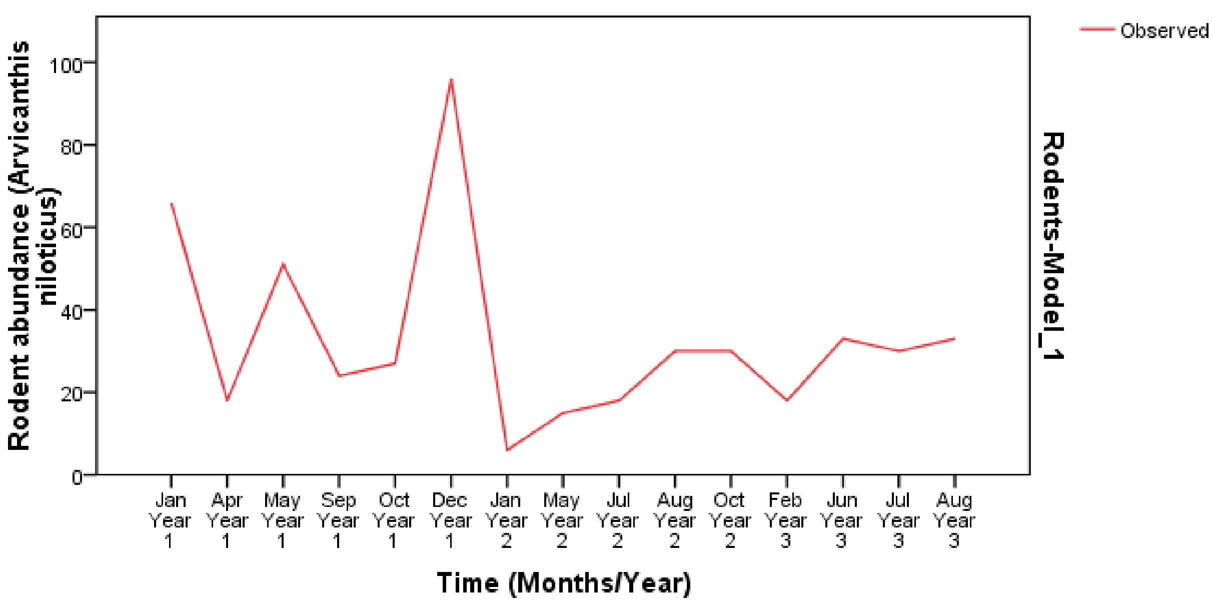

Figure16: Trend analysis for *Arvicanthis niloticus* abundance versus time

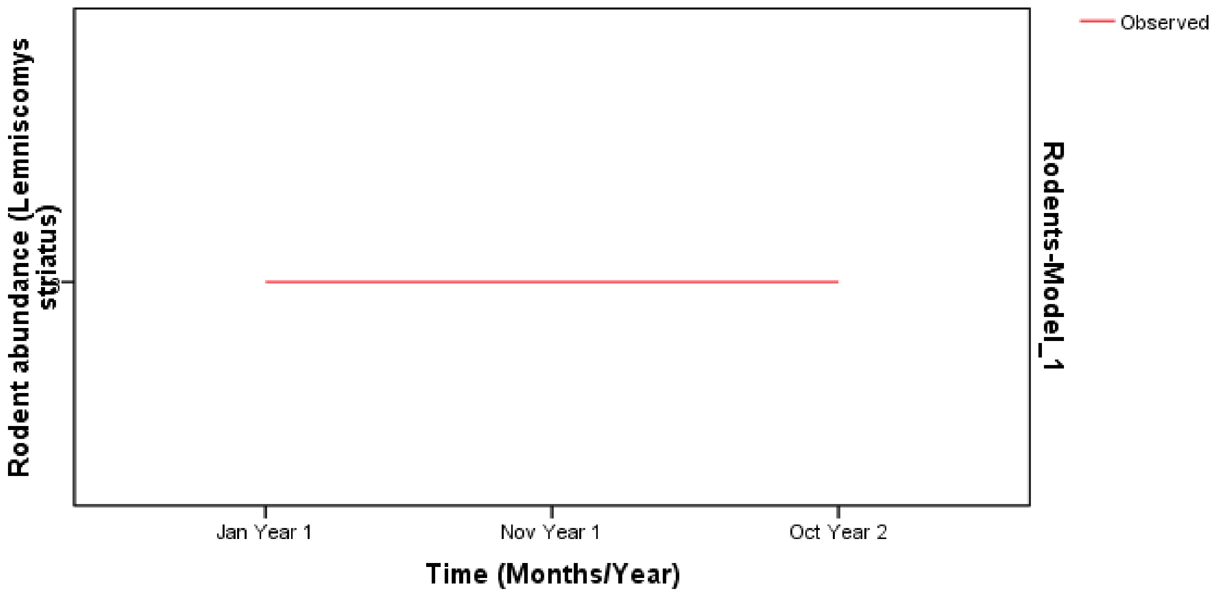

Figure 17: Trend analysis for *Lemniscomys striatus* abundance versus time

In year one, there was a statistically significant difference in distribution of rodent species in maize and wheat agro-habitats, (t (469) = 3.86, P = 0.001). In year two there was no statistically significant difference in distribution of myomorph rodent pests in maize and wheat fields, (t (178) = -0.677, P =0.499). Similarly, in year three there was no statistically significant difference in the rodent species distribution in maize and wheat fields, (t (271) =1.529, P = 0.127). The overall findings showed that there was a statistically significant difference in rodent abundance and species richness of myomorph rodents in maize and wheat fields, (t (469) = 3.523, P = 0.001; Table 11).

Table 11: Independent t-test between myomorph rodent species and habitat

	t-value	DF	P-value	Mean Difference	S.E Difference
Year one	3.86	469	0.001	0.188	0.049
Year two	-0.677	178	0.499	-0.051	0.075
Year three	1.529	271	0.127	0.089	0.058
Overall	3.523	922	0.001	0.119	0.034

The findings indicated that there was no statistically significant variation in abundance of *Mastomys natalensis* between maize and wheat farms in the three cropping years as shown by the p-values ($P > 0.05$) as shown in Table 12

Table 12 : Independent t-test for abundance of *Mastomys natalensis* between maize and wheat farms in the three cropping years

			F	Sig.	t	df	P-value	Mean Difference	Std. Error Difference
Year one	Rodent abundance	Equal variances assumed	0.507	0.482	0.847	32	0.403	1.604	1.894
		Equal variances not assumed			0.827	25.458	0.416	1.604	1.940
Year two	Rodent abundance	Equal variances assumed	1.084	0.306	0.321	31	0.750	0.200	0.623
		Equal variances not assumed			0.333	29.718	0.742	0.200	0.601
Year three	Rodent abundance	Equal variances assumed	1.061	0.312	0.407	28	0.687	0.589	1.448
		Equal variances not assumed			0.393	20.349	0.698	0.589	1.498

The results revealed that there was no statistically significant variation in abundance of *Arvicanthis niloticus* between maize and wheat farms in the three cropping years as presented in Table 13.

Table 13: Independent t-test for *Arvicanthis niloticus* abundance between maize and wheat farms in the three cropping years

			F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
Year one	Rodent abundance	Equal variances assumed	5.273	0.129	1.568	29	0.128	3.949	2.519
		Equal variances not assumed			1.792	21.901	0.087	3.949	2.204
Year three	Rodent abundance	Equal variances assumed	8.747	0.218	1.507	21	0.147	1.205	0.799
		Equal variances not assumed			1.548	16.656	0.140	1.205	0.778

There was no mean comparison for *Lemniscomys striatus* abundance between maize and wheat farms due to low rodent captures hence the independent t-test not be computed.

4.3 Rodent gender distribution of identified rodent species in maize and wheat farms for the three cropping years

Table 14 compares disparity in gender distribution per species in maize and wheat fields during the three-year study period. The findings indicate that in year one under the maize field, male *Arvicanthis niloticus* were the most prevalent (52.1%) than females (50.7%) followed by *Mastomys natalensis* which comprised 46.5% of males and females 49.2%. *Lemniscomys striatus* species had the lowest prevalence in year one, which entailed 1.37% males with no female captures. In year two under the maize field, Male *M. natalensis* were the most abundant at 78.6% and females at 60.5% followed by *A. niloticus* with 21.3%as males and 39.4% females. In year three, under the maize field, males of *M. natalensis* were most abundant at 53.9% and females 68.4% followed by males A. *niloticus* at 461% and females at 31.5%.

Table 14: Gender distribution per rodent species from maize and wheat farms for the three cropping years

Species	Total rodents captured											
	Maize						Wheat					
	Year 1		Year 2		Year 3		Year 1		Year 2		Year 3	
	M Count (%)	F Count (%)	M Count (%)	F Count (%)	M Count (%)	F Count (%)	M Count (%)	F Count (%)	M Count (%)	F Count (%)	M Count (%)	F Count (%)
M. natalensis	102 46.5	34 49.2	48 78.6	23 60.5	48 53.9	39 68.4	49 62.3	73 74.2	30 76.9	27 64.2	44 66.6	43 70.4
A. niloticus	114 52.0	35 50.7	13 21.3	15 39.4	41 46.0	18 31.5	17 25.7	41 35.0	9 23.0	12 28.5	22 33.3	18 29.5
L. striatus	3 1.3	0.0	0.00	0.00	0.00	0.00	0.00	3 2.5	0.00	3 7.1	0.00	0.00
Total	219 100	69 100	61 100	38 100	89 100	57 100	66 100	117 100	39 100	42 100	66 100	61 100

F= Female count M= Male count

On the other hand, in the wheat fields, *M. natalensis* had higher number of female being 74.2% and males 62.3% of males captured during the year one, followed by *A. niloticus* species that had females 35.0% and 25.7% males and *L. striatus* species had the lowest abundance with only females 2.5% of females captured. In year two of study, *M. natalensis* species was higher with a number being males 76.9% and females 64.2% followed by *A. niloticus* species that had males 23.1% and 28.5% females, and *Lemniscomys striatus* species had only female 7.1% captured. In year, three *M. natalensis* was higher with a number being males 66.6% and females 70.4% followed by *A. niloticus* males 33.3% and 29.5% females, and *L. striatus* species was not captured in wheat during the third year. On overall there were more males 58.4% captured than females 41.5%. There were more males of *M. natalensis* (59.4%) followed by *A. niloticus* (40%) and then *L. striatus* (0.6%) than females *M. natalensis* (62.2%), *A. niloticus* (36.2%) and *L. striatus* (1.6%) as shown in Table15.

Table 15: Myomorph rodent gender in maize and wheat habitats

Species	Habitat					
	Maize		wheat		Total	
	Count/males	Row N %	Count/female	Row N %	Count	Row N %
M. natalensis	321	59.4	239	62.2	560	60.6
A. niloticus	216	40.0	139	36.2	355	38.4
L. striatus	3	0.6	6	1.6	9	1.0
Total	540	100	384	100	924	100

There was statistically significant difference in distribution and abundance between the male and female rodents captured during the three cropping period, (t = 2.440, P = 0.016 df = 168).Table 16. The findings revealed that among the male rodents, there was statistically significant variation in population distribution between the maize and wheat farms (t = 2.16, P = 0.034 df = 83) as compared to female rodents who had no statistically significant variation in population distribution between the two farms (t = -0.84, P = 0.405 df = 83) as shown in Table 17. The gender distribution and abundance is independent of cropping years and agro habitat as shown in Tables 18. The findings presented in Table 19 revealed that the male rodents were independent of both the crop type and cropping years (χ^2 = 20.553, df = 2, P = 0.001). Both the male and female rodents showed varied trends in abundance and distribution over the three cropping years of study (Figures 18 and 19)

Table 16: Independent t-test for myomorph rodent abundance between male and female rodents

		F	Sig.	t	df	P-value	Mean Difference	Std. Error Difference
Rodent abundance	Equal variances assumed	8.260	0.105	2.440	168	0.016	1.694	0.694
	Equal variances not assumed			2.440	122.784	0.016	1.694	0.694

Table 17: Independent t-test for male and female rodents abundance between maize and wheat farms

			F	Sig.	t	df	P-value	Mean Difference	Std. Error Difference
M	Rodent abundance	Equal variances assumed	7.827	0.206	2.16	83	0.034	2.658	1.233
		Equal variances not assumed			2.39	69.29	0.019	2.658	1.108
F	Rodent abundance	Equal variances assumed	2.342	0.130	-0 .84	83	0.405	-0.518	0.619
		Equal variances not assumed			-0.85	82.98	0.398	-0.518	0.610

M= Male F= Female

Table 18: Cross tabulation for Gender * Habitat* Cropping years

		Year one	Year two	Year three	Total
Male	Maize	219	61	89	369
	Wheat	66	39	66	171
	Total	285	100	155	540
Female	Maize	69	38	57	164
	Wheat	117	42	61	220
	Total	186	80	118	384
Total	Maize	288	99	146	533
	Wheat	183	81	127	391
	Total	471	180	273	924

Table 19: Chi-Square Tests between gender, habitat and cropping years

Gender		Value	df	Sign. (2-sided)
Male	Pearson Chi-Square	20.553[b]	2	0.001
	Likelihood Ratio	20.607	2	0.001
	Linear-by-Linear Association	19.127	1	0.001
	N of Valid Cases	540		
Female	Pearson Chi-Square	4.655[c]	2	0.098
	Likelihood Ratio	4.668	2	0.097
	Linear-by-Linear Association	4.055	1	0.044
	N of Valid Cases	384		
Total	Pearson Chi-Square	4.821[a]	2	0.090
	Likelihood Ratio	4.823	2	0.090
	Linear-by-Linear Association	4.503	1	0.034
	N of Valid Cases	924		

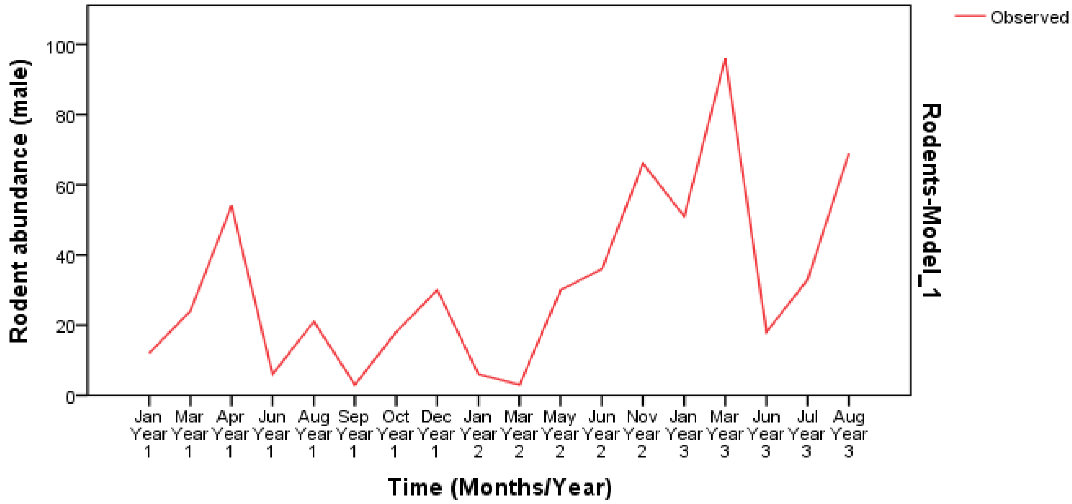

Figure 18: Trend analysis for male rodent abundance versus time

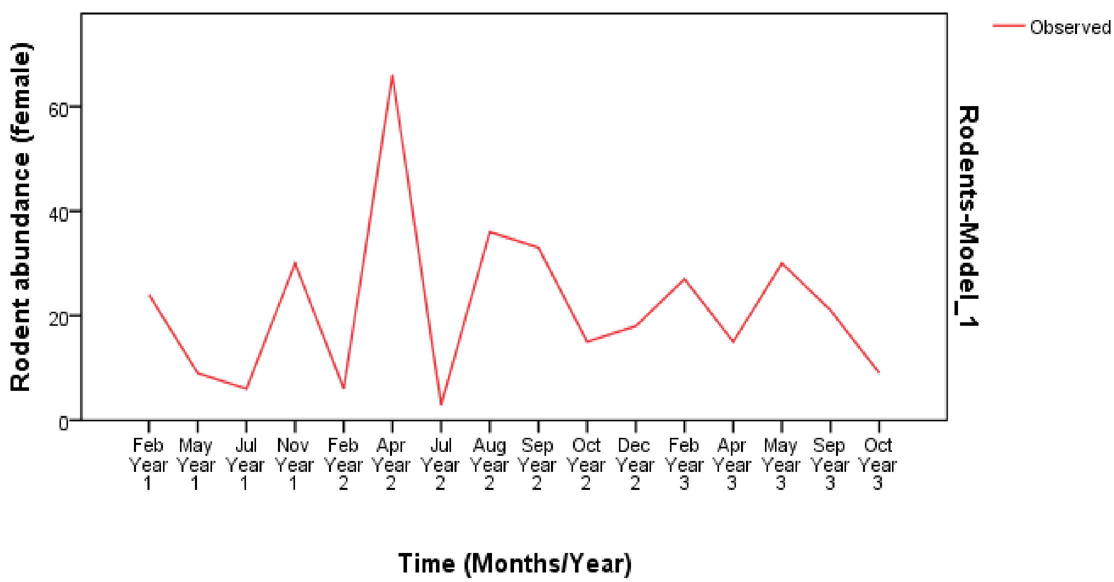

Figure 19: Trend analysis for female rodent abundance versus time

The results revealed that both male and female rodents were independent of crop type and species (χ^2 = 17.912, df = 2, P = 0.001) and (χ^2 = 6.913, df = 2, P = 0.032) respectively.

It is worth noting that it is clear that gender is independent of both the crop type and species (χ^2 = 19.820, df = 2, P = 0.001) as shown in Table 20 and Table 21.

Table 20: Cross tabulation for gender, species and habitat

		M. natalensis	*A. niloticus*	*L. striatus*	Total
Male	Maize	198	168	3	369
	Wheat	124	47	0	171
	Total	322	215	3	540
Female	Maize	97	67	0	164
	Wheat	143	71	6	220
	Total	240	138	6	384
Total	Maize	295	235	3	533
	Wheat	267	118	6	391
	Total	562	353	9	924

Table 21: Chi-Square Tests between gender, species and habitat

Gender		Value	Df	Sign. (2-sided)
Male	Pearson Chi-Square	17.912[b]	2	0.001
	Likelihood Ratio	19.242	2	0.001
	Linear-by-Linear Association	17.844	1	0.001
	N of Valid Cases	540		
Female	Pearson Chi-Square	6.913[c]	2	0.032
	Likelihood Ratio	9.109	2	0.011
	Linear-by-Linear Association	.340	1	0.560
	N of Valid Cases	384		
Total	Pearson Chi-Square	19.820[a]	2	0.001
	Likelihood Ratio	20.028	2	0.001
	Linear-by-Linear Association	12.421	1	0.001
	N of Valid Cases	924		

4.4 Determination of the influence of weather -based ecological factors of rainfall, relative humidity, and temperature on distribution of rodent pest population, species and gender in maize and wheat fields.

4.4.1 Relationship between weather- based ecological factors and populations, species abundance and gender.

No variation in captures was observed based on weather -based ecological factors of rainfall, relative humidity and temperature (Appendices V, VI and VII). However, there was a strong positive correlation between rainfall and gender in year one (r (df) = 0.17, P = 0.001; N=471). In second year, there was a negligible negative linear correlation between rainfall and gender showing a linear inverse relationship that was not statistically significant between the two variables ((r (df) = -0.06, P = 0.443; N=180). There was also a very weak negative correlation between rainfall and gender distribution in year three with no statistically significant correlation (r = -0.05, P = 0.453; N=273; Table 22).

A very weak positive linear correlation was observed for the relationship of humidity and gender in year one with a statistically significant difference between the two variables (r = 0.20, P = 0.001; N=471). In year two (r =-0.09, P = 0.220; N=180 and three (r = -0.05, P = 0.448 N =273), a negative correlation existed between relative humidity and gender with year-to-year variation. A very weak positive correlation was observed between temperature and gender distribution in year one (r (df) =0.06, P = 0.225; N= 471) and year two (r (df) =0.09, P = 0.214 N=180). In year three, the correlation was a very weak negative one (r(df) =-0.05, P = 0.449 N=273).

Table 22: Correlation Analysis between weather based ecological factors and gender

Covariates	Pearson Correlation	Year 1 Gender	Year 2 Gender	Year 3 Gender
Rainfall	r-value	0.17**	-0.06	-0.05
	P-value	0.001	0.443	0.453
	N	471	180	273
Relative Humidity	r-value	0.20**	-0.09	-0.05
	P-value	0.001	0.220	0.448
	N	471	180	273
Temperatures	r-value	0.06	0.093	-0.05
	P-value	0.225	0.214	0.449
	N	471	180	273

**. Correlation is significant at the 0.05 level (2-tailed).

A very weak negative linear correlation existed between rainfall and species distribution during this study for the three years. (r (df) = -0.04, P = 0.388; N=471; r(df) =0.04, P = 0.952 N=180; r(df) = -0.01, P = 0.836; N=273). No statistically significant difference was observed between rainfall and species (P > .01). A very weak positive linear relationship existed between relative humidity and species distribution in the three years of study (r(df) =0.06, P= 0.213 N=471; r(df) =0.03, P = 0.687 N=180; r(df) =0.02, P = 0.749 N=273). No statistically significant difference existed between relative humidity and species (*P* > .01). Relative humidity had minimal effect on species distribution of myomorph rodents that infested fields at University of Eldoret. A very weak negative correlation also existed between temperatures and species (r(df) =-0.003, P =0.940 N=471; r(df) =-0.03, P= 0.655 N=180; r(df) =-0.001, P = 0.986 N=273). Temperature change had an inverse effect on species distribution with no statistically significant variation (P = 0.986). (Table 23)

Table 23: Correlation Analysis between ecological factors and species

Covariates	Pearson Correlation	Year 1 Species	Year 2 Species	Year 3 Species
Rainfall	r-value	-0.04	0.004	-0.01
	P-value	0.388	0.952	0.836
	N	471	180	273
Relative Humidity	r-value	0.06	0.03	0.02
	P-value	0.213	0.687	0.749
	N	471	180	273
Temperatures	r-value	-0.003	-0.034	-0.001
	P-value	0.940	0.655	0.986
	N	471	180	273

**. Correlation is significant at the .01 level (2-tailed).

4.4.2. Poisson regression analysis of myomorph rodent population abundance and ecological factors

Poisson regression model was employed to determine the effect of ecological factors on rodent abundance for the three cropping years. Rainfall and relative humidity showed no significant difference in predicting the rodents population (β = 1.000, P> 0.05 and β = 0.993, P>0.05) for rainfall and relative humidity respectively (Table19). It is worth noting that among all the ecological factors, only temperature (β = 0.667, P = 0.001) turned out to be statistically significant. This meant that the number of rodents would decrease by 66.7% with each unit increase in temperature (Table24)

The Goodness of Fit test provided a number of measures used to determine how well the Poisson model fits. The value of deviance (1.025) depicted in the Appendix VIII is a clear indication that the assumption of equidispersion was not violated.

The Omnibus Test is a likelihood ratio test that assess if all the independent variables boost the model over the intercept model. It tests whether the variance within the data set is significantly greater than the unexplained variance as a whole. The P-value (0.001) indicated that the model was statistically significant (Appendix IX)

Table 24: Poisson regression between rodent abundance and ecological factors

Parameter	beta	SE	Wald Chi-Square	df	P-value	Exp(B)
(Intercept)	10.685	.9981	114.612	1	0.001	43700.828
Rain	0.000	.0005	.422	1	0.516	1.000
RH	-0.007	.0049	2.184	1	0.139	0.993
Temp	-0.409	.0547	55.998	1	0.001	0.664
(Scale)	1[a]					

Table 25: Final Poisson regression between rodent abundance and ecological factors

Parameter	beta	SE	Wald Chi-Square	df	Sig.	Exp(B)
(Intercept)	10.207	0.8901	131.509	1	0.001	27096.162
Temp	-0.409	0.0523	59.660	1	0.001	0.667
(Scale)	1[a]					

4.4.3. Binary logistic regression

The binary logistic regression was utilized in predicting the probability that an observation would be in either of the two categories of a response variable given one or more predictors. In this case, gender was used as the dependent variable and ecological factors that include rain, relative humidity and temperatures as the predictors. The model summary table was used in determining how much variation in the response variable can be explained in the model. According to Nagelkerke R^2 = 0.317, then it is clear that the model could account for 31.7% of the total variation in the rodents gender (Table 26).

Table 26: Model Summary

Step	-2 Log likelihood	Cox & Snell R Square	Nagelkerke R Square
1	242.718[a]	.213	0.317

The binary logistic regression ascertained the effect of ecological factors on gender distribution. According to the findings, it is only relative humidity (β = 1.022, P = 0.039) that turned out to be statistically significant. This implied that relative humidity was associated with the likelihood of increase in gender distribution of rodents by 1.022 times. The significant variable in determining the gender distribution is relative humidity (Table 27 and Table 28)

Table 27: Logistic regression between gender and ecological factors

	B	S.E.	Wald	df	P-value	Exp(B)	95% C.I.for EXP(B) Lower	Upper
Rain	.000	.001	.116	1	0.733	1.000	.998	1.002
RH	.022	.011	4.264	1	0.039	1.022	1.001	1.044
Temp	.107	.121	.785	1	0.376	1.113	.879	1.409
Constant	-3.461	2.234	2.400	1	0.121	.031		

Table 28: Final Logistic regression between gender and ecological factors

	B	S.E.	Wald	df	Sig.	Exp(B)	95%C.I.for EXP(B) Lower	Upper
RH	0.022	0.006	10.692	1	0.001	1.022	1.008	1.032
Constant	-1.548	0.377	16.869	1	0.001	0.213		

CHAPTER FIVE

DISCUSSION

5.1 Variations in infestation levels of myomorph rodent pest population among cropping years in maize and wheat farms of University of Eldoret

This study presents the findings on myomorph rodent species that infested agricultural commercial farms in University of Eldoret. Three species of rodents were captured and recorded in both maize and wheat farms they included *Mastomys natalensis, Arvicanthis niloticus* and *Lemniscomys striatus*. Capturing and identifying lower number of species is not isolated to present study. Similar low species were captured and identified in cultivated farmland in Ethiopia by Shenkut and Balakrishnan, (2006) where *Mus* species, *Mastomys natalensis* and *Arvicanthis niloticus* were encountered. *Mastomys natalensis* was the most dominant species of the rodents captured in both maize and wheat. Although only these three species were identified in University of Eldoret farms, other researchers reported presence of more species in Kenya, other regions of E. Africa, Africa and other regions of the world (Taylor, 1968; Oguge *et al*., 1983; Singleton, 2003). Same species were reported among others in earlier studies in Kenya where they cause damage to cereals as reported by Odhiambo and Oguge, (2003) in Nakuru area, rift valley Kenya and Ognakossan *et al*. (2018) in Kwale coastal region. The possible cause of low numbers in the study area include reduced number of nesting sites and reduced bushes, reduced agricultural land to increased residential real estate developed land and intense surveillance in study area with a possibility of elimination of myomorph near settled areas. This is reflected deliberate human activities especially use of rodenticides, snap trapping to reduce and eradicate rodent pests. Similar studies have been carried out in agricultural land where presence of diverse crops would favor rodent population increase and species diversity (Mayamba, 2020). Each species is usually found where it can derive its basic requirements for food, shelter and locate mate for reproduction and where a species can be as adaptive as possible to escape predators. Maize and wheat farms provided a habitat or site where the three-myomorph rodent pests could reside. The three types of rodent species captured in current study are in line with other studies done in most parts of sub-Saharan Africa where they were captured and identified as among important agricultural rodent pest species (Makundi *et al*., 2007; Mulungu, 2017; Swanepoel *et al*., 2017; Mayamba, 2020). *Arvicanthis niloticus* which is a grass rat and *L. striatus* a striped grass mouse were least captured. Rodent pest population infestation and distribution varied in maize and wheat fields from year to year during this study, with significant difference in distribution between year one but no difference in subsequent years.

The Pearson chi square test were carried out after meeting requisite assumptions and which led to showing a statistically significant variation. The tests are accurate in obtaining significant levels especially with few observations. The tests are over conservative, have correct coverage, and therefore prove that the population abundance varied during study period. The probability of normal distribution was the same in the two farms during the three years of study. Rodents being highly mobile animals, they move from place to place in search of food, shelter herbage and nesting sites. Lack of sustainable ecological niche could encourage immigrations into the study area. There being no identifiable barrier to rodent migration the pattern of distribution could have been different in maize and wheat farms since each field provides a unique local ecological environment. This was not observed in this study possibly because of a common trend in surveillance in both maize and wheat fields that could lead to toxic environment for rodent pests. Some of the chemicals used as biocides for example herbicide not only eradicate weeds but are toxic to rodents. Some of the biocides could also be allergens to rodents causing negative impact on rodent species survival. Although the climatic conditions remained almost similar, where population was expected to be high due available resources like food and mate that would have resulted in high fecundity the population remained low. Some of the activities that could have contributed to low populations may be fields were kept clear of weeds which constituted parts of the components of the habitat used as hiding place and because of frequent weeding, tunnels and burrows which acts as nesting sites were destroyed through machine cultivation of the land. This could also be attributed intense surveillance and use of herbicide to clean the fields making environment toxic for rodent survival. Frequent use of biocides used to control weeds and other pests may lead to high toxic levels in maize and wheat grains fed on by myomorph rodents leads to their mortality thus reducing their populations. Rodent species, according to Jurisic *et al*. (2022), cause a wide range of material losses in agriculture, forestry, storage facilities, and households through their natural feeding activities and behavior that result in damage and a decrease in crop yields. Damage to seeds, seedlings, and grains prompts intensive surveillance and action to reduce rodent population.

These species are not peculiar to the findings of this study because some have been identified as pests of crops in Tanzania by Makundi *et al.* (1999), and in Kenya by Ochilo *et al.* (2018), whereby these species caused damage to cereals. Identification of these species in maize and wheat farms during this study agrees with the findings by Ognakossan, (2017) whereby these rats and mice are pests that destroy cereals before and after harvest. They have been cited as most common species responsible for post-harvest crop damage by Fall, (2011). *M. natalensis* has also been reported as most important agricultural pest in Sub Saharan Africa, by Solveig Vibe-Paterson *et al*. (1999) and in Uganda by Mayamba *et al.* (2019). Rodents are major pests of agricultural crops and *Mastomys* species and *Arvicanthis* species are very common in Africa. The genera *Mastomys* and *Arvicanthis* have been identified by Wondifraw *et al*. (2021) as pests in maize fields of Central and Northern Ethiopia. Wondifraw *et al*. (2021) reported rodent pests in four African countries being Tanzania accounting for 24.69%, Nigeria 8.64%, Ethiopia 8.64%, and Kenya 8.02%. The rodent pests species captured in this study are not unique as same species have been identified and even classified as evasive species on some tropical Islands such as Hawaii in Hawaiian island, Ifaluk Caroline Island, Guadeloupe in Caribbean and Diego Garcia in Indian Ocean, (Harper and Bunbury 2015). *Arvicanthis* and *Mastomys* genera have been reported as most abundant rodent pest that cause heavy damage on wheat and barley when the crop was at milky and fruiting stage and just before harvest (Meheretu *et al*., 2013).

ARIMA regression model for forecasting rodent population predicted more rodent pests in months of March and July and decline in November to January each year. Higher populations observed in March coincided with planting seasons when maize seeds are in the fields and July when peaks of rainfall that contributes to increased weedy vegetation in fields provided both food for rodents. In November, all maize and wheat fields had been harvested from farms and therefore decline in population could be attributed to clearance of the fields and absence of grains. The study provides insights of rodent population abundance with predictions and trends of increase and decrease over time. Farmers and scientists can adopt this information so that they can put in place strategies for myomorph rodent species population management especially in anticipation of rodent population explosion. These species can be widespread in the surrounding fields and their number could increase and contribute to damage and loss of crop if environmental conditions in university of Eldoret maize and wheat farms could favor their high rate of reproduction and survival.

5.2 Myomorph rodent species distribution in maize and wheat fields in University of Eldoret

A total of 924 myomorph rodents were captured during the study period with 50.97%, 19.48% and 29.55% captures in year one, two and three, respectively. *Mastomys natalensis* was most abundant in maize than wheat followed by *A. niloticus* and then L. *striatus*. The findings indicate that *L. striatus* was more abundant in wheat than maize this probably could be because *Lemniscomys striatus* is typically a grass mouse would prefer short wheat grass habitat than maize. There was variation in species distribution during the period of study with rodent species showing negative correlations in terms of species and habitat with no statistically significant difference in year two and positive correlation in year one and year of study. The pooled three-year observation of the difference in distribution between maize and wheat for the three species overall findings showed that there was a significant difference in distribution of myomorph rodents pest species in the two crops. The rodent species populations differed significantly between year one, year two and year three with *M. natalensis* and *A. niloticus* showing preference for maize field than wheat and *L. striatus* being least captured. Abundance and distribution of small mammals depends on nature and density of vegetation that in turn influences food and shelter. In their studies, Barnnet *et al.* (2000) reported single species of *L. striatus* that preferred grassland with dense undergrowth in a fallow rice field. Low captures and species diversity in the current study could be attributed to low density of vegetation cover (weeds) therefore limited cover exposing rodents to natural enemies. The rodent pests were not only limited in species richness but also the abundance of the either identified species were limited. The variation in rodent population observed in the three years could be attributed to annual variation in available resources like food, regular ploughing interfering with availability of shelter for nesting ground and environmental changes due to and probably rodent poor adaptability to changes in the habitat. The observed year-to-year variations in small rodent abundance in current study agrees with the studies reported by Leirs, (1992) that rodent populations are highly dynamic and are influenced by a number of factors including, rainfall, which has an impact on vegetation growth and human activities. Human activities on the maize and wheat farm could have interfered with rodent reproductive behaviour that could have contributed to low populations observed in this study. Low incidences of these species in maize and wheat farms may reflect a frequent clearance of weeds and general vegetation ground cover through weeding. Regular use of herbicides that leads to lack of weeds and reduced nesting sites, discourage entry of rodents through immigration into farms. Lack of hiding places encourage emigrations to other areas leading to lowered populations abundance and distributions of myomorph rodents in maize and wheat farms. This agrees with Tripathi and Choudhary, (2017) who reported that regular weed control in and around the crops can reduce the entry of rodents into an area and cause stress to regular inhabitant rodents resulting in the rodent migration to other weedy and bushy areas maintaining low populations. The three rodent species *M. natalensis*, *A. niloticus* and *L. striatus* captured are also known to be responsible for most post-harvest crop damage in East Africa (Makundi *et al.*, 1999). Although not investigated in this study it could also be due to habitat destruction through harvesting such that even rodents that got into these fields could not stay long enough to establish themselves as resident populations since tunnels and burrows that act as nesting sites had been interfered with.

Myomorph rodents were dominated by *M. natalensis* followed by *A. niloticus* and *L. striatus* was rare species during the current study. These findings agree with studies by Meheretu *et al*. (2013) and Makundi *et al*. (2005) where *Arvicanthis* and *Mastomys* genera were most abundant and caused heavy damage on wheat and barley just before harvest. Shenkut *et al*. (2006) reported *Arvicanthis niloticus* and *M. natalensis* as being common rodent species in farmlands of wheat, lentils, and beans, where the population distribution and abundance showed significant temporal variation with *M. natalensis* dominating cultivated fields while *A. niloticus* dominated outside the cultivated fields. All the three species of rodents captured during this study have a wide distribution and are not unique to this study area. It has been reported that they are major agricultural rodent pests in maize fields by Bekele and Leirs, (1997). The current study also established that *M. natalensis* and *A.niloticus* exhibited inter annual differences in distribution in maize and wheat farms. Comparing *Mastomys* (*60.61%)* and *Arvicanthis* species (38.42%) distribution during the study period, *M. natalensis* was most common rodent pest during study period. In this study *Arvicanthis* was captured in both maize and wheat farms throughout the three-year study period but in low numbers this could probably be as reported by Bekele *et al*. (2003) that it prefers natural habitat for shelter but only visits farmland for food.

According to Krebs (1999), food is unquestionably one of the key ecological elements that control and restrict population size; therefore, rodent density would typically rely on the amount of food that is present in the fields. Maize habitat recorded higher population than wheat habitat throughout the study period. This is consistent with research by Leirs (1995), who estimated the population sizes of several rodents in Africa and discovered that there were often substantially bigger variations during epidemic years and several hundred during typical seasonal peaks. Singla and Babbar (2010) demonstrated that study locations depending on food abundance might be responsible for population shifts and the discontinuity between various habitats.

According to Taylor and Green (1976), removing vegetation from a habitat decreased rodent species populations, and the locations where the species were most common also provided enough cover for hiding and a sufficient supply of food. This implies that organisms can be plentiful if their chosen resources are abundant but uncommon if their preferred microhabitat is constrained. In the present study, maize was a more open habitat compared to wheat but had huge bushy fences that could act as hiding places for rodents. Rodent communities and densities are influenced by habitat uniformity in composition, whereas the population of small mammals is impacted by habitat heterogeneity, according to Bekele and Leirs' (1997) observations of rodents in natural habitats but in large numbers in maize fields during the dry season in central Ethiopia. Massawe *et al*. (2007) reported *Arvicanthis* species to be herbivorous grass loving species and they have opportunistic and generalized diets that makes them common in agricultural fields and stable crops pests where they cause pre harvest damage.

These studies showed significant relationship between habitat and abundance of each species captured with *M. natalensis* and *A. niloticus* showing year after year changes during the three years of study and annual variations in abundance in maize and wheat fields. This indicates that species abundance varies with different types of agro habitat. The findings in this study are consistent with the findings in a study by Odhiambo *et al*. (2008). According to Odhiambo *et al*. (2008), *M. natalensis* and *A. niloticus* are opportunistic feeders who consume all forms of food at various frequencies depending on the availability of those foods in their environment. *Mastomys natalensis* consumes a variety of foods, including seeds, insects, and grasses during the rainy season and various plant materials during the dry season. Although feeding habits was not investigated in this study, cleaning of fields could have affected growth of seasonal weeds that forms part of food for rodents that could have led to low captures during this study. Rodents are also known to vary in distribution in various habitats due to ground cover and food quality as reported by (Jędrzejewski and Jędrzejewska 1996). However, *M. natalensis* has a widespread range and its population abundance may vary in many types of settings.

According research by Taylor and Green, (1976), *M. natalensis* was less sensitive to the loss of vegetation than other mouse species. This could also be a result of its inherent flexibility of being cosmopolitan in distribution. This probably could have been the reason it was most abundant in the present study. According to Mulungu *et al*. (2015), *M. natalensis* abundance is known to vary with habitat and season.

5.3 Gender (males and females) distribution of each identified species of myomorph rodent pests in both maize and wheat fields in University of Eldoret

These studies found out that the distribution of gender (male and female) myomorph rodents during the study period showed year to year variations in year one, year two and year three of study. There were more males of *M. natalensis* (58.44%) followed by *A. niloticus* (40%) and then *L. striatus* (0.56%) than females *M. natalensis* (62.24%), *A. niloticus* (36.20%) and *L. striatus* (1.56%). The distribution of rodent's gender was statistically significantly different in habitats of maize and wheat in the second year of study (P = 0.009) showing variation in distribution in maize and wheat fields. The findings in this study agree with studies by Delany and Monro, (2009) which showed variation in distribution of male and females of *A. niloticus*. Delany and Monro, (2009) in their studies reported that male rodents generally traversed a wider range than females and field edges were more preferred by rodents than fields. Despite the fact male traversed a wider range than females it is not clear if it was through immigrations or emigrations that could lead to aggregation of gender in the farms and therefore traversing of male and female rodents could not be the reason why there were more males than females in the current study. The inconsistency in numbers of male and female of each species captured in the current study did not reflect effect of longer distance traversed by males. Agricultural practices of mechanisation could have also influenced rodent's preparedness to remain in farms for long duration to add to the population through reproduction and migrations. Frequent ploughing and use of pesticide could possibly affect the nesting, reproduction, and quality of food in the fields. Although Monadjem and Perrin, (2003), reported annual variability in species richness and distribution in *M. natalensis* and *striatus species*, showing a general trend of the rodent population seasonal fluctuation gender could also affected by locality and season.

5.4 Determination of the influence of weather based ecological factors of rainfall, relative humidity, and temperature on distribution of rodent pest population, species and gender in maize and wheat fields

Rodent species captured against mean monthly rainfall, relative humidity and temperatures showed significant difference in means during the three cropping years. The population distribution of rodent species and gender during study period was significant and positively correlated to rainfall, relative humidity, and temperature. There was a significant correlation between mean rainfall and relative humidity with gender number of male and female rodents captured in year one. The study demonstrates that increase unit change in rainfall and relative humidity could lead to unit increase in abundance of numbers of each identified rodent species and gender captured in maize and wheat fields. Climatic conditions can possibly cause change in productivity of a habitat, which in turn would influence the prevailing weather conditions that may be conducive for reproduction. Other researchers (Mayamba *et al*., 2020), have reported that increased rainfall is associated with fast growth of weeds which forms food and ground cover to increase rodent population and also breeding is prominent in the rainy seasons when food and weeds grow amazingly fast. According to Taylor and Green (1976), rainfall affects the crop phenology, which is the process of crop growth, development and yield formation, and the surrounding vegetation, which in turn affects the quantity and quality of food available to rats in farming settings. According to Spinks *et al*. (2000), the presence of rodents might vary depending on the weather conditions. Temporal variation in population and distribution have been observed between seasons and years. Rainfall has been shown to play an indirect role in ecology of *M. natalensis* by determining when, where and how much food is available through rainfall promoting abundant productivity of seeds and vegetation cover that is food for the species (Massawe *et al.,* 2011). Therefore, microclimatic weather changes in rainfall and relative humidity have a role in influencing distribution of myomorph rodent pest population, species, and gender.

However, negative correlations in year two and three that was not statistically significant rainfall and relative humidity showed inverse relationship with gender (both male and female) distribution. Since the correlations were not statistically significant there was no prove that variation in rainfall would significantly explain variation in population. The observed changes could be because of other confounding variables that could possibly affect rodent population such as reduced reproduction due to destruction of nests and burrows because of human activities. High use of machinery for ploughing destroys burrows, which could lead to unavailability of breeding ground that could lead to low nesting site, low reproduction output, low fecundity, and litter size. Gender distribution could have been influenced by microclimatic changes in prevailing conditions. Low populations realized in year two could be attributed to low mean rainfall, low relative humidity and high temperatures; whose effect could have caused a low variation in captures that was not statistically significant. Low incidences of captures could be attributed to improvement of maize and wheat farms that are kept clear with minimal cover and weed not allowed to choke crops therefore reduced hiding sites for rodents. Rodent population showed both positive and negative correlation with ecological factors of rainfall, relative humidity, and temperature during the study period. Although other researchers have stated that increased rainfall is associated with fast growth of weeds, which forms food and ground cover for rodents and breeding, is prominent in the rainy seasons when weeds grow amazingly fast and food becomes available. Rainfall influences growth of vegetation some of the findings were not in agreement with these findings due to unexplained factors that could have contributed to this variation. These could be possibly due to exposure to natural enemies like predators due to cleared fields, human activities through use of pesticides and movement by myomorph rodents from study area to where they could establish nesting sites. In farming settings, rodents are impacted by rainfall, the quantity and quality of food, which depends on the phenology of crops, and the surrounding flora, according to Taylor and Green (1976) and Spinks *et al*. (2000). However, because of the small population sizes in the current study, this was not the case.

Poisson regression model showed that variation in population due weather-based ecological factors was significant. Despite Poisson regression model, showing statistical significance of rainfall, relative humidity and temperature, individual statistical analysis shows that variation in rodent population abundance could be by chance. However, change in temperature, turned out to be statistically significant factor and increase in temperature leads to decrease in rodent population. This finding demonstrates that increase in amount of rainfall and relative humidity are positively associated with population abundance and species richness. This is consistent with research by Massawe *et al*. (2007), who demonstrated that rodent population dynamics follow seasonality in relation to changes in precipitation and rodent population reach the peak at the conclusion of rain season. Bekele and Leirs (1997), showed that a protracted rainy season causes large litter sizes, which increases population size and according to Jurisic *et al*. (2022), rodent populations rise as precipitation levels rises. According to Shurchfiesd (1997), temperature and relative humidity are important factors in influencing the reproductive activities of rodents where increase in temperature led to reduced reproductive activities while increase in relative humidity led to increased rodent population during warm winters.

The study demonstrates that the weather- based ecological factors had an effect on the abundance and distribution of gender in the two fields during the study period. Relative humidity was statistically significant predictor factor in the binary logistic regression model while rainfall and temperature were insignificant factors.

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

6.1 Conclusions

1. There existed variation in infestation of myomorph rodent pest population in maize and wheat farms in different cropping years at university of Eldoret with higher incidences of pests in maize than wheat fields.
2. Despite the varying numbers of either species in both maize and wheat in University of Eldoret, the types of species did not vary in both fields.
3. There was no significant difference between abundance of male and female of myomorph rodent species in maize and wheat farms.
4. The three weather-based ecological factors, rainfall, relative humidity and temperatures do not have consistent influence on myomorph rodent pest populations, gender and species distribution in the three cropping years.

6.2 Recommendations

1. A more extensive study taking more than three years should be carried out in order to establish whether the findings would be consistent with findings in this study.
2. Further research should be carried out to establish whether the identified myomorph rodent pest species compete over unique resources where some have advantage over others thereby limiting a given species population.

3. Further research should be carried out on more feasible rodent pest management strategies that would ensure ecological balance is sustained with no reduction to agricultural production and no damage to the environment.
4. In the face of climate change and impact of climatic ecological factors on rodent pest distribution, further research is needed to establish the magnitude of crop damage by identified rodents in the study area.

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APPENDICES

Appendix I: Population of Myomorph rodents captured in Maize and wheat farms every Month for 3 years of study

Month/ year	Year 1				Year 2				Year 3			
Sp	*M.n.*	*A.n*	*L.s*	captures	*M.n*	*A.n*	*L.s*	captures	*M.n*	A.n	*L.s*	captures
July	12	9	0	21	15	3	0	18	45	21	0	66
Aug	12	12	0	24	21	9	0	30	24	9	0	33
Sept	12	12	0	24	18	12	0	30	21	9	0	30
Oct	15	12	0	27	18	9	3	30	21	12	0	33
Nov	39	15	0	54	6	0	0	6	12	3	0	15
Dec	30	60	2	96	6	0	0	6	21	15	0	36
Jan	51	15	0	66	6	0	0	6	3	0	0	3
Feb	36	33	0	69	6	3	0	9	0	0	0	0
Mar	9	0	0	9	6	0	0	6	0	0	0	0
Apr	6	12	0	18	15	6	0	21	12	6	0	18
May	27	24	0	51	9	6	0	15	3	0	0	3
Jun	9	3	0	12	3	0	0	3	15	21	0	36
Total	258	207	6	471	129	48	3	180	177	96	0	273

Sp = species M.n = *Mastomys natalensis* A.n = *Arvicanthis niloticus*
L. s =*Lemniscomys striatus*.

Appendix II: *Mastomys natalensis* by gender captured in maize and wheat farms during the three years of study

	YEAR 1				YEAR 2				YEAR 3			
	MAIZE		WHEAT		MAIZE		WHEAT		MAIZE		WHEAT	
MONTH/ GENDER	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
JULY	9	0	0	3	6	3	3	3	21	9	6	9
AUG	3	6	3	0	9	3	6	3	3	9	9	3
SEPT	6	3	3	0	9	3	3	3	6	3	3	9
OCT	6	0	6	3	3	3	6	6	9	3	6	3
NOV	9	9	15	6	0	0	3	3	0	0	12	0
DEC	12	6	0	12	3	3	0	0	3	6	6	6
JAN	24	6	12	9	3	3	0	0	0	0	0	3
FEB	24	0	3	9	0	6	0	0	0	0	0	0
MAR	0	0	0	9	3	0	0	3	0	0	0	0
PRIL	0	0	3	3	3	3	6	3	3	6	0	3
MAY	6	3	3	15	3	0	3	3	0	0	3	0
JUNE	3	0	0	6	3	0	0	0	3	3	3	6
TOTALS	102	33	48	75	45	27	30	27	48	39	48	42

Appendix III: *Arvicanthis niloticus* by gender captured in maize and wheat farms

	YEAR 1				YEAR 2				YEAR 3			
	MAIZE		WHEAT		MAIZE		WHEAT		MAIZE		WHEAT	
MONTH/ GENDER	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
JULY	3	0	3	3	0	3	0	0	9	3	6	3
AUG	6	3	0	3	3	3	0	3	0	3	3	3
SEPT	3	6	0	3	3	3	3	3	3	0	3	3
OCT	9	3	0	0	3	0	3	3	6	3	0	3
NOV	3	3	3	6	0	0	0	0	0	3	0	0
DEC	33	15	3	9	0	0	0	0	6	3	3	3
JAN	12	3	0	0	0	0	0	0	0	0	0	0
FEB	27	3	0	3	0	3	0	0	0	0	0	0
MAR	0	0	0	0	0	0	0	0	0	0	0	0
APRIL	6	0	3	3	0	3	3	0	6	0	0	0
MAY	9	0	3	12	3	0	0	3	0	0	0	0
JUNE	3	0	0	0	0	0	0	0	9	3	6	3
TOTALS	114	36	15	42	12	15	9	12	39	18	21	18

Appendix IV: *Lemniscomys striatus* by gender captured in maize and wheat farms during the three years of study

	YEAR 1				YEAR 2				YEAR 3			
	MAIZE		WHEAT		MAIZE		WHEAT		MAIZE		WHEAT	
MONTH/ GENDER	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
JULY	0	0	0	0	0	0	0	0	0	0	0	0
AUG	0	0	0	0	0	0	0	0	0	0	0	0
SEPT	0	0	0	0	0	0	0	0	0	0	0	0
OCT	0	0	0	0	0	0	0	3	0	0	0	0
NOV	0	0	0	3	0	0	0	0	0	0	0	0
DEC	0	0	0	0	0	0	0	0	0	0	0	0
JAN	3	0	0	0	0	0	0	0	0	0	0	0
FEB	0	0	0	0	0	0	0	0	0	0	0	0
MAR	0	0	0	0	0	0	0	0	0	0	0	0
APRIL	0	0	0	0	0	0	0	0	0	0	0	0
MAY	0	0	0	0	0	0	0	0	0	0	0	0
JUNE	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL9	3	0	0	3	0	0	0	3	0	0	0	0

Appendix V: Rodent species, Mean ecological factors for the first cropping year in University of Eldoret farms

Species	Mean ecological factors					
	T.c	Male	Female	Rain Mean±SD	R.H Mean±SD	Temp Mean±SD
M.natalensis	258	151	107	129.99±138.86	55.80±13.76	16.94±0.65
A. niloticus	207	131	76	117.72±133.09	57.55±11.26	16.96±0.64
L. striatus	6	3	3	132.40±145.04	54.50±17.53	16.56±0.60
Total	471(50.97%)	285	186	124.63±136.27	56.56±12.77	16.94±0.64

T.c = Total captures; M = Male; F = Female; SD = Standard Deviation, R.H = Relative Humidity, Temp = Temperature

Appendix VI: Mean ecological factors for the second cropping year in University of Eldoret farms

Species	Mean ecological factors					
	T.c	M	F	Rain Mean±SD	R.H Mean±SD	Temp Mean±SD
M.natalensis	128	78	50	180.93±88.60	64.71±7.69	17.12±0.67
A. niloticus	49	22	27	193.40±87.54	66.22±6.45	17.06±0.56
L. striatus	3	0	3	104.40±0.01	58.50±0.01	17.10±0.01
Total	180(19.48%)	100	80	183.05±88.09	65.02±7.36	17.10±0.63

T.c = Total captures; M = Male; F = Female; SD = Standard Deviation, R.H = Relative Humidity, Temp = Temperature

Appendix VII Mean ecological factors for the third cropping year in University of Eldoret farms

Species	Mean ecological factors					
	T.c	M	F	Rain Mean±SD	R.H Mean±SD	Temp Mean±SD
M.natalensis	174	92	82	170.28±96.12	66.08±7.60	17.01±0.57
A.niloticus	99	63	36	167.81±91.89	66.38±6.90	17.01±0.53
L. striatus	0	0	0	-	-	-
Total	273(29.55%)	155	118	169.38±94.44	66.19±7.33	17.10±0.56

T.c = Total captures; M = Male; F = Female; SD = Standard Deviation, R.H = Relative Humidity, Temp = Temperature

Appendix VIII: Goodness of Fit test for Poisson model

	Value	df	Value/df
Deviance	480.739	30	1.025
Scaled Deviance	480.739	30	
Pearson Chi-Square	469.122	30	1.637
Scaled Pearson Chi-Square	469.122	30	
Log Likelihood[b]	-321.866		
Akaike's Information Criterion (AIC)	651.732		
Finite Sample Corrected AIC (AICC)	653.111		
Bayesian Information Criterion (BIC)	657.837		
Consistent AIC (CAIC)	661.837		

Appendix IX: Omnibus Test for testing model significance

Likelihood Ratio Chi-Square	df	Sig.
66.924	3	0.001

Appendix X: Interpreting test statistics, p-values, and significance

Interpreting test statistics, *p*-values, and significance

Analysis	Test statistic	Null hypothesis	Alternative hypothesis	Results	p-value	significance	decision
Difference-of- means test	*t* (two-tailed) (See note 1)	*1 = 2*	*1 ≠ 2*	big *t* (> +2.0 or < -2.0)	small *p* (< 0.05)	yes (Significant difference of means)	reject Ho, accept Ha
				small *t* (< +2.0 and > -2.0)	big *p* (> 0.05)	no	do not reject Ho
	t (one-tailed) (See note 2)	*1 > 2*	*1 ≤ 2*	big *t* (> +2.0 or < -2.0)	small *p* (< 0.05)	yes (Significant difference of means)	reject Ho, accept Ha
				small *t* (< +2.0 and > -2.0)	big *p* (> 0.05)	no	do not reject Ho
Analysis of variance (ANOVA)	*F* (See note 3)	*1=2=3* = ... = *k*	1≠2≠3 ... ≠ k	big *F*	small *p* (< 0.05)	yes (Significant difference among means)	reject Ho, accept Ha
				small *F*	big *p* (> 0.05)	no	do not reject Ho
Homogeneity of variance (Bartlett)	X^2 (See note 4)	*1=2= 3* = ... =*k*	*1≠2≠ 3* ≠ ... ≠*k*	big X^2	small *p* (< 0.05)	yes (sig. difference among variances)	reject Ho, accept Ha
				small X^2	big *p* (> 0.05)	no	do not reject Ho
Regression analysis	*F* (See note 5)	no relationship between response and predictor vars.	relationship between response and predictor vars.	big *F*	small *p* (<0.05)	yes (There is a relationship)	reject Ho, accept Ha
				small *F*	big *p* (>0.05)	no (there is not a relationship)	do not reject Ho
	t (See note 6)	*bp* = 0	*bp* ≠ 0	big *t* (> +2.0 or < -2.0)	small *p* (< 0.05)	yes (*xp* is an important predictor)	reject Ho, accept Ha
				small *t* (< +2.0 and > -2.0)	big *p* (> 0.05)	no (*xp* is not an important predictor)	do not reject Ho

Adopted from Bartlein, (2022)

Notes:

1. The null hypothesis here is that the means are equal, and the alternative hypothesis is that they are not. A *big t, with a small p*-value, means that the null hypothesis is discredited, and we would assert that the *means are significantly different* (while a small *t*, with a big *p*-value indicates that they are *not significantly different*).

2. The null hypothesis here is that one mean is greater than the other, and the alternative hypothesis is that it is not. A big *t,* with a small *p*-value, means that the null hypothesis is discredited, and we would assert that the *means are significantly different* in the way specified by the null hypothesis (and a small *t*, with a big *p*-value means they are *not significantly different* in the way specified by the null hypothesis).

3. The null hypothesis here is that the group means are all equal, and the alternative hypothesis is that they are not. A big *F,* with a small *p*-value, means that the null hypothesis is discredited, and we would assert that the *means are significantly different* (while a small *F*, with a big *p*-value indicates that they are *not significantly different*).

4. The null hypothesis here is that the group variances are all equal, and the alternative hypothesis is that they are not. A *big* X^2, (Chi-squared) value, with a small *p*-value, means that the null hypothesis is discredited, and we would assert that the group variances *are significantly different* (while a small X^2, with a big *p*-value indicates that they are *not significantly different*).

5. The null hypothesis here is that there is not a general relationship between the response (dependent) variable and one or more of the predictor (independent) variables, and the alternative hypothesis is that there is one. A big *F*, with a small *p*-value, means that the null hypothesis is discredited, and we would assert that there is a *general relationship between the response and predictors* (while a small *F*, with a big *p*-value indicates that *there is no relationship*).

6. The null hypothesis is that the value of the *p*-th regression coefficient is 0, and the alternative hypothesis is that it is not. A big *t*, with a small *p*-value, means that the null hypothesis is discredited, and we would assert that the *regression coefficient is not 0* (and a small *t*, with a big *p*-value indicates that it is *not significantly different from* 0).

Appendix XI: Example of a Conventional Approach to Interpreting a Correlation Coefficient

Absolute Magnitude of the Observed Correlation Coefficient	Interpretation
0.00–0.10	Negligible correlation
0.10–0.39	Weak correlation
0.40–0.69	Moderate correlation
0.70–0.89	Strong correlation
0.90–1.00	Very strong correlation

Adopted from Schober *et al*, (2018)

Appendix XII: Researcher Laying Sherman and locality woven in wheat farm

Source: Author, 2022

Appendix XIII Researcher Laying Sherman and locality woven in wheat farm

Source: Author, 2022

Appendix XIV: Researcher Laying Sherman and locality woven in mature maize farm due for harvesting

Source: Author, 2022

Appendix XV: Researcher Laying Sherman and locality woven in mature maize farm

Source: Author, 2022

Appendix XVI: Researcher Laying Sherman and locality woven laying of traps in maize farm

Source: Author, 2022

Appendix XVII: Similarity Report

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