AER Journal Volume 5, Issue 2, pp. 222-231, Nov, 2022

ISSN: 1727-8341

RESEARCH ARTICLE
Available Online at *http://ojs.uoeld.ac.ke/index.php/aerj*

The Effect of Ecological Factors on the Distribution of Myormoph Rodent Pest Species Infesting the University of Eldoret Farms, Uasin Gishu County, Kenya

M. Werunga*, D. M. Mwaniki and F. M. E. Wanjala
Department of Biological Sciences, University of Eldoret, Kenya
**Corresponding Author's Email: Mispahnelima01@gmail.com*

Abstract

Rodents are recognized ecologically as one of the most important pests of cereals. Rodents occur in a wide range of terrestrial habitat, they are diverse and form an integral part of ecosystem functioning. Rodents are pests of concern in Kenya, as they cause considerable damage to cereal crops before and after harvest and therefore affect food security by impacting on both food availability and safety. However, knowledge of the factors that affect their population and distribution in Kenya is limited. The objective of the research was to determine the effect of ecological factors namely rainfall, relative humidity and temperature on the incidences and distribution of gender, type of species and population myomorph rodent pests infesting maize and wheat farms at University of Eldoret, Uasin Gishu County, Kenya. Grids of 70 m x 70 m crop cuttings was done in commercial fields of maize and wheat both locally woven live traps and Sherman's live traps were used to capture rodents with peanut butter and sun dried Omena (Rastrineobola argentea) used as baits. The ecological factors of rainfall, relative humidity and temperature data were obtained from the metrological station based at Eldoret international airport. Three types of myomorph rodent pest species were captured and identified being Mastomys natalensis, Arvicanthis niloticus and Lemniscomys striatus. A Pearson correlation indicated a very weak positive correlation between rainfall and gender (males and females) distribution ($r = 0.171$, $P = 0.001$). A very weak linear positive correlation was observed between relative humidity and gender ($r = 0.198$, $P = 0.001$) that was statistically significant ($P < 0.01$). Rainfall and relative humidity had an effect on distribution of gender (males and females). However, there was a very weak positive correlation between temperature and gender in year one and two ($r = 0.056$, $P=0.225$; $r =0.093$ $=0.214$) and weak negative correlation in year three ($r = -0.046$, $P=0.449$) with no statistically significant difference 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 ($r =-0.001$, $P= 0.986$).The ecological factors rainfall, relative humidity were shown to influence species and gender distribution but temperature did not have any notable influence on species distribution during the present study.

Keywords: *Arvicanthis niloticus*, *Mastomys natalensis*, *Lemniscomys striatus,* Relative Abundance, Population Distribution, Ecological Factors

INTRODUCTION

Rodents are the most diverse and abundant groups of mammals accounting for approximately 2200 species and new species are being described (Monadjem *et al*., 2015). They are recognized ecologically as one of the most important pests of cereals. Rodents occur in a wide range of terrestrial habitat. They are diverse and form an integral part of ecosystem functioning.

Kumar (2008) defines an ecological factor or eco factor as any factor, abiotic or biotic that influences living organisms. Biotic factors include other organisms, completion, parasitism, predation and symbiosis while abiotic factors are physiographic factors like altitude and effect of steepness, climatic factors that include temperature, rainfall, sunlight, atmospheric pressure, humidity of the air, radiation and ionization of air and chemical composition of water. Edaphic factors include soil type, soil pH, soil temperature, soil moisture, organic carbon, nitrogen content and heavy metal content (Kumar, 2020). In the present study climatic factors of rainfall, relative humidity and temperatures were considered because they been reported to influence the population of rodents in other parts of the world, (Massawe et al. 2011; Spinks et al., 2000; Taylor & Green, 1976; Mulungu, 2012; Desoky, 2018; Massawe et al., 2008; Mayamba et al., 2020).

MATERIALS AND METHODS

Study Area

The study was carried out at the University of Eldoret Maize and wheat farms. University of Eldoret is in Uasin Gishu County, Kenya. Uasin Gishu County is located in the Kenyan rift valley, which is part of the Great Rift Valley. It borders TransNzoia County to the north, Elgeyo Marakwet County to the east, Baringo County to the southeast, Kericho County to the south, Nandi County to southwest and Kakamega County to the northwest (County Integrated Development Plan. CIDP, 2018). Uasin Gishu County is divided into six sub counties which are; Kesses, Kapsaret, Moiben, Ainabkoi, Soy and Turbo.

Uasin Gishu County has 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. (MoALF, 2017). The University of Eldoret is situated 9 km to the north of Eldoret Town at longitude 35^0 18' 20" E and latitude 0^0 34' 36" N along Eldoret – Ziwa Road off Iten Road in Moiben Sub-County. The University occupies 414.8 hactares (ha) of land at an altitude of 2140 m above sea level. The area experiences one long rainy season commencing in 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).

University of Eldoret is a learning institution where students are engaged in learning and research that has led to development of wheat variety that is resistant to wheat rust and the university farms are used as research experimental plots and although pest managenent is intense on University of Eldoret farms, the university farms were appropriate study plots on ecology of myomorph rodent pests because incidences of rodent pests from the areas bordering the University of Eldoret 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 pests.

Research Design

A quantitative and longitudinal research design was employed in this study. This was an ecological study where time and place of capture were recorded and mean captures show the level of infestation in maize and wheat farms. Environmental variables of mean monthly rainfall, temperature and relative humidity were recorded and compared to gender, species type and total populations captured each month and mean percentages calculated. The study was based on empirical field data. Models of correlations and regression were used to test variation and relationships among the independent variables (year of study, ecological factors of rainfall, relative humidity and temperatures) and dependent variables (gender, species types and population).

Materials and Methods

Materials and tools used in these study included; traps, data sheets, tape measure, waterproof markers, field note books, leather gloves and surgical gloves, trap baits and animal field guides.

Trapping Techniques and Data Collection

There are several traps used for trapping small mammals. The types of traps used to trap small mammals are, Museum special traps, Mouse traps, Rat traps, Longworth traps, Havahart traps, Tomahawk traps, Conibear traps, Pitfall traps and Sherman traps (SERAS, 2003) In the present study Sherman live-trap (7.5 × 9.0 × 23.0 cm, HB Sherman Trap Inc., Tallahassee, USA) Sourced from 3731 Peddie Drive Tallahassee, FL 32303 and locally woven live traps bought from a market in Eldoret town were used. (Figure 1). The Sherman live traps are light aluminium box traps collapsible, easy to transport and are designed to capture live animals while locally woven traps are woven wires with a provision of entry by rodent and once captured the animal cannot escape. The locally woven traps are also designed to capture live animals. Peanut butter and raw sun dried Omena (*Rastrineobola argentea*) were used as bait. Bait (Peanut butter) was obtained from Tuskys and Uchumi supermarkets in Eldoret Town and raw sun dried Omena (*Rastrineobola argentea*) was sourced from municipal market in Eldoret. The peanut butter bait was kept in a closed air tight container with a cover lid while Sun dried 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 researcher and the research assistant to avoid contamination of the baits. The Omena were sundried to avoid their spoilage, although it has been reported that moldy fish attract some species of rodents, it was important to maintain the quality of the bait since it is not clear which rodents species was going to be attracted to the moldy Omena. The Omena was sundried 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 g and 4 pieces of whole Omena was used as bait. About 10 g of bait was weighed using a Smart Weigh Gem 20 digital portable milligram scale that has a cap lid calibrated to measure precise weights. Polythene bags, tape measure sisal twin, data sheet, field note book and hand gloves were used in data collection. 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.

Field of maize and wheat farms were chosen with the help of farm manager. A grid of 70 m x 70 m grid crop cutting was done in the commercial fields of maize and wheat farms and modified trapping design referred to as the standard grid by Linzey and Kesner (1997) and standard operating procedures on small mammal sampling and processing procedures (SERAS, 2003) were adopted in the present study. The 70 m x 70 m crop cutting plot was divided into four quarters. In each quarter trapping grid were established as quadrats and marked with stakes along two lines 20 m apart and a set of 4 Sherman's traps and 4 locally woven traps were placed 10 m apart in each quadrat randomly. A total of 32 traps were set in the established grids of maize and wheat. At the site, the traps were counted, marked with water proof ink marker and labelled as traps 1 to 4 per quarter for four quarters in maize and wheat fields. This is important for maintaining a trap inventory and ensuring that the correct number of traps are set and can be retrieved. Trap areas were established in maize and wheat habitat suitable for the target species, gender (males and females) and populations and the location of these areas were recorded in a field note book. A measuring tape was be utilized to measure the distance between the grids 20 m and 1m between the two types of traps used.

The traps were baited with peanut butter and Omena (*Rastrineobola argentea*) to attract rodent pest for capture. The traps were checked twice a day early morning before 9am and late afternoon before 6pm on daily basis to maintain consistency in collection of data by both traps and detect if there is any variation in captures by traps. Also, rodents are known to be active early evening 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 ear marked with permanent ink marker after shaving, identified and released for future recapture data. In addition, data of sex, species, and farms where the rodents were captured was recorded.

The climatic ecological factors investigated were rainfall, relative humidity and temperatures. Rainfall data was measured using a standard rain gauge. Relative humidity which is the amount of water vapour actually in air data was measured using standard tool, a hygrometer. It consists of two sets of thermometer dry and wet bulb thermometers. 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 was the daily mean temperature. To get the temperature at any given time, dry bulb thermometer was used such that daily mean temperature was 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. The ecological factors of rainfall, relative humidity and temperature data were obtained from the metrological station based at Eldoret international airport.

Locally woven trap Sherman trap

Figure 1: Locally woven trap and Sherman trap.

Data Analysis

Data processing began with editing, coding and classification. Data entry in excel sheet simulations, tabulation and computation of percentages were done and then were analyzed using SPSS version 20.0 software. Descriptive statistic (Pandey & Pandey, 2015) numbers, percentages, means and standard deviations) were calculated. Correlation analysis was also carried out to evaluate the relationship between selected factors (rainfall, relative humidity, Temperature. Habitat and sex) and species abundance and distribution. The climatic ecological factors of rainfall, relative humidity and temperatures were correlated to total rodents capture, the species and gender for each cropping year to determine how they influence rodent distribution in the habitats of maize and wheat. Pearson correlation coefficient (Schober & Schwarte, 2018) was used to determine the strength of relationship between ecological factors of rainfall, relative humidity and temperatures with population, species and gender.

Pearson product moment correlation formula is 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.

RESULTS

Three myomorph rodents infested cereal fields of University of Eldoret farms. Among trapped rodents included; *Mastomys natalensis (M. natalensis), Arvicanthis niloticus (A. niloticus)* and *Lemniscomys striatus (L striatus)*. *M. natalensis* was the most dominant species of the rodents captured in both maize and wheat.

Table 1a, 1b and 1c shows the population of rodents captured, the gender and species types captured in maize and wheat fields during the study period and the means of rainfall received relative humidity and mean temperatures. The effect of ecological factors on rodent gender, species and distribution are in Table 2a and Table 2b. Pearson correlation was utilized in establishing the effect of ecological factors of rainfall, relative humidity and temperature on population distribution of gender and rodent species. There was a very weak positive correlation between rainfall and gender in year one (r= 0.171, P =0.001 N=471) indicating a significant difference in rainfall received and gender. A weak positive correlation implying unit increase in rainfall would lead to a unit increase in gender distribution. Gender distribution was only affected by rainfall received in year one of study. There was a very weak negative linear correlation between rainfall and gender in year two(r - 0.058, P= 0.443 N=180) showing a linear inverse relationship that was not statistically significant between the two variables. There was also a very weak negative correlation between rainfall and gender in year three of study (r= -0.046, P= 0.453 N=273) with no statistically significant difference. Rainfall had an effect on distribution of males and females during this study with year to year variations.

A Pearson correlation was run to determine the relationship between relative humidity with gender (males and females). A very weak linear positive correlation was observed in year one with a statistically significant difference between the two variables (r= 0.198, P =0.001 N=471) implying amount of relative humidity had an effect on gender distribution increase in relative humidity leads to increase in gender (males and females). However, a negative correlation existed between relative humidity and gender during year two and three (r =- 0.092, P=0.220 N=180: r= -0.046, P=0.448

N=273), respectively. Therefore, relative humidity had an effect on gender distribution with year to year variation. A very weak positive correlation was observed between temperature and gender in year one and year two and a very weak negative correlation in year three (r =0.056, P =0.225 N= 471; r =0.093, P =0.214 N=180; r =-0.046, P=0.449 N=273), respectively. There was no statistically significant effect of temperatures on gender distribution (P > 0.01). A positive and negative relationship shown in this study implies that temperature variations had no direct effect on distribution of male and female rodents.

Finding in Table 2b shows a Pearson correlation between ecological factors of rainfall, relative humidity and temperatures and species. A very weak negative correlation between rainfall and species distribution during this study for the three years. (r = -0.040, P=0.388 N=471; r =0.004, P=0.952 N=180; r = -0.013, P=0.836 N=273). No statistically significant difference was observed between rainfall and species (P > 0.01).

A very weak positive linear relationship existed between relative humidity and species distribution in the three years of study (r =0.057, P=0.213 N=471; r =0.030, P= 0.687 N=180; r =0.019, P =0.749 N=273). No statistically significant difference existed between relative humidity and species (P >0.01). Relative humidity had minimal effect on species distribution of myomorph rodents that infested fields at University of Eldoret.

Studies found out that a very weak negative correlation existed between temperatures and species (r =-0.003, P =0.940 N=471; r =-0.034, P=0.655 N=180; r =-0.001, P =0.986 N=273). An inverse relationship existed between temperature and rodent species. Temperature change had an inverse effect on species distribution with no statistically significant variation (P=0.9861). During the present study, the average change in temperature were minimal and as a factor it had no effect on population and distribution of rodent pest.

Table 1a: Rodents 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	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

Table 1b: 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		3	104.40±0.01	58.50±0.01	17.10±0.01
Total	180	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

Table 1c: 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						
Total	273	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

Table 2a: Correlation Analysis between ecological factors and gender

Covariates	Pearson Correlation	Year 1 Gender	Year 2 Gender	Year 3 Gender
Rainfall	r-value	0.171**	-0.058	-0.046
	p-value	0.001	0.443	0.453
	N	471	180	273
Relative Humidity	r-value	0.198**	-0.092	-0.046
	p-value	0.001	0.220	0.448
	N	471	180	273
Temperatures	r-value	0.056	0.093	-0.046
	p-value	0.225	0.214	0.449
	N	471	180	273

**. Correlation is significant at the 0.01 level (2-tailed).

Table 2b: Correlation Analysis between ecological factors and species

Covariates	Pearson Correlation	Year 1 Species	Year 2 Species	Year 3 Species
Rainfall	r-value	-0.040	0.004	-0.013
	p-value	0.388	0.952	0.836
	N	471	180	273
Relative Humidity	r-value	0.057	0.030	0.019
	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 0.01 level (2-tailed).

DISCUSSION

The three types of myomorph rodent species captured in this study are not peculiar to this area. *Mastomys natalensis, Arvicanthis niloticus* and *Lemniscomys striatus* have been identified in several parts of Africa whose abundance has been associated with biotic factors including food availability and reproductive ability (Massawe et al., 2011; Monadjem et al., 2015; Mulungu et al., 2017; Mayamba, 2020). 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 significantly positively related to rainfall, relative humidity and temperature. There was a significant correlation between mean rainfall and relative humidity with gender ($r = 0.171$, $P=0.001$; and $r = 0.198$; $P= 0.001$), respectively in year one. This implies that increase in rainfall and relative humidity amounts causes an increase in gender distribution of rodents in maize and wheat fields through their direct effect on productivity of the habitat. Climatic condition can cause change in productivity of a habitat through male and female adaptation to prevailing weather condition that can be conducive for reproduction. Other researchers have reported 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 food and weeds grow very fast (Mayamba et al., 2020). Rainfall influences growth of vegetation such that Taylor & Green (1976) reported that in farmland habitats, the rodents are influenced by rainfall, the quantity and quality of food, which is dependent on the phenology of crops and the surrounding vegetation. According to Spinks et al. (2000), different weather conditions can influence the presence of rodents. 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).

However, there was a very weak negative correlations in years two and three ($r = -0.058$, $P = 0.443$ and $r = -0.046$, $P = 0.453$) a relationship that was not statistically significant. The negative correlation where increase in rainfall and relative humidity showed inverse relationship with gender (both male and female) distribution which could be attributed to other biotic factors prevailing in the habitats. Gender distribution influenced by microclimatic changes in prevailing conditions. Population dynamics of rodents follow seasonality in relation to variations in rainfall. They reach peaks towards the end of the rainy season when food and other resources are plenty (Massawe et al., 2007). Shurchfiesd (1997) stated that temperature and relative humidity play a significant role as a factor in determining the rodent productive activities. Bekele & Leirs (1997) reported that extended rainy season results in high litter size, which leads to an increase in population size. Low populations realized in years two and three could be attributed to low mean rainfall, relative humidity and high temperatures, whose effect caused a low variation that was not statistically significant. This is in agreement with other researchers who reported 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 very fast and food becomes available and also rainfall influences growth of vegetation. Taylor & Green (1976) and Spinks et al. (2000) reported that in farmland habitats, the rodents are influenced by rainfall, the quantity and quality of food, which is dependent on the phenology of crops and the surrounding vegetation. Although this was not the case in the present study where populations were low, low incidences of captures could be attributed to proficiency in improvement of maize and wheat fields 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.

CONCLUSION AND RECOMMEDATION

In conclusion the ecological factors of rainfall and relative humidity had a significant influence on the distribution of myomorph rodent pest population, species and gender in maize and wheat farms. However, temperature had an insignificant effect on both the gender and species distribution during the study period. There was no significant difference between male and female of myomorph rodent species in maize and wheat farms and no fixed number of either gender of identified species was observed. Therefore, microclimatic weather changes in rainfall and relative humidity have a role in influencing distribution of myomorph rodent pest population, species and gender in University of Eldoret farms.

ACKNOWLEDGEMENT

We thank God for His infinite grace, inspiration and good health He bestowed on us to carry out this study. We also acknowledge and appreciate University of Eldoret which created an enabling environment for us to carry out this study and the permission to carry out research on the University farms. We thank the Department of Biological Sciences, The Univeristy of Eldoret for providing the Laboratory space and equipment for the research. The entire staff of the department of biological science is acknowledged for the support they provided during the research period. We appreciate the financial support offered through a grant by the National commission for science Technology and innovation NACOSTI-Kenya who contributed to the funding of this study. Peer reviewers for accepting to review the manuscript.

REFERENCES

Bekele, A., & Leirs, H. (1997). Population ecology of rodents of maize fields and grassland in central Ethiopia. *Belgium Journal of Zoology* 127: 39–48

CIDP (2018). County Integrated Development Plan, Uasin Gishu county.

Desoky, A. S. S. (2018). Rodent Damage in maize fields and their control. *Acta Scientific Agriculture* 2.7 (2018):53-54.

Kumar. A. (2008). A text book of environmental science.Amazon.com. https://books.google.co.ke

Kumar, A. (2020). 5ecological factors that constitute the environment of an Organism. Environmental pollution article.

Linzey, A. V., & Kesner, M. H, (1997). Small mammals of a woodland- savannah ecosystem in Zimbabwe.I. Density and habitat occupancy patterns. *Food and Agriculture Organization of the United Nations. AGRIS*. Issue1, volume 243.

Massawe, A. W., Mulungu, L. S., Makundi, R. H., Dlamini, N., Eiseb, S. J., Kirsten, F., ... & Belmain, S. R. (2011). Spatial and temporal population dynamics of rodents in three geographically different regions in Africa: implication for ecologically-based rodent management. *African Zoology*, *46*(2), 393-405.

Massawe, A. W., Mrosso, F. P., Makundi, R. H., & Mulungu, L. S. (2008). Breeding patterns of *Arvicanthis neumanni* in central Tanzania. *African Journal of Ecology*, *46*(3), 320-324.

Mayamba, A. (2020). Ecology of major rodent pest species in maize and rice cropping systems in Eastern Uganda. PhD Thesis of Sokoine University of Agriculture, Morogoro, Tanzania.

Mayamba, A., Byamungu, R. M., Broecke, B. V., Leirs, H., Hieronimo, P., Nakiyemba, A., ... & Mulungu, L. S. (2020). Factors influencing the distribution and abundance of small rodent pest species in agricultural landscapes in Eastern Uganda. *Journal of Vertebrate Biology*, *69*(2), 20002-1.

MoALF (2017). Climate Risk Profile for Uasin Gishu County. Kenya County Climate Risk Profile Series. The Ministry of Agriculture, Livestock and Fisheries (MoALF), Nairobi, Kenya.

Monadjem, A, P. J., Taylor, C., Denys, F. P. D., & Cotterill (2015). Rodents of Sub-Saharan Africa: a biogeographic and taxonomic synthesis. Walter de Gruyter GmbH & CoKG. ISBN: 978-3-11-030166-3

Pandey, P., & Pandey, M. M, (2015). Research Methodology: Tools and Techniques. © Bridge Center, 2015. ISBN 978-606-93502-7-0

Schober, P., Boer, C., & Schwarte, L. A. (2018). Correlation Coefficients: Appropriate Use and Interpretation. *Anesthesia & Analgesia* 2018: 126:1763–8.

SERAS (2003). Standard Operating Procedures. Small Mammal Sampling and Processing. Scientific Engineering Response and Analytical Services. U.S. EPA Contract EP-W-09-031

Shurchfiesd, S. (1997). Community structure and habitat use of small mammal in Grassland of different successional age. *J. Zool.Lond*. 242, 519 -530.

Spinks, A. C., Jarvis, J. U., & Bennett, N. C. (2000). Comparative Patterns of Philopatry and Dispersal in Two Common Mole-Rat Populations: Implications for the Evolution of Mole-Rat Sociality. *Journal of Animal Ecology*, Vol. 69, No. 2. British Ecological Society Stable URL: https://www.jstor.org/stable/2647436

Taylor, K. D., & Green, G. (1976). The influence of rainfall on diet and reproduction in four African rodent species. *J. Zool., Lond.* 180: 367-389.