MOLE RATS (*Tachyoryctes splendens*) INFESTATION AND SMALLHOLDER FARMERS WELL-BEING: THE CASE OF ROMBO DISTRICT, TANZANIA

HILDA J. NJAU

A DISSERTATION SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF ARTS IN PROJECT MANAGEMENT AND EVALUATION OF SOKOINE UNIVERSITY OF AGRICULTURE. MOROGORO, TANZANIA

2021

EXTENDED ABSTRACT

Rodent outbreaks cause massive crop losses. In Tanzania mole rats are among the major rodents pests; they feed on underground plants parts mainly roots, rhizomes, tubers, stem bulbs and grasses. Mole rats attack a variety of crops causing extensive damage and losses; this threatens the sustainability of smallholder farmers' livelihoods. Therefore, the study on which this dissertation is based aimed at assessing the effect of mole rats infestation on smallholder farmers' well-being since mole rats destroy crops, causing extensive damage and losses affecting farmers' well-being. The specific objectives were to: establish the extent of crop damage by mole rats, estimate the economic impact of mole rats effects on the smallholder farmers wellbeing in terms of income, food security and assets possession and determine the effectiveness of mole rats control strategies adopted by smallholder farmers in the study area. A cross-sectional research design was adopted whereby quantitative and qualitative data were collected from four villages in Rombo District. Qualitative data were collected using key informant interviews and observations. Quantitative data were collected using a structured questionnaire. Qualitative data were analysed using content analysis, and quantitative data were analysed descriptively and inferentially using multiple linear regression and binary logistic regression analysis. Findings from the study showed that bananas were the most damaged crop in the highland areas (79% of the respondents said so). In the lowland areas, maize was the most damaged crop (70% of the respondents said so). The findings also showed that hours spent on controlling mole rats had a significant statistical influence on food security. Incidence of mole rats throughout the year had a significant statistical influence on

asset value. Agriculture is the most important economic activity in Rombo District. The findings showed that trapping was the most adopted strategy to control mole rats infestation in farms ($p<0.05$), followed by excavation of burrows ($p<0.05$) and the use of fumigants in burrows. The findings further showed that trapping of root rats and excavation of burrows had a positive influence on banana production. It is concluded that proper management of mole rats in Rombo District can reduce the problems that farmers face in respect to agricultural yield loss and energy expenditure. Assessing the farmers' perception on pest status, existing control methods, costs and efficiency of controlling methods will facilitate decisions made on the application of successful pest management strategies. It is recommended that introducing and using integrated pest management strategies will reduce mole rats attack and ensure increased agricultural productivity. The study also recommends that extension agents should equip farmers with improved cultivation techniques to increase banana harvests while farmers should enhance trapping of mole rats and excavation of burrows as effective strategies to reduce crop damage and increase crop harvest. It is also recommended that farmers should consider planting of *tephrosia vogelii* which has been reported to reduce mole rats infestation in farms. Farmers should be encouraged to adopt communal cooperation during controlling mole rats to avoid crop losses in their farms.

ACKNOWLEDGEMENTS

First and foremost, I would like to present my sincere thanks to the Almighty GOD who created and gave me unquestionable health up to this end, for His blessing and wisdom did not go unnoticed. He gave me strength to go on when I was about to give up and when things did not seem so promising.

In addition, I'd like to thank everyone who helped me in one way or another in accomplishing this dissertation work. My heartfelt gratitude goes to my supervisors Prof. Apia Massawe and Prof. Rhodes Makundi for their tireless support and guidance; probably, without their assistance the completion of this dissertation would have been impossible. Special thanks go to ACE Project which provided financial sponsorship on my research work.

I would also wish to extend my acknowledgements to Rombo District farmers, extension officers and Rombo Agricultural office for their assistance during survey stage. Special acknowledgement also goes to Mr. Daniel Moshi and Mr. Kihondo Ahadi for their unique help. Furthermore, I would like to thank all of the staff at Sokoine University of Agriculture's Department of Policy Planning and Management, as well as my fellow postgraduate students Edward Mushi, Joseph Daniel and Lekumok James, for their encouragement and assistance, as they were always willing to provide their assistance at no cost. My hope is that God would continue to bless them abundantly for the rest of their lives.

Lastly, my special thanks goes to my uncle Prof. Rhodes Makundi, my father and mother, my brothers Jens and Emmanuel, my sisters Hellen, Joan, Jesca and Imelda for their love, prayers, support and encouragement. Words cannot express how grateful I am. I owe much gratitude to my friends and my fellow students of MAPME (2018/2020), thank you for your friendship and support.

DECLARATION

I, **HILDA NJAU,** do hereby declare to the Senate of Sokoine University of Agriculture that this dissertation is my original work done within the period of registration as a Master of Arts in Project Management and Evaluation student and that it has neither been submitted nor being concurrently submitted in any other institution.

_____ _____

Hilda Njau Date

(MA.PME Student)

The above declaration is confirmed by;

_____ _____

Prof. Apia Massawe Date

(Supervisor)

COPYRIGHT

DEDICATION

To the Almighty God my creator who must get honour for giving me the ability and strength to complete this work. To my beloved parents Mr. and Mrs. John Njau who together laid the foundation of my education. I also dedicate this work to my brothers and sisters who encouraged me and supported me during the entire study time.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ABBREVIATIONS

CI	Confidence Interval
FAO	Food and Agriculture Organization
FYDP	Five Year Development Plan
IBM	International Business Machines
KGS	Kilograms
OR	Odds Ratio
RDS	Rural Development Strategy
SDGs	Sustainable Development Goals
SPSS	Statistical Package for Social Science
TZS	Tanzanian Shillings
VIF	Variance Inflation Factor
MAPME	Master of Arts in Project Management and Evaluation

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Information

Rodent outbreaks occur regularly in different places worldwide causing massive crop losses (Singleton *et al*., 2015). More than one billion people in the world suffer from chronic hunger annually and rodent pests contribute significantly to this burden (Meerburg *et al*., 2009). Rodent outbreaks have been occurring throughout Europe for thousands of years, resulting in significant losses in crop output in agriculture, putting existing individual farming organizations at risk (Jacob and Tkadlec, 2010). In developing countries, rodent infestation is a serious threat causing substantial damage to food and cash crops (Shanker, 2001). This has led to losses of income and an increase in food shortage. Rodents occur all over the Africa in natural habitats, cultivated areas and human settlements (Massawe *et al.,* 2011). Rodent pest outbreaks in Africa have been recorded since the early 20th century. In Eastern Africa, up to 80% of the harvests are lost due to rodents (Leirs *et al*., 2010), but also in non-outbreak periods rodents still cause chronic crop damage (Singleton *et al.*, 1999).

In Tanzania, the common mole rats are among the major rodents pests. They feed on underground plants parts mainly roots, rhizomes, tubers, as well as stem bulbs and grasses. The rats are extensively distributed underground (Arega, 2017). They occur in a wide variety of habitats including agricultural areas, where they are regarded as a pests (Kokiso and Bekele, 2008). Their distribution pattern varies and fluctuates

seasonally based on altitude and vegetation cover as well as climatic factors. Mole rats are highly influenced by topography, soil and vegetation characteristics of the habitat (Jarvis and Sale, 1971). Mole rats are subterranean and fossorial mammals that adapt to a wide range of environments (Nowak, 1999). They spend most of their lives in self-constructed burrows underground that provide them safety from predation, climatic extremes and ensure access to food resources (Nevo, 1999; Busch *et al.,* 2000). They differ from other rodents since they mainly feed on plant roots and shoots searching through underground tunnels (Rundel *et al.,* 1994).

Rombo is one of the Kilimanjaro Region Districts where mole rats are a major problem. Mole rats have a significant impact on crop productivity in the District and managing them remains a serious concern for extension officials and farmers (Makundi and Massawe, 2011). Mole rats in the district attack a variety of plants including bananas, sugarcane, pineapples, maize, cassava, sweet potatoes, beans, egg plants and yams (Makundi *et al*., 2010). Smallholder farmers' communities are a key group requiring attention in food production and rural development. Increasing their productivity and income can make a major contribution to reducing hunger (Zhou, 2010). Despite that, rodent problems are continuously reported in various parts of the country, resulting in substantial losses of crops (Mulungu, 2017; Mdangi *et al*., 2013; Makundi *et al*., 2010). The effects of mole rats on agriculture have received less research attention, and the extent of damage to crops is not well known (Makundi *et al*., 2010). Therefore, the study intended to assess the impact of mole rats on the well-being of smallholder farmers in Rombo District, Kilimanjaro Region, Tanzania.

1.2 Problem Statement

Every year, in Tanzania, farmers suffer chronic losses of 5- 15% of their cereal crops in the field, but this can be higher when there are rodent outbreaks (Makundi *et al*., 1991). The damage to crops and levels of loss vary from year to year as a result of many interacting factors, including types of crop, time or stage of growth, number or density of rodents and availability of other crops in the same area. In most cases the economic losses of crops due to rodents have been mainly concentrated on semi-fossorial rodents such as *Mastomys natelensis* (Mulungu *et al*., 2015) and less research attention on fossorial rodents and subterranean species such as mole rats (Swanepoel *et al*., 2017). Mole rats attack a variety of crops causing extensive damage and losses, thus threatening the well-being of farmers due to food shortage (Makundi *et al*., 2010). Farmers have continuously reported an increasing magnitude of mole rats infestation for which they lack effective management strategies. Little is known on the impact of mole rats on smallholder farmers in Rombo District as revealed by a study done by Makundi *et al.* (2010), that there are no reliable estimates of the overall loss caused by mole rats in Rombo District.

Despite the efforts to apply rodenticides, an important strategy against rodents, particularly when there are outbreaks, rodents continue to be a major problem due to chronic infestation in crop fields. The application of rodenticides is too expensive for small scale farmers to adopt (Makundi *et al.*, 2010). For small scale subsistence farmers in Rombo District, as is the case in the rest of Tanzania, rodenticides are often either too expensive or are locally unavailable. For the individual farmers the cultivated fields are too small and therefore any individual action to control rodents

cannot have significant effect on the overall rodent population (Makundi *et al.,* 2010).

However, mole rats control relies mainly on traditional techniques. There are no rodenticides recommended for mole rats' control in Tanzania (Makundi *et al*., 2010). Therefore, the sustainability of livelihoods of smallholder farmers in Rombo District is threatened by mole rat infestation. The question is: To what extent is severe?. The infestation of mole rats puts crops at a high risk due to damage and consequently deteriorate of the well-being of smallholder farmers.

Several studies including Makundi *et al.,* (2010), Meerburg *et al.,* (2009), Jacobs and Tkadlec (2010) have reviewed the impact of rodents that cause damage to crops but the impact of mole rats infestation remains unclear. Therefore, the study on which this dissertation is based aims to provide empirical evidence by assessing mole rat infestation in smallholder farmers fields and its impact on well-being of smallholder farmers' in the highlands and lowlands of Rombo District.

1.3 Justification for the study

In Rombo District local people carry out mixed agriculture. Pest rodents especially mole rats have severely been affecting crop yield. They are adapted to a wide range of environments (Nowak, 1999). Mole rat infestation is a major they feed on the roots and lower stems of many crops, often killing plant and causing high yield losses. Mole rats live in extensive, underground tunnel systems and their presence is not obvious to the inexperienced observer.

Farmers traditionally attempt to control mole rats by deep ploughing of the fields, which helps to destroy burrows close to the surface and poisoning by a fumigant, but mole rats can move quickly through their complex system of tunnels, and often escape. Traps and snares are also used by farmers, but are only partially effective.

Despite their wide range of environmental adaptation, the economic importance and damage caused are still poorly known. The people in the study area have little information about the ecology, damage and proper management of mole rats. Therefore, the study was designed to gather information on the extent of crop damage, estimation of the economic impact that would have effect on the smallholder farmers' well- being and to determine the effective strategies used to control the mole rats infestation. According to Makundi *et al.* (2010), because of changing cropping patterns, mole rats have become more abundant in the Kilimanjaro Region, causing extreme crop damage unlike anywhere else in Tanzania. There are few recorded studies on the extent of the problem of mole rats and there are few intervention strategies available for farmers. Mole rats control relies mainly on traditional techniques.

The study is in line with Tanzania's development strategies including: Tanzania Development Vision 2025, Rural Development Strategy (RDS) 2001, Tanzania Five Year Development Plan (FYDP) (2016-2021) and the Sustainable Development Goals (SDGs). The strategies focus on reducing rural poverty and improving farm household well-being. Furthermore, the Sustainable Development Goals (SDGs)

request that action be taken to alleviate poverty, preserve the environment, and ensure that all people live in peace and prosperity. There are a number of goals that are directly related to long-term well-being and crop damage, such as fighting poverty in all of its forms everywhere (Goal 1); zero hunger (Goal 2); ensure healthy lives and promote wellbeing for all at all ages (Goal 3); and promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all (Goal 8).

The findings will increase the existing body of knowledge on impacts of mole rats on smallholder farmers' well-being. This information will be crucial to inform actors involved in promoting sustainable rodent pest management for sustainable agriculture and improvement of rural households' well-being.

1.4 Research Objectives

1.4.1 Overall objective

The overall objective of this study is to assess the impact of mole rats on smallholder farmers' well-being in Rombo District.

1.4.2 Specific objectives

i. To establish the extent of crop damage by mole rats.

ii. To estimate the economic impact[1] of mole rats on the smallholder farmers' wellbeing in terms of income, food security and assets possession.

[1] Economic impact in this context means negative effects of mole rats on income, food security and assets possession.

iii. To determine the effectiveness of the mole rat control strategies adopted by smallholder farmers in the study area.

1.5 Research Questions

i. To what extent are crops affected by the mole rats?

ii. What is the economic impact on the smallholder farmers' well-being at their income level, food security and asset possession?

iii. Which strategies are effectively adopted by the smallholder farmers?

1.6 Conceptual Framework

The study conceptual framework (Figure 1.1) shows the relationship existing between independent and dependent variables of the study. The primary independent variable is mole rat infestation and the dependent variable is well-being, measured by income, food security and assets ownership. Mole rats interact intensively with the environment which creates an interdependent sphere for their distribution and diversity (Hoffmann and Zeller, 2005). Environmental factors influence the increasing magnitude of mole rats in the field crops and accelerate the rate of crop harvest deterioration. Rodent distributions are influenced by environmental and biological factors such as nature and density of vegetation, climatic conditions, predation and habitat exploitation by humans (Johnson and Horn, 2008). Absence of sufficient food and ground cover largely determines the number of rodents in a certain area. The loss of ground vegetation leads to loss of cover and food supply for small mammals' thereby decreasing rodents' diversity.

Other variables in the conceptual framework are characteristics of households as background variables such as gender, age distribution, education and occupation which determine individual household strategies on mole rats coping strategies. There are institutional factors such as agricultural policy on the presence of pests, which creates a great economic risk to crop development. Crop losses are experienced at different stages that is pre-havest and post-harvest and losses are higher in case of pest outbreak (URT, 2013). If the mole rats attack is massive this will lead to low yield during the harvest, if the attack is not massive the production will be high. Extension officers play a crucial role in controlling rodents by disseminating knowledge to smallholder farmers regarding the measures they must apply to control the mole rats. If policies are well enforced, this will help reduce the magnitude of mole rats' effects. Generally, mole rat infestation of farms can affect household income, food security and accumulation of assets.

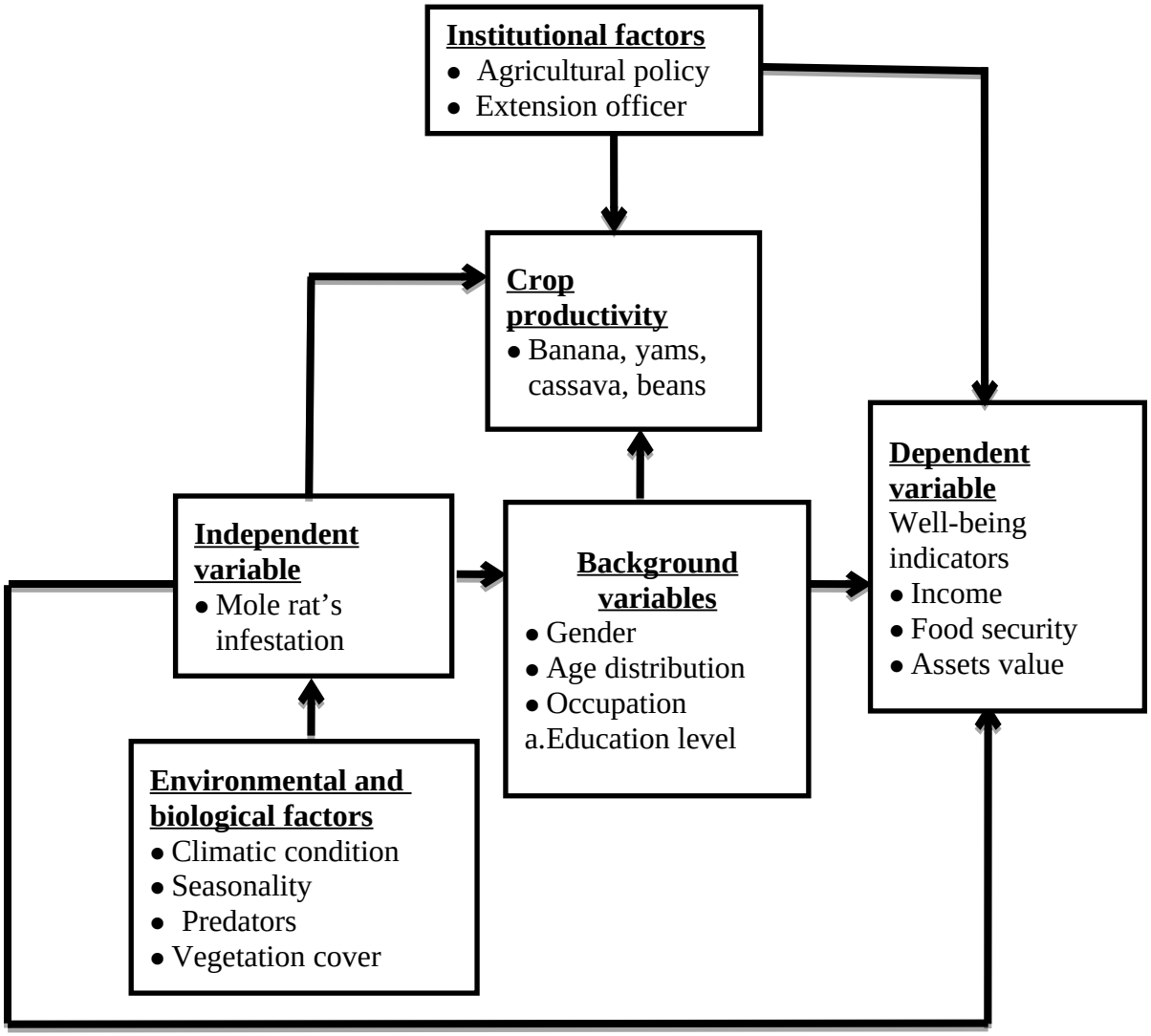

Figure 1.1: Conceptual framework involving mole rats (*Tachyoryctes splendens*) infestation and smallholders' wellbeing

1.7 Operationalization of Key Terms

1.7.1 Smallholder farmers

Smallholder farmers are farmers with land size ranging from 1-10 acres practicing farming at small scale level. Smallholders are characterized by family focused motives such as favouring the stability of the farm household system, using mainly

family labour for production and using part of the produce for family consumption (Nagayets, 2005).

1.7.2 Household

Household refers to individuals who live in the same dwelling and who share basic domestic activities such as cooking, cleaning, etc. Chambers and Conway (1991), define a household as, comprised of capabilities, assets and activities required for a means of living. A livelihood is sustainable when it can cope with and recover from stresses and shocks and maintain or enhance its capabilities and assets both now and in the future, while not undermining the natural resource base

1.7.3 Well-being

The concept “well-being” is a multifaceted phenomenon that has been defined and used widely in the development discourse but not always with a clear understanding (Forgeard *et al*., 2011). Traditionally, wellbeing has identified material progress measured by income where the link between income and wellbeing is based on the consumption. Consumption goes hand in hand with income level when income increase the consumption increases hence that represents improvement in wellbeing (Clark *et al.*, 2008, Deaton, 2008). Kiefer (2008) stated that wellbeing is equated with the quality of life and good living conditions. The traditional view of wellbeing has been broadened to encompass all aspects of human life. Others associated wellbeing with the life activities which people engage in (Clark *et al*., 2008). It is measured by the individual’s income, health, nutrition, education, assets, housing and their enjoyment.

1.7.3.1 Objective well-being

Objective wellbeing is an external level of well-being which consists of socio-economic aspects. It considers resources such as income and wealth or the things that people are able to do with the socio-economic and material resources available to them (Alatartseva and Barysheva, 2015). Objective wellbeing can be divided into two types that is resource related and consumption related (Paim, 1995). Resource related focuses on indicators such as income (Paim, 1995), earning capacity (Garfinkel and Haveman, 1977), income combined with net worth (Weisbrod and Hansen, 1977) and in terms of a debt asset ratio (Marlowe and Goodwin, 1988). Consumption related associates well-being with the consumption of goods, services and resources.

Objective well-being is commonly evaluated in terms of a gap between either a person's desired consumption and actual consumption or their current consumption and past consumption (Paim, 1995). The closer a person's actual consumption is to the level they desire, the higher their level of well-being is judged to be. Objective well-being measures are useful at a population level because they facilitate comparability by treating all individuals the same way (Hird, 2003). Also, objective well-being measures control for variations in people's expectations and experiences that can result in wide variations in reported satisfaction levels in relation to common objective conditions (Felce and Perry, 1995).

1.7.3.2 Subjective well-being

Subjective well-being is an internal level of well-being, basically involved with moral-psychological aspect (Dodge *et al*., 2012). It consists of a tripartite model including, a person's evaluation of their own life emotionally and cognitively. Under the hedonic well-being approach the tripartite model involves frequent pleasant feelings, infrequent unpleasant feelings and an overall judgment that life is satisfying (Ryan and Deci, 2001). It is associated with a balance between positive and negative mood or affect and an evaluation of life satisfaction (Keyes, *et. al*., 2002; Ryan and Deci, 2001).

1.7.4 Income

Income is defined by International Labour Organization (2003) as all receivables regardless of whether they are monetary or goods and services by households or individual members of that particular household annually or at certain intervals. Income as used in this study means amount of money in Tanzanian shillings (Tshs) gained annually by an individual.

1.7.5 Food security

Food security is a multidimensional concept that has been defined by many scholars and organizations suggesting that it has more than one definition. The Food and Agriculture Organization (FAO), defines food security as "as an assurance that all people at all times have both physical and economic access to the basic food they need" (FAO, 1983). The World Bank (1986) defines food security as "access by all people at all times to enough food for an active healthy life". European Commission

defines food security as, “absence of hunger and malnutrition” (Maxwell and Smith, 1992).

1.8 Distribution of Mole rats in Africa

Mole rats are solitary, fossorial rodents which occur in Central Africa and East Africa; they occupy a wide range of habitats including agricultural areas, where they are regarded as pests (Kokiso and Bekele, 2008). They are aggressive animals and their external form consists of small eyes and ear pinnae, short limbs, tail broad feet and large prominent incisors modified for underground life (Jarvis and Sale, 1971). *Tachyoryctes splendens* are not likely to possess many morphological modifications; their appearance is more like rats or vole (Jarvis and Sale, 1971). *Tachyoryctes splendens* spend most of their time underground and as a result they have morphological and physiological adaptations to the underground habitat including microphthalmic eyes and enhancement of senses such as olfaction and tactile stimuli (Nevo, 1999). The mole rats are not exposed to the natural day light because of their subterranean lifestyle; they also change activities in response to inverted light cycle (Bennett *et al*., 1988).

The distribution pattern of East African mole rats varies and fluctuates seasonally based upon altitude and vegetation cover as well as precipitation and other climatic factors. *Tachyoryctes splendens* favour deep, well-drained, often-volcanic soils, rainfall over 510 mm a year and vegetation cover of grass to open forests (Jarvis and Sale, 1971). Additionally, local distribution of any subterranean rodents is influenced by topography, soil and vegetation characteristics of the habitat. As areas of suitable

soil and vegetation are patchily distributed, individuals also tend to be spatially clumped (Bennett and Faulkes, 2000).

1.8.1. Burrowing and feeding behaviour

Subterranean mammals spend most of their lives in self-constructed burrows that provide them safety from predation, climatic extremes and ensure access to food resources (Nevo, 1999; Busch *et al.,* 2000). The burrow system of all mole rats has a similar architecture, which consist of a superficial network of foraging tunnels interconnected with a system of more deeply located chambers used for nesting, food storage and sanitation (Bennet *et al.,* 1990; Hickman, 1979; Brett, 1991; Spinks *et al.,* 2000). The level of social organization, group size, habitat characteristics and individual variability are relevant factors influencing the architecture of mole-rat burrow systems (Herbst and Bennett, 2006).

The common mole rats are herbivorous. Due to their fossorial behaviour they mainly feed on the underground storage organs such as grassroots, rhizomes, stem and leaves, herbs, shrubs and tree roots, bulbs and corms (Jarvis and Sale, 1971). The positioning of the burrow system appears to remain more or less fixed although the burrow patterns are normally changing. Not all soil excavated is disposed on the surface mounds; some of the soil is used by the mole rats to block the old burrows. Other factors that can stimulate the increase of the burrow extension include rainfall and breeding season (Davies and Jarvis, 1986).

1.8.2 Breeding

Tachyoryctes splendens have mainly two periods of seasonal breeding events in long seasonal rainfall, hence for their natal burrow system occurs during the onset of the next rains to ensure that the off spring have maximum vegetation and food resource available (Katandukila *et al*., 2013). The average annual litter size of a female mole rat is 2.1 litters; its gestation period is up to 37-40 days in Kenya (Jarvis, 1973). Moreover, the gestation period determined by Rahm (1969) is 45-50 days in eastern Zaire (Congo). Females deliver up to four young in a litter, but usually one or two. The young are under protection for 4-6 weeks, reach maturity at 6-months of age but they have an average life expectancy of about one year and as they are matured each adult lives alone in its own burrow system (Nowak, 1999).

1.9 General Methodology

The research was carried out in Tanzania's Kilimanjaro Region's Rombo District. Rombo District is located in the Kilimanjaro Region's Northern most region, encompassing 1 442 square kilometers and home to 260 963 people, including 136 435 females and 124 528 men (URT, 2013). Data was gathered from both secondary sources. The respondents were chosen using both purposive and simple random sampling techniques. Quantitative and qualitative data were collected from four villages in Rombo District using a cross-sectional research design. Key informant interviews and observations were used to gather qualitative data. A structured questionnaire was used to obtain quantitative data. Content method was used to analyze qualitative data, while multiple linear regression and binary logistic regression analysis were used to analyze quantitative data descriptively and

inferentially. In the following chapters, detailed descriptions of the methodology used in this study are discussed.

1.10 Organisation of the Dissertation

This dissertation consists of two publishable manuscripts, presented in respective chapters. The whole dissertation is organized in four chapters: The first chapter consists of the extended abstract, introduction, the problem statement and justification, objectives and research questions and conceptual framework. Chapter two presents the first manuscript on the effect of mole rats (*Tachyoryctes splendens*) on smallholder farmers' well-being in Rombo District, Tanzania, while chapter three presents the effectiveness of mole rats (*Tachyoryctes splendens*) control strategies adopted by smallholder farmers in Rombo District, Tanzania. Lastly, overall conclusions and recommendations are presented in chapter four.

1.11 References

Alatartseva, E. and Barysheva, G. (2015). Well-being: subjective and objective aspects. *Procedia-Social and Behavioral Sciences* 166 (1): 36-42.

Arega, Y. (2017). Feeding Ecology and Pest Status of the Mole Rats *(Tachyoryctes splendens)* in Farmland. Published Thesis for Award of M.Sc. Degree at Addis Ababa University, Southwest Ethopia. 101-130pp.

Bennett, N. C., Jarvis, J.U.M. and Davies, K.C. (1988). Daily and seasonal temperatures in the burrows of African rodent moles. *South African Journal of Zoology* 23:189–195.

Bennett, N.C. and Faulkes, C.G. (2000). *African Mole Rats: Ecology and Eusociality*. Cambridge University Press, Cambridge. 98pp.

Busch, C., Antinuchi, C. D., del Valle, J. C., Kittlein, M., Malizia, A. I., Vassallo, A. I. and Zenuto, R. R. (2000). Population ecology of subterranean rodents. *Life underground: the biology of subterranean rodents* 42(2): 183-226.

Chambers, R. and Conway, G. (1991). *Sustainable Rural Livelihoods: Practical Concepts for the 21st century*. Institute of Development Studies (UK). 33pp.

Clark, A. E., Paul, F. and Shields, A. (2008). Relative income, happiness and utility: an explanation for the Easterlin paradox and other puzzles. *Journal of Economic Literature* 46(1): 95-114.

Davies, K. C. and Jarvis, J. U. M. (1986). The burrow systems and burrowing dynamics of the mole-rats Bathyergussuillus and Cryptomyshottentotus in the fynbos of the south-western Cape, South Africa. *Journal of Zoology* 209: 125–147.

Deaton, A. (2008). Income, health, and well-being around the world: Evidence from the Gallup world poll. *Journal of Economic Perspective* 22(2): 53-72.

Dodge, R., Daly, A. P., Huyton, J. and Sanders, L. D. (2012). The challenge of defining wellbeing. *International Journal of Wellbeing* 2(3).

FAO (Food and Agriculture Organisation) (1983). World Food Security: *A reappraisal of the concepts and approaches, Director General's Report*, Rome 86pp.

Felce, D. and Perry, J. (1995). Quality of life: Its definition and measurement. *Research in developmental disabilities 16*(1): 51-74.

Forgeard, M. J., Jayawickreme E., Kern, M. L. and Seligman, M. E. (2011). Doing the right thing: Measuring wellbeing for public policy. *International Journal of Wellbeing* 1(1): 79-10.

Garfinkel, I. and Haveman, R. (1977). Earnings capacity, economic status, and poverty. In: M. Moon and E. Smolensky. *Improving Measures of Economic Well-Being*. New York: Academic Press, 52-74pp.

Herbst, M. and Bennett, N. C. (2006). Burrow architecture and burrowing dynamics of the endangered Namaqua dune mole rat (Bathyergus janetta)(Rodentia: Bathyergidae). *Journal of Zoology* 270(3): 420-428.

Hickman, G. C. (1979). Burrow system structure of Bathyergid: Cryptomys hottentotus (Rodentia: Rhizomidae) during flood conditions in Kenya. *Journal of Zoology*, *London* 200: 71 – 82.

Hird, S. (2003). What is wellbeing? A brief review of current literature and concepts, NHS Health Scotland, 28pp.

Hoffmann, A. and Zeller, U. (2005). Influence of variations in land use intensity on species diversity and abundance of small mammals in the Nama Karoo, Namibia. *Belgian Journal of Zoology* 135: 91-96.

Jacob, J. and Tkadlec, E. (2010). Rodent outbreaks in Europe: dynamics and damage. *Rodent outbreaks: ecology and impacts*. International Rice Research Institute Press. 207pp.

Jarvis, J. U. (1973). The structure of a population of mole-rats, Tachyoryctes splendens, (Rodentia: Rhizomyidae). *Journal of Zoology*, *171*(1): 1-14.

Jarvis, J. U. M. and J. B. Sale. (1971). Burrowing and burrow patterns of East African mole-rats. *Tachyoryctes, Heliophobius and Heterocephalus. Journal of Zoology* (London) 163:451–479.

Johnson, M.D. and Horn, C.M. (2008). Effects of rotational grazing on rodents and raptors in a coastal grassland. *Western North American Naturalist* 68: 444-453.

Katandukila, J. V., Faulkes, C. G., Chimimba, C. T. and Bennett, N. C. (2013). Reproduction in the East African root rat (Tachyoryctessplendens; Rodentia: Spalacidae) from Tanzania: the importance of rainfall. *Journal of Zoology* 291: 258-268.

Keyes, C. L. M. (2002). The mental health continuum: From languishing to flourishing in life. *Journal of Health and Social Behavior* 43: 207–222.

Kiefer, R. A. (2008). An integrative review of the concept of well-being. *Holistic Nursing Practice 22*(5): 244-252.

Kokiso, A. and Bekele. A. (2008). Ecology of mole rats *Tachyoryctes splendens* and its impacts on farmlands at Angacha, Central Ethiopia. *Acta Zoologica Sinica* 54:30–35.

Leirs, H., Sluydts, V. Makundi, R. (2010). Rodent outbreaks in sub-Saharan

Africa. *Rodent Outbreaks: Ecology and Impacts 11*(7), 250-269.

Makundi, R. H. (2011). *Community-Based Rodent Pest Management In Kilimanjaro Region, Tanzania*. Consultation Report. 81pp.

Makundi, R. H. and Massawe, A. W. (2011). Ecologically based rodent management in Africa: potential and challenges. *Wildlife Research 38* (7): 588-595.

Makundi, R. H., Ngowo, V., Massawe, A. W. and Mshuza, E. (2010). *Community-Based Rodent Pest Management In Kilimanjaro Region, Tanzania*. Consultation Report. 91pp.

Marlowe, J. and Godwin, D. (1988). The relationship of income and human capital to debt/asset ratio of farm families. *Home Economics Research Journal* 17(1): 95-105.

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

Maxwell, S. and Smith, M. (1992). Household food security: a conceptual review. *Household food security: Concepts, indicators, measurements 1*: 1-72.

Mdangi, M., Mulungu, L. S., Massawe, A. W., Eiseb, S. J., Tutjavi, V., Kirsten, F., Dlamini, N. Mahlaba, T., Malebane, P., Von Maltitze, E., Monadje, A., Makundi, R. H. and Belmain, S. R. (2013). Assessment of rodent damage to stored maize (Zea mays L.) on smallholder farms in Tanzania. *International Journal of Pest Management 59*(1): 55-62.

Meerburg, B. G., Pest, D., Singleton, G. R. and Leirs, H. (2009). The Year of the Rat ends – time to fight hunger. *Pest Management Science* 65:351-352.

Mulungu, L. S. (2017). Control of rodent pests in maize cultivation: the case of Africa. *Achieving sustainable maize cultivation.* Burleigh Dodds Science Publishing Limited. 88pp.

Mulungu, L. S., Mrosso, F. P., A.A.S., K., Mdangi, M. E., Tesha, P. P. H., Ngowo, V. and Kilonzo, B. S. (2015). Farmer's knowledge, attitude and practice on rodent management in lowland irrigated rice in Central-eastern Tanzania. *International Research Journal of Plant Science* 6: 7–14.

Nevo, E. (2007). Mosaic evolution of subterranean mammals: tinkering, regression, progression, and global convergence. *In Subterranean Rodents* 2(1):375-388.

Nowak, R. M. (1999). *Walkers Mammals of the World* Vol. II 6th ed. The John Hopkins University Press, Baltimore and London 835: 233-270.

Paim, L. (1995). Definitions and measurements of wellbeing: a review of literature *Journal of Economic and Social Measurement* 21: 297-309.

Rahm, U. H. (1969). Gestation period and litter size of the mole rat, Tachyoryctes ruandae. *Journal of Mammalogy 50*(2): 383-384.

Rundel, P.W., Smith, A.P. and Meinzer, F.C. (1994). *Tropical Alpine Environments: Plant form and Function.* Cambridge University Press. Cambridge 358: 76-98.

Ryan, R. M. and Deci, E. L. (2001). On happiness and human potentials: A review of research on hedonic and eudaimonic well-being. *Annual Review of Psychology* 52: 141–166.

Shanker, K. (2001). The role of competition and habitat in structuring small mammals communities in a tropical montane ecosystem in southern India. *Journal of Zoology* (London). 253:15–24.

Singleton R, G., Jens, J., Krebs, C. J. and Monadjem, A. (2015). Rodent Ecology, Behaviour and Management, *Wildlife Research*, 42: 83-85.

Singleton, G.R., Leirs, H., Hinds, L.A. and Zhang, Z. (1999). Ecologically-based management of rodent pests–re-evaluating our approach to an old problem. *Ecologically-based Management of Rodent Pests. Australian Centre for International Agricultural Research (ACIAR), Canberra* 31:17-29.

Spinks, A. C., Jarvis, J. U. and 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 69*(2): 224-234.

Swanepoel, L. H., Swanepoel, C. M., Brown, P. R., Eiseb, S. J., Goodman, S. M., Keith, M., Belmain, S. R., Kirsten, F., Leirs, H., Themb'alilahlwa, Mahlaba A. M., Makundi R. H., Malebane, P., Maltitz, E. F., Massawe, A. W., Monadjem, Mulungu, A. S., Singleton,G. R., Taylor, P.J. and Soarimalala, V . (2017). A systematic review of rodent pest research in Afro-Malagasy small-holder farming systems: Are we asking the right questions. *Journal of Public Library of Science 12*(3): 32-55.

Tkadlec, E. (2010). Rodent outbreaks in Europe: dynamics and damage. *Rodent outbreaks: ecology and impacts*. International Rice Research Institute Press. 207pp.

URT (United Republic of Tanzania) (2013). Population and Housing Census, 2012. Population Distribution by Administrative Areas. National Bureau of statistics Dar es Salaam and Office of Chief Government Statistician Zanzibar. 36pp.

Weisbrod, B. A. and Hansen, W. L. (1977) “An income net-worth approach to measuring economic welfare. In M. Moon and E. Smolensky (Eds.) *Improving Measures of Economic Well-Being. New York: Academic Press* 3(1):35-50.

Zhou, Y. (2010). Smallholder agriculture, sustainability and the Syngenta Foundation. *Syngenta Foundation for Sustainable Agriculture* 1-15.

CHAPTER TWO

2.0 THE EFFECT OF MOLE RATS (*Tachyoryctes splendens*) ON SMALLHOLDER FARMERS' WELL-BEING IN ROMBO DISTRICT, TANZANIA

Hilda J. Njau[1], Apia Massawe[2,3] and Rhodes Makundi[2,3]

[1] MA (PME) Student, Department of Policy, Planning and Management, College of Social Sciences and Humanities, P. O. Box 3035, Morogoro, Tanzania,

E-mail: ms.hildanjau@gmail.com

[2] Pest Management Center, Sokoine University of Agriculture, P. O. Box 3110 Morogoro, Tanzania. Email**:** massawe@sua.ac.tz | apiamas@yahoo.com

[3] Africa Centre of Excellence for Innovative Rodent Pest Management and Biosensor Technology Development. Sokoine University of Agriculture, Morogoro Tanzania.

2.1 Abstract

This paper aimed at assessing the effect of mole rats on smallholder farmers' well-being in Northern, Tanzania. Specifically, the paper focuses on establishing the extent of crops damage by mole rats and estimating the economic effects on the smallholder farmers in terms of income, food security and assets possession. A cross-sectional design was used, and data were collected at a single point in time.

Both purposive and simple random sampling techniques were used to select the respondents (n=200). Data collected were analyzed using IBM SPSS software where descriptive statistics and multiple linear regression techniques. It was observed that bananas were the most damaged crop in the highlands (79%), also while in the lowland areas, maize was the most damaged crop (70%). The findings showed that hours spent on controlling mole rats had a significant statistical influence on food security. On the other hand, the incidence of mole rats throughout the year had a significant statistical influence on asset value. It is concluded that proper management of mole rats in the present study area can solve the problems that farmers face regarding agricultural yield loss and energy expenditure. Assessing the farmers' perception on pest status, existing control methods, costs and efficiency of controlling methods will facilitate decision making on the application of successful pest management strategies. Introducing and using different integrated pest management techniques will also reduce mole rats attack and ensure increased agricultural productivity. From the current study, it is recommended that community based mole rats management should be applied in Rombo District.

Key words: Extent of crop damage, crop diversification, income, food security, assets possession, well-being

2.2 Introduction

In developing countries, rodent infestation is a serious threat causing substantial damage to food and cash crops (Shanker, 2001). This has led to loss of income and an increase in food shortage. Rodents occur all over the African continent in natural

habitats, cultivated areas and human settlements (Massawe *et al.,* 2011). Rodent pest outbreaks in Africa have been recorded since the early 20th century. In Eastern Africa, up to 80% of the harvests are lost due to rodents during outbreaks (Leirs *et al*., 2010), but also during non-outbreak periods rodents still cause chronic crop damage (Singleton *et al.,* 1999). In Tanzania, crops damage and levels of loss vary from year to year as a result of many interacting factors, including types of crops, time or stage of growth, number or density of rodents, and availability of other crops (Makundi *et al*., 1991).

The concept of well-being is a multifaceted phenomenon that has been defined and used widely in the development discourse but not always with a clear understanding (Forgeard *et al*., 2011). Traditionally, well-being has been measured in terms of material progress measured by income where the link between income and well-being is based on consumption. Consumption goes hand in hand with income level; when income increases the consumption also increases which represents an improvement in well-being (Clark *et al.,* 2008). Kiefer (2008) stated that well-being is equated with the quality of life and good living conditions. The traditional view of well-being has been broadened to encompass all aspects of human life. Others associate well-being with the life activities in which a person is engaged (Clark *et al*., 2008). It is measured by the individual's income, health, nutrition, education, assets, housing and their enjoyment. The term well-being as used in this study indicates income, food security, and assets possession.

Income as used in this study means the amount of money in Tanzanian Shillings (TShs) gained annually by an individual. Food security is defined in various ways: the Food and Agriculture Organization (FAO, 1983), defines food security as "assurance that all people at all times have both physical and economic access to the basic food they need". The World Bank (1986) defines food security as "access by all people at all times to enough food for an active healthy life". The European Commission defines food security as, "absence of hunger and malnutrition" (Maxwell and Smith, 1992).

Smallholder farmers' communities are a key group in food production and rural development. Increasing their productivity and income can make a major contribution to reducing hunger (Zhou, 2010). Rodent pest continuously affects smallholder farmers, resulting in substantial losses of crops (Mulungu, 2017; Mdangi *et al*., 2013; Makundi *et al*., 2010). The effects of mole rats in agriculture have received less research attention, and the extent of damage to crops is not well known (Makundi *et al*., 2010). Therefore, the study intended to assess the effect of mole rats on the well-being of smallholder farmers in Rombo District being representation of the whole Kilimanjaro Region, Tanzania. The specific objectives were to establish the extent of crop damage by root rats and estimate the economic effect of root rats on the smallholder farmers' well-being in Rombo District.

2.3 Methodology

2.3.1 Description of the study area

The study was conducted in Rombo District in Kilimanjaro Region, Tanzania. Rombo District lies in the Northern part of Kilimanjaro Region, covering 1 442 square kilometres with a population of 260 963 people; comprising 136 435 females and 124 528 males (URT, 2013). It is bordered to the North and east by Kenya, to the west by Siha and Hai Districts, and to the South by Moshi Rural District. The major economic activities in the District are agriculture (subsistence and small-scale farming), livestock keeping and retail business. The lower zone of Rombo District accommodates a variety of agricultural activities and is suitable for rain fed agriculture because of favourable long and short rain seasons. Crops like finger millet, maize, beans, banana, sunflower, coffee and groundnuts are grown in the lower zone of the District.

2.3.2 Research design and sample size

A cross-sectional research design was used in the study whereby data were collected from the field at a single point in time (Creswell, 2004). The design is useful for descriptive purposes as well as for the determination of the relationship between and among variables at a particular point in time (Bailey, 1994). In addition, the design is relatively cost effective since it takes little time to conduct and to make follow-up (Hemed, 2015). Further, the study used a mixed-methods approach whereby qualitative data were collected using key informant interviews and quantitative data were collected using a structured questionnaire.

2.3.3 Sampling procedures and sample size

The study used both purposive and simple random sampling techniques to select the respondents. Purposive sampling was used to select the villages in the study area where the incidences of crops damage by root rats was established (Makundi *et al.*, 2010). Simple random sampling technique was used to select smallholder farmers from the district who were actively involved in crop farming. The choice of a simple random sampling technique is fundamental to the quality of data gathered to ensure reliability and competence of the informants. Minimum sample size for social science research can be 30-200 which is reasonable when it comes to generalization of the findings to the population (Kish, 2004) .

2.3.4 Data analysis

Data collected were analysed using IBM SPSS software. The extent of crops damage was analysed using descriptive statistics as proportions of plants damaged by mole rats. Data presentation included frequencies, percentages and means. To determine the effect of mole rats on smallholder farmers' well-being multiple linear regression was used whereby dependent variables were farm income, food security and monetary value of assets possessed. Farm income was established by taking the actual number of banana yields per acre in kilograms (kgs) that a farmer was able to produce within a month and change input to amount of money that one would gain after sale at the market. Based on this study, food security was regarded as assurance of all people at all times having access to physical basic food determined by the number of meals per household per day. Furthermore, asset value was established by the physical assets the smallholder farmers owned independently. Hence, they were

regressed on indicators of mole rats' damages after the mole rats incidences on the smallholder farmers' fields.

The independent variables included indicators of mole rats damage such as costs used in control, the incidence of mole rats throughout the year, hours spent in control activities, and members of household involved. Logarithm transformation was applied to this objective as a convenient means of transforming a highly skewed variable into a more normalized data set (Osborne, 2010). Modelling variables with non-linear relationship, have a high chance of producing errors leading to negative skewedness.

$$Food_{Security} = \beta_0 + \beta_1 cost + \beta_2 occurrence + \beta_3 Time + \beta_4 Household_{¿+\varepsilon_i¿}$$

$$Assets\,Value = \beta_0 + \beta_1 cost + \beta_2 occurence + \beta_4 Household_{¿+\varepsilon_i¿}$$

$$Farm\,Income = \beta_0 + \beta_1 cost + \beta_2 occurrence + \beta_3 Time + \beta_4 Household_{¿+\varepsilon_i¿}$$

Where;

β_0 to β_4 are the coefficients of variables to be estimated and ε_i is the error term.

Table 2.1: Description of variables used in Multiple Regression Model

Variables	Descriptions	Measurements
Food security	Meals consumed	Number of meals consumed per day
Assets possession	Asset value	Tanzanian shillings
Income	How much they earn per month	Tanzanian shillings
Occurrence	Presence of mole rats	Number of occurrence throughout the year
Time	Hours used in controlling mole rats	Number of hours
Household size	Household members involved in controlling mole rats	Number of household members

2.4 Findings and Discussions

2.4.1 Extent of crops damage by mole rats

Smallholder farmers in Rombo District practise mixed farming in their fields. Most of the respondents reported banana crop to be the most damaged by mole rats (72%) while the least damaged crop was sugarcane 3.5% (Table 2.2). This finding is consistent with a report by Makundi *et al*. (2010) who revealed that banana was severely attacked by mole rats and this led to stunted growth and fallen stems. Most of the households grows banana as a staple food crop at a much larger scale than all other crops.

Bananas were most damaged in the rhizomes and corms leading to poor fruit production. Banana production was most common in the highland areas due to better rainfall conditions throughout the year compared to the drier areas in the lowland zone. While maize production was practised in both lowland and highland areas, the damage was almost similar. The findings show that maize damage was 59.5% (Table 2.2). Previous reports (Mulungu, 2017) indicated that mole rats cause serious damage to the maize crop by attacking the stems. The observed frequency of damage is high since maize is an important staple crop after bananas in Rombo District.

Table 2.2: Crop damage in the study area as reported by the respondents.

Crop	Yams		Banana		Maize		Sweet Potatoes		Coffee		Sugarcane	
	Freq	(%)	Freq	(%)	Freq	(%)	Freq	(%)	Freq	(%)	Freq	(%)
Damage	98	49.0	144	72.0	119	59.5	50	25.0	1	0.5	7	3.5
No damage	102	51.0	56	28.0	81	40.5	150	75.0	199	99.5	193	96.5
Total	**200**	**100**	**200**		**200**		**200**	**100**	**200**	**100**	**200**	**100**

	100	**100**	

Yams are both for food at the household and for sale. Most of the yams grown in the highland areas are intercropped with banana. Mole rats attack the roots causing losses of harvested crop of up to 49% (Table 2.2). Other crops such as sweet potatoes, sugarcane and coffee are also attacked by mole rats (Table 2.2) but damage estimates were low compared to other crops, and is consistent with findings reported by Makundi *et al*. (2010).

Figure 2.1 shows the crop damage between the highlands and lowland areas. In the highlands most of the respondents reported banana (79%) and yams (70%) were the most damaged crops compared to lower levels of damage for potatoes (34%) and sugarcane (6%). In the lowland areas, most of the farmers interviewed reported maize (70%) to be the most damaged crop followed by bananas (65%). Coffee and sugarcane were the least damaged in the study area (Figure 2.1).

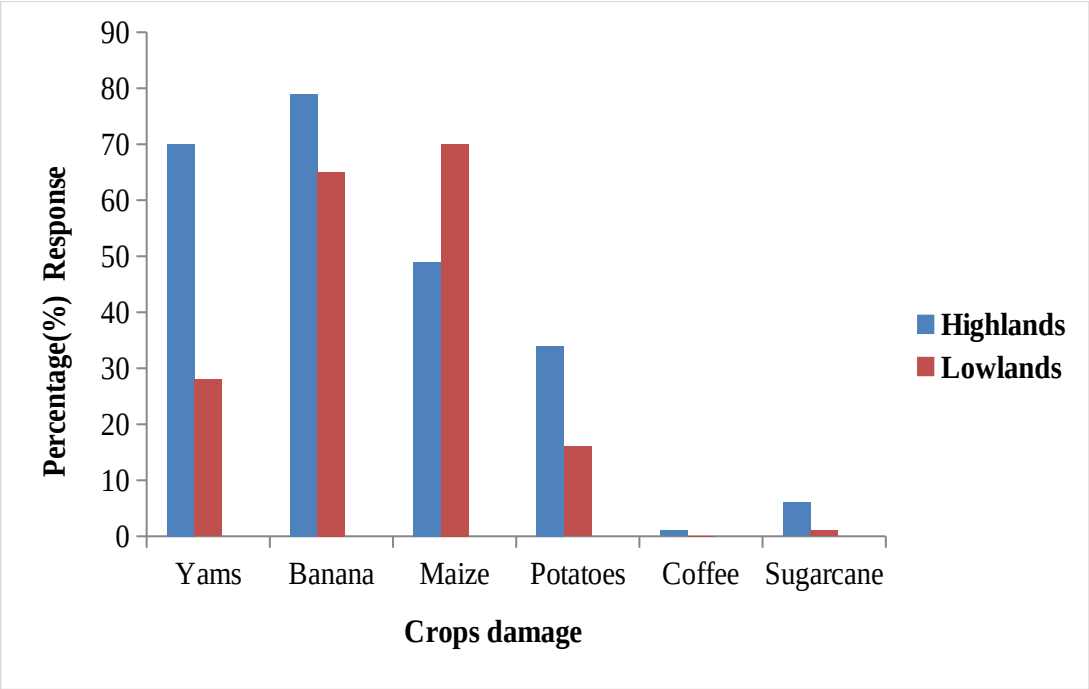

Figure 2.1: Farmers' responses on crop damage in highland and lowland areas of Rombo District, Tanzania

2.4.2 Mole rats effects on smallholder farmers' well-being

Table 2.3, shows the multiple linear regression analysis of farm income on indicators of mole rats damage which includes costs used in control, occurrence throughout the year, hours spent and members of household involved in their control. The R-square test indicates that 19.6% of the observed variation of farm income is explained by the variation in the model. The Variance Inflation Factor (VIF) was done and shows that no severe collinearity exists among the independent variables in the model. The results (Table 2.3) show that costs used to control mole rats and the occurrence throughout the year had statistically significant influence on farm income at ($p \leq 0.05$: $t = 4.780$, and 2.479 respectively). In other words, they were positively correlated with the farm income. On the other hand, hours spent in controlling the

mole rats and household members involved had no statistical significant effect on farm income at ($p \leq 0.05$, t= -0.673 and 0.867).

Independent variables	B	S.E	Beta	T	Sig.	95.0% C.I for EXP (B) Lower	Upper
Natural log of cost used to control mole rats	.186	.214	.069	.867	.387	-.238	.609
Natural log of household members involved in mole rats control	-.089	.133	-.056	-.673	.502	-.352	.173
Natural log occurrence of mole rats throughout the year	.608	.127	.380	4.780	.000***	.356	.860
Natural log of cost used to control mole rats	.378	.152	.207	2.479	.014*	.076	.679

Table 2.3: Multiple linear regression analysis for farm Income

Note: ***, **, *, implies significance at p<0.01, p<0.05 and p<0.1 probability levels, respectively. Nagelkerke R^2 = 19.6%.

Table 2.4 shows the multiple linear regression analysis of food security (number of meals taken) on indicators of mole rats damage which includes costs used in controlling mole rats, occurrence throughout the year, hours spent and members of household involved in controlling them. The multiple linear regression model of food security and hours spent in controlling mole rats was statistically significant (p = .090). The findings show hours spent in controlling mole rat problems had statistically significant influence on number of meals taken at ($p \leq 0.05$). In other words, hours spent in controlling the mole rats were negatively correlated with number of meals taken this implying that number of meals taken decreases as hours spent in controlling mole rats decreases. On the other hand, costs used in controlling the mole rats, the incidence throughout the year and members of household involved in control activities were not important factors in influencing number of meals taken.

Table 2.4: Multiple linear regression analysis for food security

Independent variables	Coefficient	Std. Error	Beta	t	Sig.	95.0%C.IforB		
						Lower Bound	Upper Bound	Tolerance
Natural Log of household members involved in mole rats control	-.103	.071	-.127	-1.458	.147	-.243	.037	.931
Natural Log of hours spent in controlling mole rats	-.075	.044	-.156	-1.706	.090*	-.162	.012	.848
Natural Log of occurrence of mole rats throughout the year	.040	.042	.083	.955	.341	-.043	.123	.942
Natural Log of costs used in controlling the mole rats	.037	.050	.067	.735	.464	-.063	.137	.851

Note: ***, **, *, implies significance at p<0.01, p<0.05 and p<0.1 probability levels, respectively. Nagelkerke R^2 = 4%

Table 2.5 shows findings of multiple linear regression analysis of physical current assets value (land, bicycle, motorcycle and car) at present on indicators of mole rats damage which includes costs used to control, occurrence throughout the year, hours spent and members of the household involved in controlling them. The multiple linear regression model of asset value and indicators of mole rats damage were statistically not significant. It was observed that all mole rats indicators had no influence on the assets value presented.

Table 2.5: Multiple linear regression analysis for asset value

Note: ***, **, *, implies significance at p<0.01, p<0.05 and p<0.1 probability levels, respectively.

Independent variables	B	Std. Error	Beta	t	Sig.	95.0% C.I for B		
						Lower	Upper	Tolerance
Natural Log of household members involved in mole rats control	-.017	.485	-.003	-.035	.972	-.977	.943	.931
Natural Log of hours spent in controlling the mole rats	-.297	.301	-.092	-.987	.326	-.893	.298	.848
Natural Log of occurrence of mole rats throughout the year	-.139	.288	-.043	-.483	.630	-.710	.431	.942
Natural log of the cost used to control the mole rats	.125	.345	.033	.361	.719	-.558	.808	.851

2.5 Conclusion and Recommendations

2.5.1 Conclusion

From the study, banana crop was the most damaged by mole rats in the highland areas. In the lowland maize was reported to be the most damaged crop. Costs used in controlling the mole rats, the incidence throughout the year and members of household involved in controlling the mole rats had statistically significant influence on farm income. Hours spent in controlling mole rat problems and incidence of mole rats throughout the year were important influencing factors on asset value.

2.5.2 Recommendation

From the study, it is recommended that a community participatory mole rats control framework is required for Rombo District. Specifically, the mole rat management strategies have to be identified for upland areas which have a complex farming system. The main principle for mole rat management in this complex farming system is to encourage farmers to work together at key times of the year. Community management of mole rats should be encouraged in all the villages, advising farmers to work together because the mole rats have no boundaries between farms. Introducing and using different integrated pest management techniques will also reduce mole rat attack and ensure increased agricultural productivity. Rombo District Council and Central Government should enhance public-private partnership to ensure farmers access to all necessary information to increase crop harvests by establishing Farmer Field Schools and farmer’s cooperatives.

2.6 References

Bailey, K. D. (1994). *Methods of Social Science Research* (4th Edition). Free Press. Collier Macmillan Publisher, New York. 588pp.

Clark, A. E., Paul, F. and Shields, A. (2008). Relative income, happiness and utility; an explanation for the Easterlin paradox and other puzzles. *Journal of Economic Literature* 46(1): 95-114.

Creswell, J. W. (2004). *Research Design; Qualitative and Mixed Method Approach* (2nd Edition). Sage Publication Inc., California. 246pp.

FAO (1983). World Food Security: *A reappraisal of the concepts and approaches, Director General's Report*, Rome 86pp.

Forgeard, M. J., Jayawickreme, E., Kern, M. L. and Seligman, M. E. (2011). "Doing the right thing: Measuring wellbeing for public policy". *International Journal of Wellbeing* 1(1): 79-106.

Hemed, M. (2015). Cross- sectional studies. *Training course in sexual and reproductive Health Research.* GFMER Tanzania. 90pp.

Kiefer, R. A. (2008). An integrative review of the concept of well-being. *Holistic Nursing Practice 22*(5): 244-252.

Kish, L. (2004). *Statistical design for research* (Vol. 83). John Wiley & Sons. 45pp.

Leirs, H., Sluydts, V. and Makundi, R. (2010). *Rodent outbreaks in sub-Saharan Africa: Ecology and Impacts* 2(1)*:*269-280

Makundi, R. H., Mbise, T. J. and Kilonzo, B. S. (1991). Observations on the role of rodents in crop losses in Tanzania and control strategies. *Beiträge zur tropischen Landwirtschaft und Vertirinärmedizin 29*(4), 465-474.

Makundi, R. H., Ngowo, V., Massawe, A. W. and Mshuza, E. (2010). *Community-Based Rodent Pest Management In Kilimanjaro Region, Tanzania*. Consultation Report. 91pp.

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

Maxwell, S. and Smith, M. (1992). Household food security: a conceptual review. *Household food security: Concepts, indicators, measurements 1*: 1-72.

Mdangi, M., Mulungu, L. S., Massawe, A. W., Eiseb, S. J., Tutjavi, V., Kirsten, F., Dlamini, N. . Mahlaba, T., Malebane, P., Von Maltitze, E., Monadje, A., Makundi, R. H. and Belmain, S. R. (2013). Assessment of rodent damage to stored maize (Zea mays L.) on smallholder farms in Tanzania. *International Journal of Pest Management 59*(1): 55-62.

Mulungu, L. S. (2017). Control of rodent pests in maize cultivation: the case of Africa. *Achieving sustainable maize cultivation.* Burleigh Dodds Science Publishing Limited. 80pp.

Osborne, J. (2010). Improving your data transformations: Applying the Box-Cox transformation. *Practical Assessment, Research, and Evaluation* 15(1), 12.

Shanker, K. (2001). The role of competition and habitat in structuring small mammals communities in a tropical montane ecosystem in southern India. *Journal of Zoology (London)* 253:15–24.

Singleton, G.R., Leirs, H., Hinds, L.A. and Zhang, Z. (1999). Ecologically-based management of rodent pests–re-evaluating our approach to an old problem. *Ecologically-based Management of Rodent Pests. Australian Centre for International Agricultural Research (ACIAR), Canberra* 2(1):17-29.

World Bank (1986). Poverty and hunger. Issues and options for food security in developing countries. A world Bank policy study, Washington, 184pp.

Zhou, Y. (2010). Smallholder agriculture, sustainability and the Syngenta Foundation. *Syngenta Foundation for Sustainable Agriculture* 1-15.

CHAPTER THREE

3.0 THE EFFECTIVENESS OF MOLE RATS (*Tachyoryctes splendens*) CONTROL STRATEGIES ADOPTED BY SMALLHOLDER FARMERS IN ROMBO DISTRICT, TANZANIA

Hilda J. Njau[1], Apia Massawe[2,3] and Rhodes Makundi[2,3]

[1] MA (PME) Student, Department of Policy, Planning and Management, College of Social Sciences and Humanities, P. O. Box 3035, Morogoro, Tanzania,

E-mail: ms.hildanjau@gmail.com

[2]Pest Management Center, Sokoine University of Agriculture, P. O. Box 3110 Morogoro, Tanzania. Email**:** massawe@sua.ac.tz | apiamas@yahoo.com

[3] Africa Centre of Excellence for Innovative Rodent Pest Management and Biosensor Technology Development. Sokoine University of Agriculture, Morogoro Tanzania.

3.1 Abstract

Crop damage by mole rats is a persistent problem in Rombo District, Kilimanjaro Region, Tanzania although there are no reliable estimates of the overall loss caused by pest. The general objectives of this paper were to determine the effectiveness of the mole rats control strategies adopted by smallholder farmers in Rombo District. The paper focuses on the socio-demographic characteristics of smallholder farmers and their adoption of mole rats control strategies, identification of mole rats control strategies and an evaluation of the effectiveness of the control strategies in the paper area. A cross-sectional design was used to collect data at a single point in time. Both purposive and simple random sampling techniques were used to select the respondents (n=200). Data collected were analyzed using IBM SPSS software. Agriculture was the most dominant economic activity in Rombo District. Trapping was the most adopted strategy to control mole rats infestation in farms ($p<0.05$), followed by excavation of burrows ($p<0.05$) and the use of fumigants in burrows. Trapping of root rats and excavation of burrows had a positive influence on banana production. It is recommended that there is a need for the extension agents to promote practical mole rats control strategies among farmers in Rombo district and generally in Kilimanjaro Region.

Key words: Mole rats, Trapping, Excavation, Fumigation

3.2 Introduction

Rodent outbreaks occur regularly in different places worldwide causing massive crop losses (Singleton *et al*., 2015). In Ethopia, the common mole rats feed on underground plant parts mainly roots, rhizomes, tubers, as well as stems, bulbs and grasses (Arega, 2017). Rodents occur in a wide variety of habitat types including agricultural areas, where they are regarded as pests (Kokiso and Bekele, 2008). Mole rats distribution pattern varies and fluctuates seasonally based on the altitude and vegetation cover as well as climatic factors. Mole rats are highly influenced by topography, soil, and vegetation characteristics of the habitat (Jarvis and Sale, 1971). The diverse species of rodents in Rombo District are highly influenced by habitat complexity and heterogeneity in the highland and lowland areas. Rodent infestations in the district have a significant limitation to crop production; their management remains a major challenge to the extension officers and farmers (Makundi and Massawe, 2011). Mole rats in Rombo District attack a variety of plants such as bananas, sugarcane, pineapples, maize, cassava, sweet potatoes, beans, eggplants, and yams (Makundi *et al.,* 2010).

Every year farmers in Tanzania suffer chronic losses of above 15% of their cereal crops such as maize, sorghum and rice in the field, but this can be higher when there are rodent outbreaks (Makundi *et al*., 1991). Damage to crops and levels of loss vary from year to year as a result of many interacting factors, including types of crop,

time or stage of growth, number or density of rodents, and availability of other crops in the same area. In most cases, the economic losses due to rodents have mainly been investigated for semi fossorial rodents such as *Mastomys natelensis* (Mulungu *et al*., 2015) and less research attention has been on fossorial rodents and subterranean species such as mole rats (Swanepoel *et al*., 2017). Farmers have continuously reported an increasing magnitude of mole rats infestation for which they lack effective management strategies. Little is known on the impact of mole rats on smallholder farmers in Rombo District (Makundi *et al.,* 2010), and there are no reliable estimates of the overall loss caused by mole rats in Rombo District.

Despite the efforts to apply rodenticides as an important strategy against rodents, particularly when there are outbreaks, rodents continue to be a major problem due to chronic invasion of crop fields. The use of rodenticides to control rodents is too expensive thus it is very difficult for small scale farmers to adopt them (Makundi *et al.,* 2010). For small scale subsistence farmers in Rombo District, as the case in the rest of Tanzania, rodenticides are too expensive or are locally unavailable. For the individual farmers, the cultivated fields are too small, and therefore any individual action to control rodents cannot have any effect on the overall rodent population (Makundi *et al.,* 2010). However, mole rats control relies mainly on traditional techniques such as digging and trapping. There are no rodenticides recommended for mole rats control in Tanzania (Makundi *et al*., 2010). Tephrosia plant *(Tephrosia vogellii)* is considered to be a promising method used to control mole rats in the field, the plant leaves and roots contain rotenone which is toxic to mole rats (Mkenda *et al*., 2015). Sustainability of livelihoods of smallholder farmers in Rombo District

is threatened by mole rats infestation for lack of effective management strategies. The impact has remained a critical challenge for the majority of smallholder farmers' communities where mole rats infestation is severe. The infestation of mole rats puts crops at high risk due to damage and consequently deteriorating the well-being of smallholder farmers.

The overall objective of this paper was to determine the effectiveness of mole rats control techniques adopted by smallholder farmers in Rombo District. The specific objectives were to determine the socio-demographic characteristics which influence mole rats control strategies.

3.3 Methodology

3.3.1 Description of the study area

The study was conducted out in Tanzania's Kilimanjaro Region's Rombo District. Agriculture (subsistence and small-scale farming), livestock husbandry, and retail commerce are the main economic activities in the districts. In both long and short rain seasons, the lower zone of Rombo District can handle a wide range of agricultural operations and is suitable for rain-fed agriculture. In the lower zone, crops such as finger millet, maize, beans, banana, sunflower, coffee, and groundnuts are grown.

3.3.2 Research design and data collection techniques

The study used a cross-sectional research approach, in which data was collected from the field at a single point in time (Creswell, 2004). Because it requires minimal time to perform and there is no follow-up loss, the design is relatively cost effective

(Hemed, 2015). Furthermore, the research used a mixed-methods approach, with qualitative data collected through key informant interviews and observation and quantitative data collected using a structured questionnaire.

3.3.3 Sampling procedures and sample size

The respondents were chosen using both purposive and simple random selection techniques. Purposive sampling was utilized to identify communities where root rats had caused agricultural damage. By observing the amount of mole hills, burrows pattern, and habitat type, Makundi *et al.* (2010) concluded that majority of the fields were highly infected by mole rats. Smallholder farmers in the district who are actively engaging in crop cultivation were selected using a simple random sample approach. The use of a simple random sampling strategy is essential to the quality of data gathered in order to assure the informant's reliability and competency. When it comes to generalization of findings, a minimum sample size of 30-200 might be used in social science research (Kish, 2004).

3.3.4 Data analysis

Data collected were analysed using IBM Statistics (SPSS) Version 20.0 for Windows software. The effectiveness of mole rats control strategies adopted by households was analysed using binary logistic regression. Production of the main crop (banana) was used as a proxy indicator of effectiveness of the control measures, because the effectiveness of the strategies was expected to reduce damage on the crop. Amounts of field per harvest was the dependent variable and agronomic practices, socio-demographic factors and the trapping techniques were the independent variables. The

analysis carried out was to examine how haversts are influenced by uindependent variables. To obtain Odds Ratio (OR) at 95% Confidence Interval (95% CI) the study employed adjusted model as all covariates were fitted once during the analysis and statistical significance level of 5%. Note that, this model was considered as the dependent variable has two categories: high yields or low yields. We defined our outcome as:

$$\begin{cases} 1, \wedge \textit{if the subject has high yields} \\ 0, \wedge \textit{low yields}. \end{cases}$$

The distribution of Y is specified by probabilities $P(Y=1)=\pi$ of high yields and the probability of low yields$1-P(Y=0)=1-\pi$.

Thus, the model is represented as follows:

$$\textit{logit}(\pi(x))=\log\left(\frac{\pi(x)}{1-\pi(x)}\right)=\beta_0+\beta_1 * X_1+\beta_2 * X_2+\ldots+\beta_k * X_k$$

β_0=constant term.

$\beta_1 \ldots \beta_k$ Coefficients of the independent (predictor) variables.

k = number of independent variables.$X_1 \ldots X_{12}$ are independent variables included in the model, which are:

X_1= Actual age (Number of years)

X_2= Marital status (1 = Single, 0 = Married)

X_3= Types of fertilizers used (1 = Organic, 0 = Inorganic)

X_4= Times of contacting the extension officer (number of meetings)

X_5= Hire labour (1 = Yes, 0 = No)

X_6= Non-farm activities (1 = Yes, 0 = No)

X_7= Distance to the market (1 = Far, 0 = Near)

X_8= Trapping (1 = Yes, 0 = No)

X_9= Fumigation (1 = Yes, 0 = No)

X_{10}=Digging (1 = Yes, 0 = No)

Table 3.1: Description of variables used in Multiple Linear Regression model

Variables	Descriptions	Measurements
Harvests	Crops harvested	Kilograms (kgs) per acre (1 = High, 0 = Low)_
Actual age	Age of the smallholder farmer	Number of years
Marital status	Marital status of farmers	Dummy whereby; 0 = Single and 1 = Married
Fertilizers	Types of fertilizers used by smallholder farmers	Dummy whereby; 0 = Organic and 1 = Inorganic
Time of contact	Average number of time a farmer contact extension officer	Number of contacts per month
Labour	Whether the farmer hired labour for farming activities	Dummy whereby; 0 = No and 1 = Yes
Distance	The Distance from the field to the market place	Dummy whereby; 0 = Near and 1 = Far
Trapping	Mole rat controlling strategies adopted by farmers	Dummy whereby; 0 = No and 1 = Yes
Fumigation	Mole rats controlling strategies adopted by farmers	Dummy whereby; 0 = No and 1= Yes
Excavation	Mole rats controlling strategies adopted by farmers	Dummy whereby; 0 = No and 1 = Yes
Non-farm activities	Whether the farmer was engaged in other non-farm activities	Dummy whereby; 0 = No and 1 = Yes

3.4 Results and Discussion

3.4.1 Socio-demographic characteristics of respondents

The results show that, out of the 200 respondents interviewed in the study area, 52% were males and 48% were females (Table 3.2). Smallholder farmers involved themselves in both cash and food crops cultivation but it was observed that male farmers were more likely to engage in cash crop production while female farmers were more involved in food crop production. According to Edward (2008), men and women play different roles within particular systems of agricultural production and occupy different socio economic positions. Furthermore, 55.5% of the respondents indicated agriculture to be their major source of income compared to livestock (32%). Only 13% of the respondents reported non-agricultural activities (small business and salaries) as their main source of income (Table 3.2).

The age of majority of the respondents ranged from 46 to 70 years (44.5%) (Table 3.2). Most of the respondents (74.5%) had primary school education. In most rural areas of Tanzania the majority have never attended secondary education. However, in the current study the majority had formal education, implying that they were literate enough to learn various crop production methods including pest problems and their management strategies provided through different sources such as mass media, agricultural extension agents and publications (William, 2016).

It was observed that the majority of the respondents were engaged in agricultural activities which imply that agriculture is the main economic activity in Rombo

District (Table 3.2). Studies by URT (2013) showed that the agricultural sector in Tanzania is a key driver of socio and economic development.

Table 3.2: Demographics and socio-economic characteristics (n = 200)

Variable	Category	Percentage Respondents	
		Highlands	Lowlands
Gender	Male	55.0	49.0
	Female	45.0	51.0
Age	20-45	40.0	28.0
	46-70	40.0	49.0
	71-96	20.0	22.0
	97- above	0	1.0
Education level	No formal education	8.0	10.0
	Primary education	69.0	80.0
	Secondary education	17.0	8.0
	Tertiary education	4.0	1.0
	Adult education	2.0	1.0
Marital status	Single	20.0	7.0
	Married	80.0	93.0
Occupation	Farmer	48.0	63.0
	Livestock keepers	31.0	33.0
	Entrepreneur	14.0	3.0
	Business	5.0	1.0
	Employed	2.0	0

3.5 Mole Rats Control Strategies Used by Small scale Farmers in Rombo District

3.5.1 Trapping

About 57% of the respondents reported using traditional trapping methods to control mole rats (Figure 3.1). Farmers design and make the traps on their own; the traditional trap is made of a stem cylinder fixed with a string placed within the tunnel and captures the mole rat as it tries to go through the trap chamber (Figure 3.1). This

trap can catch only one rat at a time. Often the farmers employ persons who are experts in trapping of the mole rats. This exercise may cost between 5,000 – 10,000 Tshs, (2.00- 4.00 USD) per animal captured. The presence of mole rats activities in their fields was identified by observing mole hills on the ground surface, this was also reported by Makundi *et al.* (2010).

Figure 3.1: A sample of a traditional mole rat trap used in the study area

3.5.2 Digging

This method demands intensive labour involving digging a burrow system to locate the mole rats. Farmers would practise this method off season when there are few crops in cultivation. Occasionally the burrows are flooded with water to drown the animals. Makundi *et al*. (2010) reported that digging burrows is an effective strategy of controlling mole rats. Flooding of burrows depends on the availability of water and is more common in highland are than in lowland areas. Ideally, this practice will

be of low cost because you only have to open the burrow at one end to allow water to flow in.

Figure 3.2: Digging structure

3.5.3 The use of fumigants

Fumigants are chemicals that produce poisonous gas to kill the animals. According to Makundi *et al.* (2010), aluminium phosphide (phosphotoxin) tablets are placed in burrows and produce phosphine gas that kills the root rats. During the survey, only 13% of farmers were used this method, but it was considered expensive and the tablets have a strong toxic smell which can cause eye itching. Furthermore, a previous study reported that the least method used by farmers to control mole rats destruction was the use of toxic chemicals because it is ineffective and dangerous (Arega, 2017).

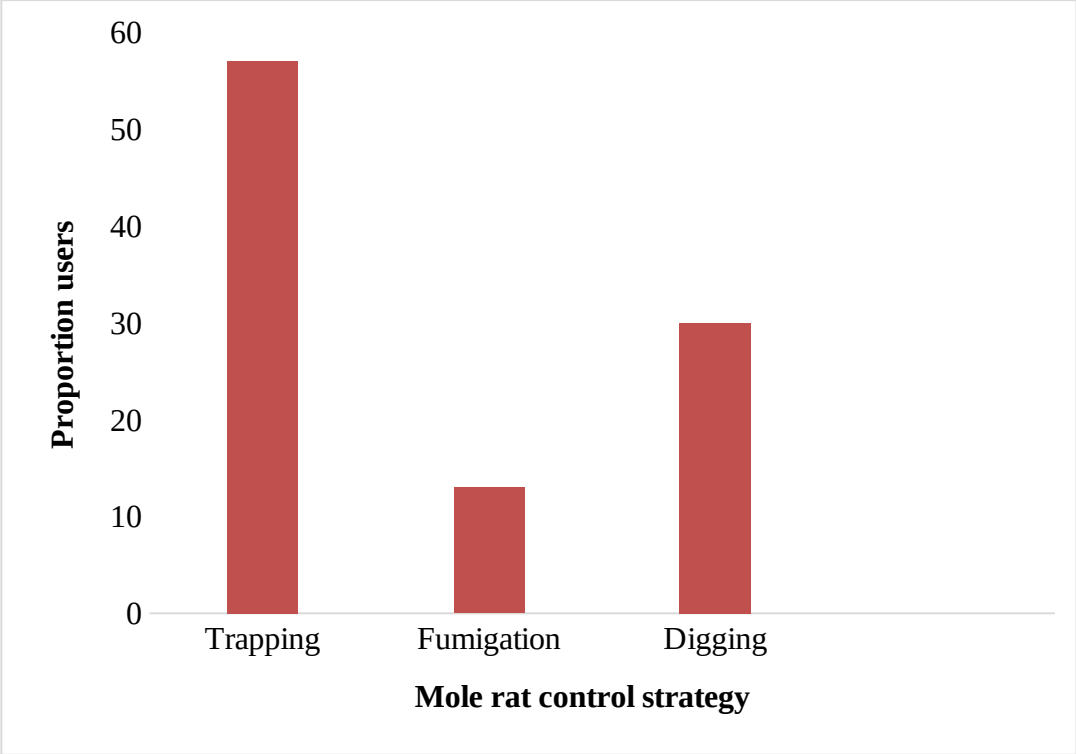

Figure 3.3: Proportional (%) use of techniques to control mole rats in Rombo District.

3.6 Banana harvests estimate in highland and lowland areas

Bananas are severely attacked by mole rats in Rombo District. The results agree with results of a study by Arega (2017) who reported that mole rats mostly fed on banana plant by attaching the corn. Figure 4 shows the percentage of smallholder farmers growing the banana plant and average harvests per month in lowland and highland areas in Rombo District.

Three quarters (75%) of smallholder farmers from the lowland areas harvested 10 kg to 25 kg of banana per acre per month only compared to only 10% of farmers in highland areas. About 63% of the farmers from the highlands produced an estimated

50 kg to 100 kg of bananas per month compared to only 10% of the farmers from the lowlands. The areas have poor climatic conditions particularly low rainfall and less fertile soil. The lowland zone has low rainfall and less fertile soils sparse population, and low agricultural productivity (Newmark, 1991).

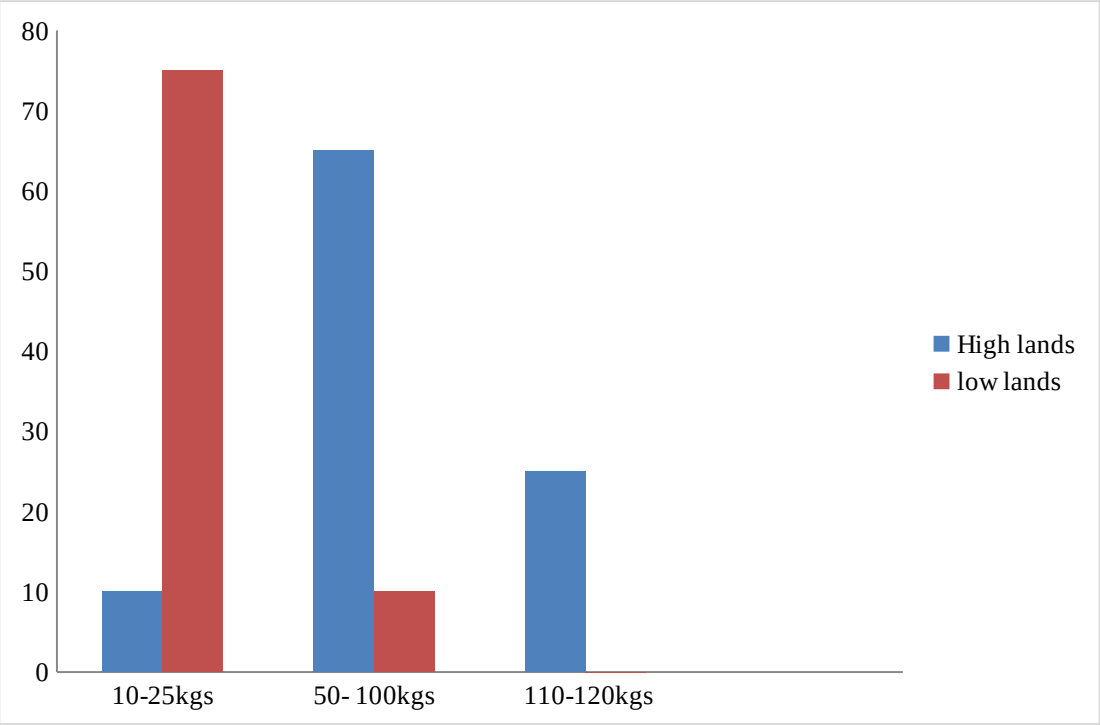

Figure 3.4: Banana harvest (kg) and proportions of smallholder farmers (%) growing the crop in the lowland and highland areas of Rombo District

3.7 Effectiveness of mole rats control strategies adopted by smallholder farmers

Binary logistic regression analysis was used to test the influence of socio-demographic factors, control strategies and agronomic practices on the banana yields. The results are summarised in Table 3.3 and show a log likelihood of 83.302. The Nagelkerke R^2 value of 0.820 means that the predictor variables entered in the

model explained 82.0 % of the variance in the outcome variable. The results (Table 3.3), show that out of ten variables entered in the model two variables; trapping ($p<0.05$) and excavation of the burrows ($p<0.05$), had significant effects on the banana harvests.

Table 3.3 shows that among the strategies that farmers adopted to reduce the mole rats infestation, trapping was significantly ($p<0.05$) effective in reducing the mole rats effect on banana yield. The results show that the odds ratio of using traditional trapping was 8.87 times effective when controlling mole rats infestation (OR = 8.866, CI = 95%). Studies elsewhere show remarkable control of mole rats destruction using local conical trapping method and that the least used method was rodenticides application (Arega, 2017).

Burrow excavation or digging was significantly ($p<0.05$) effective in managing mole rats infestation. The study results further show that the odds of using excavation or digging increased by 18.512 times (OR = 18.512, CI = 95%) when controlling mole rats infestation. Kasso (2013) argued that techniques such as flooding burrows had a better chance of killing the mole rats because the animals cannot survive in the burrow after flooding. Demographic factors such as marital status and actual age had no influence on the harvests. Theoretically, there should be a linkage, but there was poor variation among the variables presented.

Table 3.3: Binary Logistic Regression analysis results for determining effectiveness of control strategies chosen by smallholders farmers (n = 200)

Variables	B	S.E	Wald	df	Sig.	Exp (ODDS RATIO)
Actual age	-.020	.022	.821	1	0.365	.980
Marital status	-1.309	1.073	1.488	1	0.222	.270
Type of fertilizer	-.668	.797	.702	1	0.402	.513
Time containing the field officer	.568	.377	2.269	1	0.132	1.765
Hire labour	.608	.671	.821	1	0.365	1.837
Non farming	-.526	.725	.525	1	0.469	.591
Trapping	2.182	1.070	4.160	1	0.041**	8.866
Fumigats	1.681	1.212	1.924	1	0.165	5.372
Excavation	2.918	1.170	6.220	1	0.013**	18.512
Distance to the market	-23.46	3795.122	.000	1	0.995	.000
Constant	-.105	1.629	.004	1	0.949	.900

Note: ***, **, *, imply significant at p<0.01, p<0.05 and p<0.1 probability levels, respectively. Nagelkerke R^2= 0.820

3.8 Conclusion and Recommendation

3.8.1 Conclusion

According to the result of this study, agriculture is the most important economic activity in Rombo District. Trapping was the most common method for controlling mole rats, followed by digging and fumigant use. Although trapping, burrow excavation, and fumigants were all used to control mole rats, only trapping and excavation had a significant effect on banana harvest. Damage by mole rats has been highlighted as one of the most major barriers to banana farming. F farmers in the study area were aware of the various mole rat control strategies. Farmers who were

unaware of the mole rat control strategies, on the other hand, they will tend to be were less successful.

3.8.2 Recommendations

The study recommends that extension agents should equip farmers with improved banana agronomic practices to increase banana harvests. Farmers should engage more in trapping of root rats and excavation of burrows to reduce crop damage and increase crop harvest in the study area. Extension officers must promote practical mole rat control strategies to farmers in order to boost agricultural yields. To limit the risk of rodent-borne diseases like plague, leptospirosis, and hemorrhagic fevers, farmers should be taught about the potential health risks when handling captured rats. This should involve the proper disposal of rodents seized.

For pest management to be effective, management strategies should be practised by farmers in their fields collectively because the mole rats have no plot boundaries. The introduction of *Tephrosia vogelii* intercropping with crops has been effective in other countries and could be used to supplement the other mole rats control strategies.

3.9 References

Arega, Y. (2017). *Feeding Ecology and Pest Status of the Mole Rats (Tachyoryctes splendens) in Farmland, Masha, and South west Ethopia* Masters of Science, Thesis Addis Ababa University.101-130pp.

Creswell, J.W. (2004). *Research Design; Qualitative and mixed Methods Approach* (2ed). Sage Publication Inc., California. pp. 246.

Edward, C. (2008). *Men's crops and Women's crop: The Importance of Gender to the Understanding of Agricultural and Development Outcomes in Ghana's Central Region*, World Development. 36pp.

Hemed, M. (2015). Cross- sectional studies. *Training course in sexual and reproductive Health Research.* GFMER Tanzania. 44pp.

Jarvis, J. U. M. and Sale, J. B. (1971). Burrowing and burrow patterns of East African mole-rats *Tachyoryctes, Heliophobius and Heterocephalus. Journal of Zoology* (London) 163:451–479.

Kasso, M. (2013). Pest rodent species composition, level of damage and mechanism of control in Eastern Ethiopia. *International Journal of Innovation and Applied Studies* 4(3): 502-11.

Kish, L. (2004). *Statistical design for research* (Vol. 83). John Wiley and Sons. 45pp.

Kokiso, A. and Bekele, A. (2008). Ecology of mole rats *Tachyoryctes splendens* and its impacts on farmlands at Angacha, central Ethiopia. *Acta Zoologica Sinica* 54:30–35.

Makundi, R. H. and Massawe, A. W. (2011). Ecologically based rodent management in Africa: potential and challenges. *Wildlife Research 38*(7), 588-595.

Makundi, R. H., Ngowo, V., Massawe, A. W. and Mshuza, E. (2010). *Community-Based Rodent Pest Management In Kilimanjaro Region , Tanzania*. Consultation Report. pp.91.

Makundi, R. H., Mbise, T. J., and Kilonzo, B. S. (1991). Observations on the role of rodents in crop losses in Tanzania and control strategies. *Beiträge zur tropischen Landwirtschaft und Vertirinärmedizin* 29(4), 465-474.

Mkenda, P., Mwanauta, R., Stevenson, P. C., Ndakidemi, P., Mtei, K., and Belmain, S. R. (2015). Extracts from field margin weeds provide economically viable and environmentally benign pest control compared to synthetic pesticides. 35pp.

Mulungu, L. S., Mrosso, F. P., Katakweba,A.A.S., Mdangi, M. E., Tesha, P. P. H., Ngowo, V., Mchomvu. M. and Kilonzo, B. S. (2015). Farmer' s

knowledge, attitude and practice on rodent management in lowland irrigated rice in Central-eastern Tanzania. *International Research Journal of Plant Science* 6: 7–14.

Newmark, W. D. (Ed.). (1991). *The Conservation of Mount Kilimanjaro* (Vol. 16). International Union for Conservation of Nature and Natural Resources. 67pp.

Singleton R, G., Jens, J., Krebs, C. J. and Monadjem, A. (2015). Rodent Ecology, Behaviour and Management, *Wildlife Research* 42: 83-85.

Swanepoel, L. H., Swanepoel, C. M., Brown, P. R., Eiseb, S. J., Goodman, S. M., Keith, M., Belmain, S. R., Kirsten, F., Leirs, H., Themb'alilahlwa, Mahlaba A. M., Makundi R. H., Malebane, P., Maltitz, E. F., Massawe, A. W., Monadjem, Mulungu, A. S., Singleton,G. R., Taylor, P.J. and Soarimalala, V . (2017). A systematic review of rodent pest research in Afro-Malagasy small-holder farming systems: Are we asking the right questions?. *Public Library of Science*, *12*(3).

URT (2013). Population and Housing Census, 2012. Population Distribution by Administrative Areas. National Bureau of statistics Dar es Salaam and Office of Chief Government Statistician Zanzibar. 36pp.

William, E. (2016). *Knowledge and Innovations for farmers from Teaching Agriculture in Uganda Primary Schools*: A study of Kumi Communities in the Teso Sub-Region. *Sustainable Agriculture Research* 5(2):56-66.

CHAPTER FOUR

4.0 SUMMARY OF MAJOR FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

4.1 Summary of Major Findings

Below is a summary of the major findings as per presented manuscripts.

4.1.1 The Effect of Mole Rats (*Tachyoryctes splendens*) on Smallholder Farmers' Well-Being in Rombo District, Tanzania

This manuscript aimed at establishing the extent of crops damage by mole rats and estimating the economic effect on the smallholder farmers in terms of income, food security and assets possession. The study findings show that banana was the most damaged crop in the highlands (79%). In the lowland areas, maize was the most damaged crop (70%). The results also show that hours spent in controlling mole rats had a significant statistical influence on food security. On the other hand, the incidence of mole rats throughout the year had a significant statistical influence on asset value.

4.1.2 The Effectiveness of Mole Rats (*Tachyoryctes Splendens*) control strategies adopted by Smallholder farmers in Rombo District, Tanzania.

The manuscript aimed at determining the socio-demographic characteristics of smallholder farmers and their adoption of mole rats control strategies. It also aimed at identifying mole rats control strategies and perceptions of the effectiveness of mole rats control strategies in the study area. Generally, the study findings show that agriculture was the most important economic activity in Rombo District. Trapping was the most preferred strategy to control mole rats infestation in farms ($p<0.05$) followed by excavation of burrows ($p<0.05$) and the use of fumigants in burrows. Trapping of root rats and excavation of burrows had a positive influence on banana production.

4.2 Conclusion

Banana was the most damaged crop particularly on the rhizomes and corms leading to poor fruit production. Banana cultivation was mostly practised in the highland areas due to better rainfall conditions throughout the year compared to the drier lowland areas. Costs used in controlling the mole rats, incidence throughout the year and members of household involved in controlling the pest were important factors influencing farm income. Hours spent in controlling mole rats had statistically significant influence on food security and that incidence of mole rats throughout the year was important factors influencing asset value.

Farmers were using in controlling the mole rats infestation in their fields namely trapping and excavation had a positive influence in the banana harvest. The

constraints/barriers to banana cultivation was infestation from mole rats. The study also show that farmers in the study area had access to traditional ways of controlling mole rats. However, few farmers are aware of control strategies, and as a result, farmers who are uninformed of control measures think that such strategies are less accurate.

4.3 Recommendations

i. Rombo District Council and Central Government should enhance public-private partnership to ensure farmers access all necessary information pertaining to mole rats control in the fields in order to increase farm productivity.
ii. Farmers should increase hours spent on controlling the problems caused by rats in order to increase food security in the study area.
iii. Extension agents are needed to spread practical information such as the adoption of different strategies besides those currently in use to boost agricultural yields, particularly for bananas, which are the most widely grown crop in the research region.
iv. In order to successfully control mole rats in Rombo District and the Kilimanjaro Region as a whole, farmers should practice proper pest management strategies collectively over large areas.

4.4 Areas for Further Study

It was observed that trapping was the most adopted strategy to control mole rats infestation in farms ($p<0.05$), followed by excavation of burrows ($p<0.05$) and the use of fumigants to burrows. As a result, study on additional mole rat control

strategies used by farmers in other parts of Tanzania is recommended. Trapping, excavation, and fumigation were chosen as the most well-known and traditional mole rat control methods in the study.

APPENDICES

Appendix 1: A copy of questionnaire used for Research

SOKOINE UNIVERSITY OF AGRICULTURE COLLEGE OF SOCIAL SCIENCE AND HUMANITIES
DEPARTMENT OF POLICY PLANNING AND MANAGEMENT

A Household Questionnaire for Research on

MOLE RATS (*Tachyoryctes splendens*) INFESTATION AND SMALLHOLDER FARMERS WELL-BEING: A CASE STUDY OF ROMBO DISTRICT, TANZANIA

BY
HILDA NJAU
M.A. (Project Management and Evaluation) Student
E-mail: ms.hildanjau@gmail.com

Section A: Background information:

1. Gender Male ( ) Female ( )
2. Single ( ) Married ( ) Separated ( ) Widow/ ( ) Widower ( )
3. Age of respondent …….
4. Residence:
   a. Village name: ……...
   b. Ward name: ……
   c. District name: ……
5. Education level of respondent

a. No formal education

b. Primary education

c. Secondary

d. Beyond secondary education

6. Number of people within the household

a. Adults and children above 18 years: ……

b. Children below 17 years: ……...

Section B: Economic activities:

7. Which crops do you grow?

……..…….

…….

…….

…….

……

8. Which crops do you value most as:

a. Food crops: ……..

b. Cash crops: ……..

9. If, banana is the main source of cash crop how many kilograms do you harvest per month per acre? .....

10. The average banana harvest in a year ……

Section C: Mole rat problem:

11. Do you consider mole rats as a problem in your farm?

……...

……

……..…

12. How severe is the mole rat a problem in your farm?

    a. Very severe

    b. Moderately severe

    c. Low

13. Which of your crops are mostly attacked by the mole rat?

……...

…….……..

……

……..……

14. Damage of each crop type by mole rat?

    a. Low < 25%

    b. Medium 25%- 50%

    c. High >50%

15. Which season of the year has high mole rat attack?

.....

.....

16. Do mole rats affect your income level?

    a. Yes

    b. No

17. If yes, at what extent do mole rats affect your income?

    a. <25% (low rate)

b. 25 > 50% (moderate rate)

c. 75% (high rate)

18. How many meals do you take per day?

a. 1

b. 2

c. 3

d. 4

19. Do you own any assets?

a. Yes

b. No

20. What assets do you own?

a. Motorcycle

b. Bicycle

c. Land

d. Car

21. What is the estimate of the assets you own in Tanzanian shillings at present?……..

22. How do you control/manage mole rats in your farm?

i. Trapping

ii. Rodenticides

iii. Both

iv. Others (specify)

23. Which is the most effective and successful method you use in controlling the mole rats?

……

…….

……

……..……

24. How regular do you use to apply the strategy?
    i. Very often
    ii. Sometimes
    iii. Not regularly
25. Are there any combinations of strategies that you use?

……..……

……

26. What are the most common challenges you face during controlling the mole rats in your farm?

……...

……

……

……

27. Do you have an extension officer in your village?

    a) yes b) no

28. If yes, how many times do you contact the extension officer per month?

    ……..

29. Are the extension officers aware of the mole rats problems? a) yes b) no
30. Are there any agricultural organisations in your village?

    a) yes b) no

31. If yes, are you a member of any agricultural organisation?
32. Do you hire a labour to work in your farm?
    a) yes b) no
33. If yes, how many? …….
34. What type of fertilizers do you use in your farm?
    a) Organic b) Inorganic
35. Are you aware of any improved seeds?
    a) yes b) no
36. Do you use improved seeds in your farm?
    a) yes b) no
37. How far is the market from your home or farm?
    a) far b) near
38. Do you practise non-farm activities?
    a) yes b) no
39. Are your household members involved in controlling mole rats in the farm?
    a)yes b) no
40. If yes, how many are involving themselves in controlling the mole rats?.....
41. How many hours do you spend in controlling the mole rats in a day?.....

THANK YOU VERY MUCH FOR YOUR COOPERATION

Appendix 2: Interview Guide for Extension Officer

1. In your working area, are mole rats among problematic pests?
2. Within 5 years what was the extent of destructions made by the mole rats?
3. Which crops are mostly affected by the mole rats?
4. What government strategies do you use to overcome the problem?
5. What methods do farmers use to overcome the problem?
6. Which method among those has been successful?
7. What challenges do farmers face during controlling?
8. What are your suggestions on the methods that farmers use to overcome the destructions made by mole rats so they can increase their productivity?

THANK YOU VERY MUCH FOR YOUR COOPERATION