ADOPTION INTENSITY, PERCEPTION AND PROFITABILITY OF ORGANIC BASED SOIL FERTILITY MANAGEMENT TECHNOLOGIES IN MURANG'A AND THARAKA-NITHI COUNTIES, KENYA

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DECLARATION

Student declaration

I **GEORGE GACHERU MWAURA** declare that this thesis is my original work and has not been presented for the award of a degree in any other university or any other award.

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DEDICATION

To my Parents Mary Njeri and Peter Mwaura, and siblings Jane Wanjuhi, Grace Mbari, Anthony Ndung'u and Natasha Alice Wanjiku for their prayers and blessing.

To my mentor Prof. Jayne Mugwe for encouraging me to pursue this degree; I hold you in high regard.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ABBREVIATIONS AND ACRONYMS

SSA:	Sub-Saharan Africa
SOM:	Soil organic matter
TLU:	Total livestock unit

ABSTRACT

There have been major efforts to introduce and promote organic based technologies among the smallholder farmers to address low and declining soil fertility. Despite these efforts, adoption of these organic based technologies has been dismal. This study aimed to; (1) determine the socio-economic factors that influence adoption intensity of organic based technologies for soil fertility management, (2) determine perceived benefits by farmers of using organic based technologies, and (3) determine the profitability of using organic based technologies for managing soil fertility. The study was carried out in two sub-counties; Meru-South and Gatanga where these organic based technologies have been introduced and promoted previously. The study adopted a survey research design. A sample of 150 households selected randomly from each study area were interviewed. Tobit regression model was used to analyse the adoption intensity of organic based technologies. Nine organic based technologies were adopted. Socio-economic factors that influenced the adoption intensity in Murang'a were gender of the household (+), age (-), level of education (+), household size (+), access to external labour (+), training (+), total livestock unit (+), total land under cultivation (+), title deed ownership (+), agricultural group membership (+), household access to credit (+). In Tharaka-Nithi, the following were determinants of adoption intensity gender of the household (+), education level (+), size of the household (+), access to external labour (+), years of experience (+), training (+), total livestock unit (+), land under cultivation (+), title deed ownership (+), agricultural group membership (+), access to credit (+). The study further examined farmer perception. The perceptions were based on four variables; potential to improve soil fertility, potential to improve yields, profitability and labour requirements of organic based inputs. To analyse farmers' perceptions, an ordered logit regression model was fitted into the data. Farmers' perception results showed that majority of the respondents in Murang'a (115, 76.7%) and Tharaka-Nithi (104, 69.3%) strongly agreed that organic based technologies can improve yields. Factors that influenced perception were gender (-), household size (+), external labour (+), total livestock unit (+), group membership (+), training (+), land under cultivation (-), and credit access (+). Financial analysis of the maize enterprise was carried out using the gross margin analysis. Manure and manure+fertilizer was considered, while sole inorganic fertilizer was included in the analysis for comparison purposes. Gross margins showed that in Murang'a manure+fertilizer yielded 1962 $Kgha^{-1}$, manure yielded 1820$Kgha^{-1}$, and inorganic fertilizer recorded 1483 $Kgha^{-1}$. In Tharaka-Nithi, manure +fertilizer yielded 1940 $Kgha^{-1}$, manure yielded 1723 $Kgha^{-1}$, inorganic fertilizer 1689 $Kgha^{-1}$. Manure reported higher gross margins (44074) in Murang'a while manure+fertilizer showed higher gross margins (45625) in Tharaka-Nithi. This study recommends using organic-based inputs because they have been perceived to have the potential to increase crop yields and improve soil fertility. Also, the gross margins of sole manure and manure+fertilizer were higher than the gross margins of sole fertilizer.

CHAPTER ONE

INTRODUCTION

1.1 Background

Low soil fertility in sub-Saharan Africa has been consistently reported as a major biophysical factor deterring agricultural productivity (e.g. Sanchez & Jama, 2002; Mugendi *et al*., 2011). The low soil fertility is mainly caused by continuous cropping without replenishing the soil (Ngetich *et al.*, 2012). Degradative land cultivation has also caused a decline in soil organic matter, an important soil quality parameter (Kiboi *et al*., 2017). Organic based inputs can improve soil fertility and improve crop productivity (Niggli *et al*, 2017). The organic based inputs can substitute or complement inorganic fertilisers (Odendo *et al*., 2011). Thus, there is a need to encourage increased use of organic based inputs by farmers because they are cost-effective nutrient sources and can tackle low soil fertility.

In contrast to inorganic fertilizer, organic-based inputs are sustainable and environmentally friendly (Kimemia *et al.*, 2006; Niggli *et al*., 2017). Resources like: manure, compost, agroforestry, crop residue incorporation, intercropping and or relay of legumes, biomass transfer, and natural and improved fallows are commonly cited in the literature as crucial soil fertility amendments (Palm *et al*., 2001; Savala *et al*.,2003; SUSTAINET EA, 2010; Ahlem and Hammas, 2017). The organic based inputs improve soil fertility, structure, water holding capacity, and infiltration (Tiamiyu *et al*., 2012; Chukwuka, 2014). Organic based inputs also improve microbial activities, which are important in soil fertility parameters (Oriola and Hammed, 2012). However, these resources have not been fully embraced possibly because their potential profitability is still unknown by farmers.

In sub-Saharan Africa (SSA), the farming system is characterized by subsistence mixed farming with low external input use (Kisaka *et al*., 2016). Low external input use has contributed to the aggravated poverty level (Ndufa *et al*., 2007). The high poverty levels have led to fertilizer application rate being low compared to developed nations (Kaplan & Thompson, 2019). The low utilization of inorganic fertilizer has led to stagnated agricultural productivity. For instance, cereal yields in the SSA is about 1.5 MT/ha compared to Latin America (8 MT/ha) (FAO, 2015). The low agricultural productivity has been deteriorating in the Central Highlands of Kenya. Organic based inputs could serve as an alternative to inorganic inputs.

1.2 Problem statement

Adoption of organic based inputs has been reported to be low in areas that continue to experience low soil fertility due to poor soil fertility management practices. The situation is not different in Meru South and Gatanga sub counties. Continuous cultivation without replenishing soil nutrients is a major cause of continued soil deterioration, leaving the soil less fertile and fragile. As a result of the soil fertility deterioration, smallholder farmers have continued to experience low yields over time in these regions (Mugwe *et al*., 2009a). In effort to curb low soil fertility, there have been concerted efforts to promote organicbased inputs in the two counties for some time. However, the uptake of the organic based inputs by the farmers remains low. It is not well understood why farmers in the Central Highlands of Kenya, despite relying on agriculture for their livelihood, adopt scantly organic based inputs. Studies examining the socio-economic factors influencing adoption and intensity of adoption of organic based inputs in the study area are scanty. Those studies have only focused on determing factors that influence adoption of organic based technologies leaving a gap on the intensity of adoption, which the study seeks to fill. Furthermore, studies conducted in the area do not show how farmers perceive the profitability of these organic technologies and their associated benefit. Hence, there is a need to understand why, despite the salient benefits attributed to the use of organic based inputs in soil infertility amelioration; there is still low adoption by smallholder farmers in the study area. Therefore, this study was carried out to determine the socio-economic factors that influence the intensity of adoption of organic based input; the farmer perceived benefits of using organic based inputs, and the profitability of organic based technologies in Gatanga and Meru South sub-counties.

1.3 General objective

The general objective of the study was to assess the influence of socio-economic factors on the adoption intensity, perception, and profitability of organic based soil fertility management technologies in Tharaka-Nithi and Murang'a counties, Kenya

1.3.1 Specific objectives

i) To determine the socio-economic factors that influence adoption intensity of organic based technologies in Murang'a and Tharaka-Nithi Counties

ii) To determine the perception on organic based technologies among farmers in Murang'a and Tharaka-Nithi Counties

iii) To determine the profitability of using organic based technologies for managing soil fertility in Murang'a and Tharaka-Nithi Counties

1.5 Research questions

The following questions guided the study:

1) What are the socioeconomic factors influencing adoption intensity of organic based technologies in Murang'a and Tharaka-Nithi Counties?
2) What is the perception on organic based technologies among farmers in Murang'a and Tharaka-Nithi Counties?
3) What is the profitability of selected organic based technologies in Murang'a and Tharaka-Nithi Counties?

1.6 Justification of the study

Farmers in the Central Highlands of Kenya continue to face declining soil fertility resulting in low yields. This study sought to understand why despite the promotion of organic based inputs the adoption of these technologies continued to be dismal. The profitability of these organic based technologies is still unknown. The knowledge generated from this study contributes to the pool of knowledge in the technology uptake in Kenya's Central Highlands. The study identified key determinants of adoption intensity, which are important for designing soil replenishment programmes, and informed soil conservation policy.

Additionally, the study assessed how farmers' perceived technology attributes and the profitability of the organic based inputs. Knowledge generated from the perception of farmers guides the stakeholders to understand how farmers perceive organic technologies, and their profitability on the farm level. Overall, farmers' knowledge of profitable technologies will encourage them to practice cultivation under organic based technologies and realize the benefits, including improved soil fertility, increased yields, and higher profitability.

1.7 Theoretical Framework

This study used the discrete choice analytical model and the consumer utility maximization theory. The endogenous random variables used to represent the dichotomous choice represent 'yes' or 'no' decision (Amemiya, 1981; Greene, 1993; Wonnacott & Wonnacott, 1979). The dichotomous choice could take the discrete values 1 or 0. The unobservable utility (U_{ij}) is as follows:

$$U_{ij} = \bar{U}_{ij} + e_{ij} \qquad (1)$$

Where U_{ij} is the unobservable random utility derived by an individual i from consuming the j^{th} alternative of a technology; $i = 1, 2 \ldots . n$ and $j = 1, 0$; $\bar{U}_{ij}$ is a systematic part and e_{ij} is the random part of the choice model.

Considering the probability denoted by P_i that the i^{th} individual chooses one of the two alternatives expressed as follows:

$$P_i = Prob[y_i = 1] = Prob[U_{i1} \geq U_{i0}] \quad \text{Adopt the innovative technology} \qquad (2)$$

$$1 - P_i = Prob[y_i = 0] = Prob[U_{i1} < U_{i0}] \quad \text{Prefer the old technology} \qquad (3)$$

1.8 Conceptual Framework

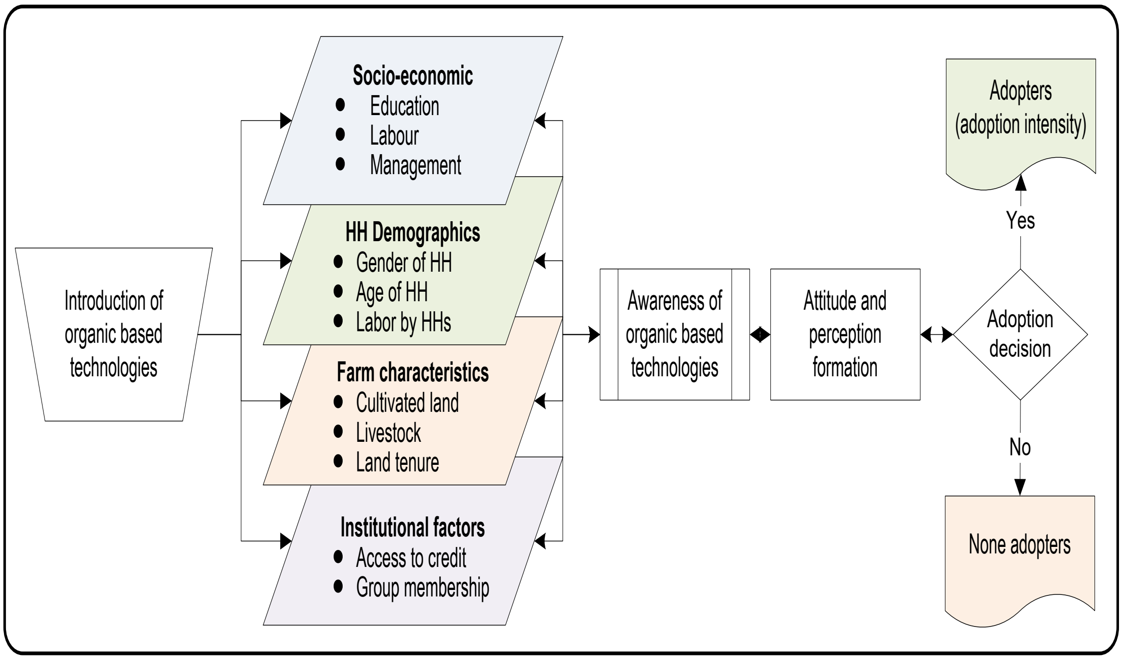

Figure 1.1: Conceptual framework of the study (Rogers, 1995)

Determinants of the decision to adopt and the extent of adoption of agricultural technologies are described as a complex process that initially includes establishing whether a farmer has adopted or not and the extent of the adoption (Meijer et al., 2015). Seminal work on adoption by Gunawan (1998) and Rogers (1995) put forward a theoretical framework that showed that farmers become aware of the new technology, which forms the first stage in the process of adoption, referred to as innovation-diffusion. In the innovation-diffusion stage, farmers form an attitude about technology before deciding whether to adopt or not (Rogers,1995). Additionally, according to Rogers (1995), new technology information is transferred from its source to the farmers through a medium such as field extension officers and media. The technology diffusion to potential adopters relies on the attributes of the individual user. The adoption behavioural framework has been used in several studies to examine the adoption of various technologies by farmers (Neupane et al., 2002; Adnan & Bakar, 2017) and was adopted for this study, as presented in Figure 1. The influence of farmers' awareness and attitude formation is unobservable. However, what is observable is the farmer's adoption behaviour, whether they adopt or not, and the extent of adopting the new technology. While the decision of whether to adopt or not is dichotomous, the extent of adoption is a continuous variable (Choudhury & Goswami, 2013). Therefore, we assume that; (1) the farmer decides whether to adopt or not adopt, (2) upon the decision to adopt, the farmer decides to what extent the new technology should be applied. The extent of the adoption decision will be dependent on the farmer characteristic, defined by the four dimensions socio-economic, household demographics, Farm and Institutions (see Figure 1). The conceptual framework is to build a Tobit regression model that predicts how a particular farmer with given household and farm attributes decides the extent of technology adoption (Waithaka et al., 2007; Mazvimavi & Twomlow, 2009; Mugwe et al., 2009b).

1.9 Definition and Operationalization of key terms

Adoption: A decision that is made by a farmer every time they consider using organic based technologies.

Adopter: A farmer who applies the organic-based technologies on the farm to improve soil fertility over a period of time

Non-adopter: A farmer who has not used the organic-based resources for soil replenishment

Organic based input technologies: Use of soil-restoring inputs that are solely organic in nature or in combination with inorganic inputs so as to improve soil fertility.

Smallholder farmer: A farmer whose parcel of land is less than 3 acres and whose main occupation is farming as a source of livelihood

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

In this chapter, literature relevant to the research study is reviewed. The main sub-themes include organic based input technologies, socio-economic factors and adoption of soil organic resources, farmer perception of organic based technologies, the profitability of organic resource management, analytical review, and summary and research gap.

2.2 Organic based input technologies

The use of organic resources is not new. In the temperate regions where agriculture has been practiced for centuries, soils were replenished using organic resources (Kassam *et al*., 2015). Their use was characterized by the planting of winter crops and crop rotations (Schlecht *et al*., 2006). The use of the organic resources has essential benefits over mineral fertilizer. The major advantages of using organic resources are associated with sustainability and they include; nutrient replenishment, contribute to the building and maintenance of the SOM, improving soil physical and biochemical properties (Chukwuka, 2014)

The use of organic based input technologies supplies a wide variety of options to the farmers in the face of heterogeneous soils that tend to dictate the type of organic resources to be used and the crops to be grown. There are various reliable organic resources available to the farmers, including animal manure, compost, natural fallow, improved fallow, incorporation of biomass, agroforestry, intercropping, or relay with legumes, and biomass transfer (Mukuralinda *et al*., 2011).

Earlier studies focused on organic inputs as just sources of nutrients and, specifically nitrogen. This focus guided many studies that quantify nitrogen available in the different organic inputs (Palm *et al*., 2001). However, the studies that have been conducted recently have been focusing on the organic inputs as a source of both macro and micronutrients. The importance of organic resources in improving agricultural productivity through replenishing and building soil fertility cannot be overemphasized. However, there are concerns about the quantity and quality of organic resources (Lambrecht et al., 2014). While keeping the quality of some organic resources is a constraint (e.g., manure), training the farmers has significantly addressed this constraint.

Moreover, to improve the quality of the nutrient composition, cattle can be fed leguminous fodder. By so doing, the nitrogen content in the manure is higher compared to the manure from cattle that do not feed on leguminous fodder. To address the issue of quantity, farmers are trained on how to apply the organic resources precisely. For example, placement of organic resources in the planting hole is recommended than broadcasting the manure.

2.3 Socio-economic factors and adoption of soil organic resources

Adopting new agricultural technology innovation is essential because it increases agricultural productivity and income (Feder et al., 1985). Further, Feder et al. (1985) define adoption as a psychological process of a person from the time he/she hears about an innovation to ultimately adopting the innovation. The diffusion rate, defined as the process of distributing the information, is influenced by many factors, among them farmers' contact with field extension officers and the frequency in which farmers discuss agricultural topics amongst themselves (Rogers, 1995).

The decision to adopt technology is influenced by many factors making it complex (Alene *et al*., 2000). Factors that influence adoption can be classified into farmer constraints and farmer conditioning described by Feder et al. (1985). The farmer constraints include lack of credit, minute land sizes, unreliable supply of sources of soil replenishing nutrients, risk, and uncertainty. Studies on organic resources management have concentrated more on the biophysical aspects. Nevertheless, the socio-economics factors have been overlooked by researchers (Himshikha, 2016). Even though these factors have been overlooked, they are fundamental, and they influence the uptake of organic based resources.

A study in the Central Highlands of Ethiopia, studying adoption on improved varieties of maize by Alene *et al*. (2000) focussed on socioeconomic factors influencing the adoption of the hybrid maize. Similarly, Aura (2016) studied the determinants of technology adoption. However, the two studies overlooked the determinants of intensity of adoption. It is important to know the adopters and non-adopters and to go further and investigate what socio-economic factors influence the intensity of technologies. The present study did not only consider the socio-economic factors and how they affected adoption, but it went further and assessed the factors that influenced the intensity of adoption of the organic resource technologies.

Few studies have focussed on the factors that influence the intensity of using a technology. For instance, Kunzekweguta *et al*. (2017), studied factors affecting adoption and intensity of conservation agriculture in Zimbabwe. The study reported the importance of socio-economic factors. However, the study used the number of conservation agriculture technology to measure the intensity without considering each technology's land size.

2.4 Farmer perception of organic based technologies

Farmer perception plays an important role in decision to adopt a technology (Mwangi & Kariuki, 2015). Farmers who perceive a technology as not profitable are less likely to invest in that technology (D'Antoni et al., 2012). Research conducted on farmer perception on soil fertility management technologies have considered farmer perception on soil fertility whether the farmers perceive it as a problem in their farm or not, also, based on the unique characteristics and potential benefits accrued from the technology (Maro et al. 2013; Mponela et al., 2016).

The studies on farmer perception of soil fertility management technologies have indicated that farmers who perceive soil fertility as a challenge are more likely to accept and adopt a soil fertility improvement technology (Haile et al., 2009; Yageta et al., 2019). Seminal work by Shepard et al. (1995) showed that low adoption of hedgerow intercropping technology was due to inaccurate targeting because farmers did not perceive low soil fertility as a priority problem. Therefore, farmer participation was encouraged by giving incentives such as providing inorganic fertilizers, improved crop variety for cultivation and restricted monitoring of labour, crop and economic performance.

Research conducted on specific technology features and benefits accrued from them (Adesina, & Baidu-Forson, 1995; Tatlıdil et al., 2009). The unique technology features are perceived differently by farmers based on their socio-economic attributes and asset endowment (Adesina & Baidu-Forson, 1995; Somda et al., 2002; Prager & Posthumus, 2010). For example, a study conducted by Sanchez (1999) in Rwanda indicated that farmers who owned less than a hectare of land had adopted grass fallow. This finding dismissed the impression that extensive land sizes are a prerequisite for fallow technology adoption.

A study conducted by Farouque and Hiroyuki (2007) whose objective was to determine farmer perception on integrated soil fertility and nutrient management revealed that farmer households who did not own land and those who owned small farms had limited awareness while those households that had medium to large farms had a higher level of awareness which affected their perception. Majority (78%) had low or negative perception. On the other hand, 22% recorded average to high perception perception was positive. Factors that were influenced positively by farmers' perception were farm size, level of education, years of farming experience, and communication exposure, while factors that had a negative influence were the household size and inorganic fertilizer use.

A study by Shrestha and Alavalapati, (2006) in Nepal applied an ordinal logistic regression to model the attitude of the local people towards Koshi Tappu Wildlife Reserve. The study reported that larger households that lived closer to the wildlife reserve were more likely to reveal a negative attitude towards conservation. However, responded who were educated and farmers are likely to demonstrate a positive conservation attitude.

2.5 Profitability of organic resource management

According to Offermann and Nieberg (2000) and Kelly *el at*. (2003), profitability is commonly recognized as an indicator of the success of the economic endeavor. Many adoption studies overlook the profitability of given technologies (Mulugetta, 2008; Karki, 2011). Farmer decisions are rational and are made based on utility maximization (Negatu and Parikh, 1999). This means that for a farmer to choose one technology over another s/he considers the financial gain derived from each technology. The farmer will choose the technology for which financial gains outweighs its cost.

Researchers have focussed on determining the profitability of organic based inputs mainly on a controlled experiment, which is not an accurate representation of the farmer conditions and constraints (Mucheru-Muna et al., 2014). For example, controlled experiments show that organic resources increase maize yields and profitability (Kiboi et al., 2019). Higher yields and profits are attained when the organic input is applied in combination with an inorganic input (Ajayi et al., 2007).

Many studies in an experiment setting have used partial budget to test for technologies' economic viability (Shiluli *et al*., 2003; Kangai, 2007; Mugabo *et al*., 2011; Nyambati *et al*., 2014;). However, the present study used gross margin analysis to determine profitability. Even though gross margins do not give an entire account of the net profits because it accounts only for the variable cost, it is still important in determining profitability.

2.6 Analytical review

Analysis of the decision to adopt technology has been analysed using different econometric models. The choice of the model depends on the characteristic of the dependent variable of the study. If the dependent variable's characteristic is a dummy variable, it takes 1 when adoption takes place and 0 otherwise, then a regression model whose dependent variable is a dummy is used. Probit and logit models have been used widely in such studies. However, there are other models like the linear probability model (LPM) which are criticized for their inability to control the probability of an event occurring to 0 and 1 even though interpreting of results proceeding from analysis using such a model are easy to interpret because it uses the Ordinary Least Square Method. Such limitations are dealt with by choosing to use a logit or a Probit model.

In modelling the Probit or Logit model, the effect of the hypothesised explanatory variable on the dependent variable is evaluated. Logit and Probit models do not have a significant difference in the way they model the regressors (Amemiya, 1981). However, it is worth noting that the logit model follows a logistic distribution in modelling the given set of data while the Probit model models the data following a normal cumulative distribution (Amemiya, 1981).

The two models can have different estimators when large sample sizes are used in the analysis. In this case, when relatively small sample size is used, no difference is observed (Amemiya, 1981). Therefore, the decision to employ

Probit or logit in the analysis of the dependent variable is optional. The logit model has close variations which can extend to a multinomial logistic model which is employed; the dependent variable has more than the typical dummy variable and the third value is not ordered in anyway. However, this study does not utilize Probit or Logit models because the dependent variable is continuous in nature. In cases where the dependent variable is the continuous use of the Tobit regression model is appropriate (Feder et al., 1985; Montgomery *et al*., 2001).

2.7 Summary and research gap

Adoption rates of various organic resources are still not well documented while past studies portray low adoption of organic resources in Kenya (Mugwe *et al*., 2009a; Odendo *et al*., 2011). Furthermore, the intensity of adoption and the farmer perception of the organic resources are under studied. Past studies have also not considered the profitability of these resources as one of the key determinants of the adoption patterns.

Minimal attention has been given to socio-economic factors' role in influencing the intensity of adoption of organic based technologies in the study area. However, in other areas, studies have shown that indeed the socio-economic factors influence the decision to adopt and the intensity of technologies' adoption (Graaff *et al*., 2007; Marenya and Barrett, 2007; Günter *et al*., 2009; Zhang *et al*., 2012; Jaleta *et al*., 2015; Murage *et al*., 2015; Sanou *et al*., 2017). In contrast, however, these studies have overlooked the socio-economic factors that influence the intensity of adoption. Additionally, farmers' perceived benefits and profitability emanating from the use of organic resource management are understudied. Profitability perception is important in decision making of to what extent the farmer should adopt a technology. Therefore, there is a need to understand how socioeconomic factors influence adoption and the intensity of adoption of organic based technologies; and assess the perceived benefits and profitability of organic resources by smallholder farmers in the study area.

CHAPTER THREE

METHODOLOGY

3.1 Introduction

This chapter presents the methodology that was used in the present study. The chapter includes a description of the two-study area, sample size considered, and sampling technique used, which comprises the research design. Furthermore, the data collection and analysis procedures are discussed.

3.2 Study area

The study was carried out in Murang'a and Tharaka-Nithi Counties (Fig 3.1).

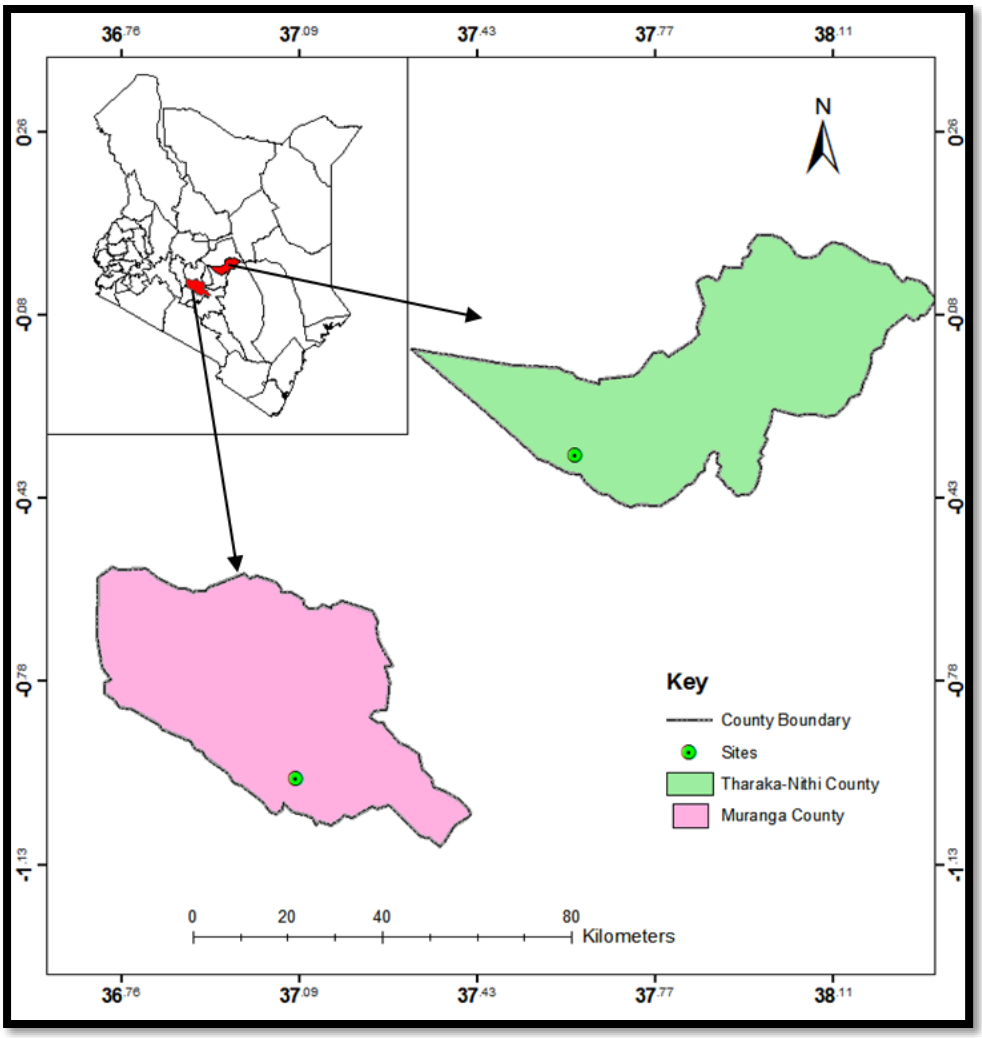

Figure 3.1: Study area map

3.2.1 Gatanga Sub County

Murang'a County comprises of five sub-counties. The county lies between Lower Highland one to three (LH1-3) and Upper Midland one to two (UM1-2) agro-ecological zones on the east slope of the Aberdare Range (Jaetzold *et al.*, 2006). The study was carried out in Gatanga Sub County.

The sub-county experiences a bimodal rainfall pattern which presents two cropping seasons; long rains (LR) (from March through June) while the short Rains (SR) (fall from October through December), with an annual rainfall average of 850 to 1,500 mm and average annual temperature of 26.0ºC (Jaetzold *et al*., 2006). The dominant soil type is dark brown *Humic Nitisols*, which is well-drained, deep to extremely deep, dark reddish in colour with moderate to highly fertile (Jaetzold *et al*., 2006). However, due to continuous cropping, this soil has lost fertility over time (Jaetzold *et al*., 2006). The main economic activity is agriculture, which is characterized by low productivity in a subsistent mixed farming system. The dominant cash crops include tea and coffee and, recently, macadamia, mango and avocado, while the annual crops include maize, beans, kales, and cowpea. The sub-county is estimated to have a population of over half a million, with a population density of about 410 per square kilometre (Murang'a County, 2013).

3.2.2 Meru south sub-county

Tharaka-Nithi County comprises four sub-counties, namely Maara, Chuka-Igamba Ng'ombe, and Meru South. The study was carried out in Meru south sub-county. Meru South is on the East of Mt. Kenya. According to Jaetzold *et al*. (2006), the Agro-ecological zones of the area is between Upper Midland Zone two (UM2) and Upper Midland Zone three (UM3), at an altitude of 500m-1500m above sea level. It has a mean temperature of 20°C and a two-rainfall pattern, which range between 500–1,400 mm. The two-rainfall pattern form two cropping seasons, a long rain season which starts from March and ends in June, while the short Rain season starts from October and ends in December. The soils of the study area are primarily *Rhodic Nitisols* (Jaetzold *et al*., 2006). The soil is inherently fertile, deep and well-weathered (Jaetzold *et al*., 2006). The main economic activities are agriculture, which is characterized by low productivity in a subsistent mixed farming system.

3.3 Research design and sampling procedure

The study followed a cross-sectional survey research design. A cross-sectional survey design collects data to make inferences about a population of interest at one point in time (Rindfleisch et al., 2008). Cross-sectional surveys have been described as snapshots of the populations about which they gather data (Setia, 2016) which makes this approach appropriate for this study. A multi-stage sampling strategy was employed in the selection of the study sample. In the first stage, Meru south (Tharaka-Nithi) and Gatanga (Murang'a) sub-counties were purposively selected because previous work by Kangai, (2004), Mugwe et al. (2009b), Mucheru-Muna et al. (2014) and Kiboi et al. (2019) introduced and promoted organic resource management interventions to the farmers in the two sub-counties. This made the two study areas relevant for the study of adoption. The farmers dominantly grow maize as their staple food.

Secondly, a simple random sampling was used to select half the number of locations from each division in both Meru South and Gatanga. From each sampled location, two sub-locations were randomly selected for the household survey. Since population differed in the different sub-locations, the number of households interviewed was determined proportionally according to the number of households in each sub-locations. In every sub-location, a footpath or a minor road leading to homes were randomly identified, and the 10^{th} household interviewed. A total of 300 households were interviewed in Meru south and Gatanga.

3.4 Sample size

A sample of 150 households per study area was selected bringing to a total of 300 households sampled in Murang'a and Tharaka-Nithi. The sample size was calculated using a formula adopted from Wonnacot and Wonnacot (1977) as shown below:

$$S = \frac{Z^2 \times P \times (1 - p)}{C^2} \qquad (3)$$

Where:

S = Sample size, Z = Z value (1.96 for 95% confidence level), P = percentage picking a choice, expressed as decimal (50%) and C = confidence interval, expressed as decimal (0.08)

3.5 Data source and collection

The study used primary data. Data were collected using a structured household questionnaire. The main themes of the questionnaire were household and farm characteristics, the land tenure system, workforce and family size, adoption of technologies, source of information on organic resource management, group membership, perception of soil fertility, challenges in organic resource technologies, innovativeness, perception on profitability, household income and household assets (Appendix 1).

Before data collection, enumerators were trained to ensure uniformity and dependability on the administration of the questionnaires. Five farmers from each county took part in pretesting of the questionnaire to ensure a thorough and precise collection of data.

3.6 Empirical models of the study

3.6.1 Adoption intensity of organic based technologies

Probit and Logit regression models have been used widely to study factors that influence the adoption of different technologies in Kenya (e.g, Mugwe *et al*., 2009b; Odendo *et al.,* 2011). The two regression models are suitable when adoption is measured as a discrete variable. However, when measuring the intensity of adoption, these models cannot be applied. The present study used a Tobit regression model to analyse the adoption intensity of organic based technologies among smallholder farmers in Murang'a and Tharaka-Nithi counties.

An improved agricultural technology adoption choice is observed to be due to a complex set of inter-technology preferences made by farmers through comparison. Thus, the area under organic based technologies represents a censored distribution since some farmers assume a value of zero for non-adoption farmers (non-users). Consequently, a cluster of households with zero adoption of the organic based technology are seen at the limit. The use of Tobit analysis is applicable in this case as it employs data at the limit and data above the limit. Following McDonald and Moffit (1980), the Tobit model is specified as follows: Let I be the intensity of the use of organic based technology, I* is equal to an index reflecting the combined effect of the explanatory variables hindering or promoting the use of an organic based technology, I* is not observable and is recorded as zero for not having area under an organic based technology. I* can be expressed as:

$$I^* = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots \beta_n X_n + \mu_i = f(X_i)$$

$$I = I^*, if\ I^* > 0$$

$$= 0\ if\ I^* \leq 0$$

The equation above illustrate a censored distribution of intensity of use of an organic based technology where X is a vector of explanatory variables, β a vector of Tobit maximum likelihood estimates, μ_i is the independently and normally distributed error term assumed to be normal with mean zero and constant variance σ. The value of **I** for all non-users equals zero.

Therefore, to examine the intensity of use of organic based technologies, the number of hectares of land under the organic based technology is specified as a function of socio-economic and institutional factors as follows:

$$I_i = \beta_0 + \beta_1 Gender + \beta_2 AGE + \beta_3 EDUCATION + \beta_4 HHSIZE + \beta_5 EXTERNALLABOUR + \beta_6 FARMEXPERIENCE + \beta_7 TRAINING + \beta_8 TLU + \beta_9 AGRIGROUP + \beta_{10} LANDCULT + \beta_{11} TITLEDEED + \beta_{12} CREDITACCESS$$

3.6.2 Farmers' perception of organic based technologies

Ordinal logistic regression model and ordinal Probit regression model have been used frequently to study the perception of technology. The two models have been used when the outcome variable is ordered. Additionally, the use of ordinal logistic and ordinal Probit regression models results in similar output because the two belong to the family of generalized linear regression models. Ordinal variables are similar to a categorical variable. However, the difference between the two is that there is an explicit ordering of the variables in ordinal variables. For example, an ordered outcome will have categories such as low, medium and high. Ordinal regression (weather logistic or Probit) is used to model the causal association between the dependent variable and a set of explanatory variables (which are either continuous and/or categorical) (Sentas *et al*., 2005).

Ordinal regression has been used to study the effect of the predictor variables on the levels of an ordered categorical outcome. For example, a study by Shrestha and Alavalapati (2006) in Nepal applied an ordinal logistic regression to model the attitude of the local people towards Koshi Tappu Wildlife Reserve. Other studies that have used ordinal logistic are Sentas *et al*. (2005), Rutherford *et al*. (2007), and Lohse *et al*. (2008).

This study used an ordinal logistic regression model to empirically estimate factors that influence the perception of organic based technologies. The dependent variables were obtained from a 5-point Likert scale that ranged from strongly disagree (1) to strongly agree (5). The four parameters that the 5-point Likert scale was used were a) increase in yield b) improve soil fertility c) profitability and d) high labour requirement of organic based technologies. The perception parameter was treated as the dependent variable while the explanatory variables were *AGE, EDUCATION HHSIZE, EXTRNLLABOUR,*

FRMEXP, TRAINING, TLU, LANDCULT, TITLEDEED, AGRIGRP, CREDITACCES.

The ordered logistic regression model parameters were defined as shown below:

$$\theta_1 = prob(score\ of\ 1)/prob\ (score\ greater\ than\ 1)$$

$$\theta_2 = prob(score\ of\ 2)/prob\ (score\ greater\ than\ 2)$$

$$\theta_3 = prob(score\ of\ 3)/prob\ (score\ greater\ than\ 3)$$

$$\theta_4 = prob(score\ of\ 4)/prob\ (score\ greater\ than\ 4)$$

Where θ is the probability of even (1,2,3,4) occurring.

It should be noted that the last category has no odds associated with it since the probability of scoring up and including the last is one.

Therefore, all the odds are of the form shown below:

$$\theta j = prob\,score \leq j/prob\ (score > j)$$

$$\theta j = prob\,score \leq j/1 - prob\ (score > j)$$

Additionally, the ordinal logistic model for one explanatory variable will be:

$$\ln(\theta j) = \alpha j - \beta x$$

Where j denotes the Likert scale score of 1 to the number of categories minus 1; αj are threshold values where α is the intercept and β is the logit coefficient to be estimated, and x is the explanatory variable.

3.6.3 Testing explanatory variables for multicollinearity

Gujarati (2004) defines multicollinearity as a linear relationship between explanatory variables. In the presence of multicollinearity, the coefficient estimates become indeterminate while the standard error becomes highly inflated. To test this, the Variance Inflation Factor (VIF) method was used. The decision rule is that if the VIF of an explanatory variable is more than 10 and the R^2 exceeds 0.90, then the variables are highly collinear. After running this test, the values of VIF in the current study were less than ten, implying that there was no problem of multicollinearity.

3.6.4 Financial profitability of using organic resources

The gross margin of an enterprise is defined as the financial output less the variable cost (Ojiako *et al*., 2018). Therefore, the gross margin is the difference between the total revenue and the total variable cost of an enterprise. This is also perceived as a measure of what the farm adds to the total farm profit. Gross margin is a crucial tool for making managerial decisions on future enterprise investment. Additionally, gross margin analyses are carried out to evaluate each enterprise's financial worthiness in the farm. Hence, the farm management can decide to adjust according to improving overall farm operations (Mohammed *et al*., 2011).

This study used gross margins to analyse the profitability of using organic based technologies on maize plantation. Maize was considered because majority of the farmer cultivated maize in their farm. Secondly, maize is a staple crop in Murang'a and Tharaka-Nithi counties. Nine organic based technologies were considered in this study. However, only two technologies (animal manure and animal manure + fertilizer) were used in the gross margin analysis. The other six organic based technologies did not yield significant data that could be analysed. Additionally, the use of sole inorganic fertilizer was included in the analysis to be a comparison check for the two organic based inputs. It was comparing how they perform against the sole inorganic fertilizer.

The maize gross margin data were subjected to analysis of variance (ANOVA) to statistically test whether the gross margins derived from the different organic based technologies and the control had significant differences.

The gross margins were calculated as follows:

$$GM_i = TR_i - TVC_i \quad i = 1, .. n$$

Where GM_i is the gross margins for the ith farmer reported in Kenya shillings per hectare; TR_i is the total revenue from sales of maize by the ith farmer reported in Kenya shillings per hectare; TVC_i represents the total variable cost incurred by an i^{th} farmer in Kenya shillings per hectare.

The total revenue (TR_i) is calculated as follows: $TR_i = P_i(Q_i); i = 1, .. n$

Where P_i is the selling price of maize and (Q_i) is the quantity of maize sold per kilogram by the i^{th} farmer while the total variable cost (TVC_i) are calculated as follows: $TVC_i = X_{ij}P_{ij}$

Where X_{ij} is the j^{th} input the i^{th} farmer used per hectare in the production of maize (e.g. labour, seed, fertilizer, manure etc.); P_{ij} is the price of the j^{th} input used by the i^{th} farmer.

3.6.5 Technologies and definitions of variables used in empirical estimations

Technologies applied in Murang'a and Tharaka-Nithi

(i) Agroforestry: the planting of leguminous trees and applying the leaves or other materials harvested from such trees to enrich the soil. Mercer and Pattanayak (2003) argued that the use of agroforestry is important in protecting the ecological capital, such as replenishing low fertile soils, among other environmental benefits.

(ii) Compost: decomposing organic materials before applying them in the soil. The use of composts is considered as an option for recycling organic wastes available on the farm (Paul et al., 2017). The advantage of using compost is that it improves soil structure and aeration and increases the soil's water-holding capacity (Twarog, 2006).

(iii) Residue incorporation: burying maize stalks in the soil after harvesting maize. Residue incorporation is reported to increases soil organic matter content crop yield and soil aggregate stability (Lehtinen et al., 2014; Spiegel et al., 2014).

(iv) Cover cropping: the planting of legumes to cover the soil rather than for the harvest. Application of cover crop protects the soil from runoff and improves the physical and biological properties of soils and increased biodiversity (Celette et al., 2008).

(v) Crop rotation: planting crops (cereal and legume) in rotation to ensure the best-balanced nutrient supply. The inclusion of leguminous crops in the rotation potentially contributed to the nitrogen in the soil for the subsequent crops grown (Lundy et al., 2015).

(vi) Mulching: application of organic materials on the soil such that the soil has a 30% cover. Mulching enriches and protects the soil. Also, it helps provide a better growing environment for crops (Akinola & Owombo, 2012).

(vii) Intercropping defined as planting cereals with legumes. The legumes have a unique role in sustaining soil fertility through symbiotic biological N fixation (Sauer et al., 2018).

(viii) Manure: application of well-cured manure before planting. Manure is a major component of the organic-based technologies with the potential benefits of long-term improvement of low soil fertility, organic matter, and supply of nutrients, especially nitrogen (N), phosphorus (P), and potassium (K) macronutrients (Kassie et al., 2013).

(ix) Combination of manure and fertiliser: the application of a combination of well-cured manure and fertiliser in the soil. The combination use of manure and fertiliser inputs leads to positive synergistic effects and hence replenishes the soil (Mucheru-Muna et al., 2014).

Definitions of variables used in empirical estimations

Table 3.1: Definitions of variables used in empirical estimations

Variable	**Description/measurement**	**Expected sign**
Dependent variable		
Agroforestry	Agroforestry adoption (Adopter=1)	
Compost	compost adoption (Adopter=1)	
Residue incorporation	Residue incorporation adoption (Adopter=1)	
Cover crop	Cover crop (Adopter=1)	
Crop rotation	Crop rotation adoption (Adopter=1)	
Mulch	Mulch adoption (Adopter=1)	
Manure	Manure adoption (Adopter=1)	
Intercropping	Intercropping adoption (Adopter=1)	
Manure + Fertilizer	Manure + Fertilizer adoption (Adopter=1)	
Independent variables		
GENDER	Gender of household head (male=1)	+
AGE	Age of household head	+/-
EDUCATION	No formal Education	+
	Primary education	
	Secondary Education	
	Tertiary education	
HHSIZE	Size of the household	+
EXTRNLLABOUR	Access to external labour	+
FRMEXP	Farming experience in years	+/-
TRAINING	Organic-based training (Yes=1)	+
TLU	Number of mature cattle	+
LANDCULT	Size of land under cultivation (ha)	+
TITLEDEED	Possession of land title deed (Yes=1)	+
AGRIGRP	Agricultural group membership (Yes=1)	+
CREDITACCESS	Access to credit (Yes=1)	+/-

3.7 Data analysis

Questionnaires were scrutinised to make sure they were completed and consistently filled. The response to the questions were numerically coded. The coded responses were stored in a database template using statistical package for social sciences (SPSS) computer software. The data was summarised using descriptive statistics such as frequency, means, and percentages. For inferential statistics, the Tobit regression model was used to estimate the socioeconomic variables that influenced the adoption intensity of organic-based technologies in Murang'a and Tharaka-Nithi using STATA (version 14).

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1 Introduction

This chapter presents the findings of the study. The study's general objective was to assess the influence of socio-economic factors on the adoption intensity, perception, and profitability of organic based soil fertility management technologies in Tharaka-Nithi and Murang'a counties, Kenya. The study used a sample of 150 households in Tharaka-Nithi and 150 households in Murang'a. The results obtained from the analysis are presented and discussed in this chapter as per each specific objective.

4.2 Characteristics of the respondents

4.2.1 Socio-demographic characteristics of respondents in Murang'a and Tharaka-Nithi

Results showed that most households were male-headed households with 54.7% and 65.3% males in Murang'a and Tharaka-Nithi counties, respectively (Table 4.1). This finding collaborates with Macharia et al. (2014), who did a study in the Central Highlands of Kenya and found that 87.67% of the households were male-headed.

The majority of the respondents were full-time farmers. Murang'a county had 88% (132) while Tharaka-Nithi had 91.3% (137) (Table 4.1). Also, majority of the respondents in Mursang'a (72, 48%) and Tharaka-Nithi (77, 51.3%) had attained primary education (Table 4.1).

Many of the respondents in Murang'a (114, 76%) and Tharaka-Nithi (106, 70.7%) had not received training on organic based technologies (Table 4.1). This implies that there were more untrained respondents in Murang'a and Tharaka-Nithi.

In regard to hiring labour, results showed that 52% (79) and 67.3% (101) of the respondents hired labour in Murang'a and Tharaka-Nithi, respectively. Most of the households in Murang'a (72%, 108) and Tharaka-Nithi (82.7%, 124) had a title deed (Table 4.1).

Most of the farmers in Murang'a (44%) and Tharaka-Nithi (56%) were not members of agricultural group (Table 4.1). In addition, compared to Murang'a, more household heads in Tharaka-Nithi were members of agricultural groups (Table 4.1).

Table 4.1: Univariate results of socio-demographic characteristics of respondents in Murang'a and Tharaka-Nithi: Categorical variables

Variables	Murang'a (N=150)	Tharaka-Nithi (N=150)
Gender of the HH		
Male	82 (54.7%)	98 (65.3%)
Female	68 (45.3%)	52 (34.7%)
Occupation of HHH		
Farming	132(88%)	137(91.3%)
Off Farm Business	2(1.3%)	4 (2.7%)
Employed	13 (8.7%)	7 (4.7%)
Retired	3 (2%)	2 (1.3%)
Education of HHH		
No formal education	14 (9.3%)	5 (3.3%)
Primary School	72 (48%)	77 (51.3%)
Secondary School	39 (26%)	43 (28.7%)
Tertiary education	25(16.7%)	25 (16.7%)
Organic based training		
Yes	36 (24%)	44 (29.3%)
No	114 (76%)	106 (70.7%)
Hiring labour		
Yes	79 (52.67%)	101 (67.3%)
No	71 (47.3%)	49 (32.7%)
Title deed		
Yes	108 (72%)	124 (82.7%)
No	42 (28%)	26 (17.3%)
Agricultural group membership		
Yes	38 (25.3%)	66 (44%)
No	112 (74.7%)	84 (56%)
Credit access		
Yes	63 (42%)	62 (41.3%)
No	87 (58%)	88 (58.7%)

The mean age of the household head Murang'a and Tharaka-Nithi counties was about 54 and 51 years, respectively (Table 4.2). The results show a statistical difference in the means between the ages of household heads in Murang'a and in Tharaka-Nithi ($t_{295.060} = 1.80, p = 0 .074$) (Table 4.2). This implies that households in Murang'a were older than their Tharaka-Nithi counterparts. The average household size in Tharaka-Nithi was significantly larger (4.23) than the average household size in Murang'a (3.79) (Table 4.2).

The average years of respondents' farming experience was 24.72 and 24.11 years in Murang'a and Tharaka-Nithi, respectively (Table 4.2). This implies that, on average, household heads in Murang'a had 0.61 more years of experience than their Tharaka-Nithi counterparts. The means between the years of farming experience in Murang'a and Tharaka-Nithi was not statistically different ($t_{293.366} = 0.35$, $p >0 .05$) (Table 4.2).

Households in Murang'a cultivated 0.49 ha of land while those in Tharaka-Nithi cultivated 0.46 ha (Table 4.2). The total livestock unit (TLU) was significantly higher in Murang'a with 4.04 units than in Tharaka-Nithi with 1.64 units (Table 4.2).

Table 4.2: Demographic socio-economic and farm characteristics in Murang'a and Tharaka-Nithi: Continuous variables

	Murang'a N=150	Tharaka-Nithi N=150	
Variable	Mean (SD)	Mean (SD)	t-test
Age	53.68 (15.946)	50.53 (14.427)	1.80*
Household size	3.79 (1.78)	4.23 (1.59)	2.27**
Farming experience	24.72 (16.178)	24.11 (14.565)	0.35
Land cultivated (ha)	0.49 (0.41)	0.46 (0.36)	0.60
TLU	4.04 (3.63)	1.64 (1.39)	2.28**
Cattle herd size	2.37 (2.35)	1.75 (1.55)	2.67***

** is 5% level of significance, * is 10% level of significance

4.3 Adoption of selected organic based technologies in Murang'a and Tharaka-Nithi counties

4.3.1 Adopters and non-adopters of selected organic based technologies in Murang'a and Tharaka-Nithi counties

Results showed that farmers adopted nine organic based technologies in the study area. These were agroforestry, compost, residue incorporation, cover crop, crop rotation, mulch, intercropping, manure, and manure + fertilizer (Table 4.3).

Adoption of agroforestry was lower in Murang'a (13, 8.7%) compared to Tharaka-Nithi (40, 26.7%) (Table 4.3). In general, the adopters of agroforestry were few (53, 17.7%) in the two counties compared to non-adopter (247, 82.3%) (Table 4.3).

There were more adopters of compost in Murang'a than in Tharaka-Nithi with 14.7 % and 11.3 %, respectively (Table 4.3). Residue incorporation had a higher (32, 21.3%) adoption in Murang'a than Tharaka-Nithi (11.3%) (Table 4.3). However, in the two counties, the non-adopters of residue incorporation were more (251, 83.7%) than the adopters (251, 83.7%). In Murang'a 58 (38.7%) of the household adopted cover crop while in Tharaka-Nithi, non-adopter were majority (130, 86.7%) (Table 4.3).

Few (64, 42.7%) households reported adopting crop rotation in Murang'a (Table 4.3). However, in Tharaka-Nithi majority (102, 68.0%) of the households adopted crop rotation (Table 4.3). This means that in Murang'a, most households were non-adopter of crop rotation while in Tharaka-Nithi, most households were adopters of cover crops.

In regard to mulching, many households in Murang'a (91, 60.7%) and in Tharaka-Nithi (139, 92.7%) adopted mulching (Table 4.3). In the two counties, there were more (230, 76.7%) adopters than non-adopters (70, 23.3%) of mulch (Table 4.3).

Seventy-two percent (108) of the households in Murang'a adopted intercropping, whereas 48% (72) of the households in Tharaka-Nithi adopted intercropping (Table 4.3). This means there were adopters of intercropping in Murang'a compared to Tharaka-Nithi. Total adopters of intercropping in the two counties were 180 (60.0%) and 120 (40.0%) non-adopters (Table 4.3). Therefore, adopters of intercropping were more.

In Murang'a and Tharaka-Nithi, 93.3% (280) of the households adopted manure (Table 4.3). This means that manure was the most adopted organic based technology in both counties. In Murang'a, 96.7% (145) households adopted manure, while 3.3% (5) households were non-adopters of manure (Table 4.3). In Tharaka-Nithi, 90.0% (135) of the households adopted manure, whereas 10.0% (15) of the households were non-adopters.

Ninety-two percent of sampled households in Tharaka-Nithi adopted manure +fertilizer in contrast to 81.3% (122) of sampled households in Murang'a (Table 4.3). This implies that manure + fertilizer was adopted more in Tharaka-Nithi compared to Murang'a.

Table 4.3: Adoption of selected organic based technologies in Murang'a and Tharaka-Nithi counties

Technology adoption		Murang'a N=150	Tharaka-Nithi N=150	Pooled N=300
Agroforestry	Yes	13 (8.7%)	40 (26.7%)	53 (17.7%)
	No	137 (91.3%)	110 (73.3%)	247 (82.3%)
Compost	Yes	22 (14.7%)	17 (11.3%)	39 (13.0%)
	No	128 (85.3%)	133 (88.7%)	261 (87.0%)
Residue incorporation	Yes	32 (21.3%)	17 (11.3%)	49 (16.3%)
	No	118 (78.7%)	133 (88.7%)	251 (83.7%)
Cover crop	Yes	58 (38.7%)	20 (13.3%)	78 (26.0%)
	No	92 (61.3%)	130 (86.7%)	222 (74.0%)
Crop rotation	Yes	64 (42.7%)	102 (68.0%)	166 (55.3%)
	No	86 (57.3%)	48 (32.0%)	134 (44.7%)
Mulch	Yes	91 (60.7%)	139 (92.7%)	230 (76.7%)
	No	59 (39.3%)	11 (7.3%)	70 (23.3%)
Intercropping	Yes	108 (72.0%)	72 (48.0%)	180 (60.0%)
	No	42 (28.0%)	78 (52.0%)	120 (40.0%)
Manure	Yes	145 (96.7%)	135 (90.0%)	280 (93.3%)
	No	5 (3.3%)	15 (10.0%)	20 (6.7%)
Manure + Fertilizer	Yes	122 (81.3%)	138 (92.0%)	260 (86.7%)
	No	28 (18.7%)	12 (8.0%)	40 (13.3%)

4.3.2 Land under organic based technologies in Murang'a and Tharaka-Nithi

Overall, sole manure and manure + fertilizer were used on the most extensive land sizes. This was followed by mulching with about 0.33 ha (Table 4.4). Out of the nine organic based technologies, six were used in land sizes that were different between the two counties (Table 4.4). On the other hand, three technologies; land under agroforestry, sole manure, manure plus fertilizer were statistically similar in both counties (Table 4.4).

Table 4.4: Area (ha) under organic based technologies in Murang'a and Tharaka-Nithi

Technology	Murang'a N=150 Mean (SD)	Tharaka-Nithi N=150 Mean (SD)	t-test
Agroforestry	0.04 (0.01)	0.06 (0.04)	-1.15
Compost	0.03 (0.02)	0.02 (0.03)	1.69***
Residue incorporation	0.05 (0.04)	0.03 (0.01)	2.06**
Cover crop	0.05 (0.04)	0.02 (0.01)	3.34***
Mulch	0.14 (0.10)	0.25 (0.2)	-4.92***
Intercropping	0.17 (0.16)	0.11 (0.10)	3.01***
Manure	0.39 (0.32)	0.39 (0.30)	0.14
Manure + Fertilizer	0.37 (0.37)	0.4 (0.28)	-0.83
Crop rotation	0.1 (0.10)	0.22 (0.20)	-5.02***

*** is 1% level of significance, ** is 5% level of significance, * is 10% level of significance

The minimum possible percentage of land under a given technology was 0%, this means that no land was dedicated for that technology. On the other hand, if a household had dedicated all its total land under cultivation to one technology then that technology will have 100% allocation. In the present study, sole manure and manure+fertilizer had the highest land allocation in Murang’a and Tharaka-Nithi (Table 4.5). Agroforestry in Murang’a and cover crops in Tharaka-Nithi had the smallest allocation of land (Table 4.5). Apart from compost and manure+fertilizer, all the other technologies had significantly different allocations in Murang’a and Tharaka-Nithi (Table 4.5).

Table 4.5: Percentage of land under organic based technologies in relationship to total cultivated land in Murang'a and Tharaka-Nithi

	Murang'a (N=150)			Tharaka-Nithi (N=150)			
Technology	Mean (SD)	Min	Max	Mean (SD)	Min	Max	t-test
Agroforestry	1.64 (1.46)	0.00	36.36	2.84 (2.21)	0.00	31.25	-1.76*
Compost	2.45 (2.19)	0.00	44.44	1.89 (1.48)	0.00	30.95	0.74
Residue incorporation	3.41 (3.17)	0.00	33.33	1.68 (1.41)	0.00	25.00	2.42**
Cover crop	3.35 (2.52)	0.00	39.47	1.61 (1.40)	0.00	30.77	2.62***
Mulch	13.16 (12.27)	0.00	85.71	20.68 (12.94)	0.00	83.33	-4.54***
Intercropping	13.52 (12.41)	0.00	50.00	9.37 (8.94)	0.00	40.00	3.01***
Manure	31.26 (17.00)	0.00	100.00	24.34 (19.90)	0.00	100.00	3.72***
Manure + Fertilizer	23.39 (14.67)	0.00	64.29	24.84 (10.31)	0.00	59.52	-0.99
Crop rotation	6.49 (5.21)	0.00	50.00	12.75 (12.58)	0.00	97.06	-4.73***

*** is 1% level of significance, ** is 5% level of significance, * is 10% level of significance

4.4 Determinants of adoption intensity of selected organic-based technologies in Murang'a and Tharaka-Nithi counties

The area under the selected organic based technologies was used as the dependent variable in the Tobit regression model. This was used to determine the intensity of organic based use in Murang'a and Tharaka-Nithi counties.

A Tobit regression model results showed that in Murang'a, the gender of the household head had a significant positive influence on the adoption intensity of manure + fertilizer ($\beta=0.132$, $p<0.05$) (Table 4.6). This implies that male-headed households were more likely to have more land under manure + fertilizer than female-headed households.

Age of the household head had a negative influence on the adoption intensity of intercropping (β= -0.004, $p<0.05$) and manure + fertilizer (β= -0.004, $p<0.1$) (Table 4.6). Older farmers were less likely to have a higher adoption intensity compared to younger farmers. If an intercrop adopter increases his/her age with one unit, his/her expected land under intercrop would decrease by 0.004 a *ceteris paribus*. Therefore, younger farmers are more likely to have a higher adoption intensity compared to elderly farmers.

The level of education attained by the household head positively influenced the adoption intensity of manure + fertilizer (β= 0.049, $p<0.05$) (Table 4.6). This means that educated household heads were more likely to have a large piece of land under manure + fertilizer. The household size had a positive influence on the adoption intensity of mulch (β= 0.024, $p<0.05$), intercropping (β= 0.024, $p<0.05$), manure (β= 0.026, $p<0.1$) and manure + fertilizer (β= 0.035, $p<0.05$) (Table 4.6). This implies that households with large families were more likely to have more land under intercropping, manure + fertilizer, and sole manure than families with small families

Access to external labour influenced positively the adoption intensity of mulch (β= 0.080, $p<0.05$), intercropping (β= 0.225, $p<0.05$), manure (β= 0.110, $p<0.05$), manure + fertilizer (β= 0.084, $p<0.05$) (Table 4.6). Training on the household head had a positive influence on the adoption intensity of mulch (β= 0.064, $p<0.05$) and manure (β=0.067, $p<0.05$) (Table 4.6).

Total Livestock Unit (TLU) owned by the household had a positive influence on the adoption intensity of manure (β= 0.367, $p<0.01$) and manure + fertilizer (β=

0.023, $p<0.05$) (Table 4.6). Total land under cultivation had a positive influence on the adoption intensity of mulching (β= 0.132, $p=<0.05$), intercropping (β= 0.195, $p<0.01$), manure (β= 0.395, $p<0.01$), and manure + fertilizer (β= 0.605, $p<0.01$) (Table 4.6).

Title deed ownership had a significant and positive influence on the adoption intensity of manure (β= 0.055, $p<0.05$) (Table 4.6). Household membership to an agricultural group positively affected the adoption intensity of mulch (β= 0.105, $p<0.1$) and manure + fertilizer (β= 0.131, $p<0.1$) (Table 4.6). Household access to credit affected positively and significantly the adoption intensity of manure + fertilizer (β= 0.092, $p<0.1$) (Table 4.6).

Table 4.6: Tobit regression estimates of determinants of selected organic based technology adoption intensity in Murang'a

	Mulch	Intercropping	Manure	Manure + Fertilizer
Gender	-0.010 (0.047)	-0.007 (0.035)	0.053 (0.043)	0.132 (0.054) **
Age	-0.001 (0.002)	-0.004 (0.002) **	0.001 (0.003)	-0.004 (0.002) *
Education level	0.012 (0.027)	-0.016 (0.023)	0.007 (0.026)	0.049 (0.033) **
Household size	0.024 (0.014) **	0.024 (0.011) **	0.026 (0.016) *	0.035 (0.016) **
Hiring labour	0.110 (0.054) **	0.084 (0.040) **	0.059 (0.005) **	0.080 (0.054) **
Farming experience	0.002 (0.002)	-0.001(0.001)	0.002 (0.003)	-0.002 (0.003)
Training	0.064 (0.053) **	0.012 (0.045)	0.067 (0.052) **	0.046 (0.059)
TLU	0.005 (0.009)	0.003 (0.009)	0.367 (0.009) ***	0.023 (0.016) **
Cultivated land	0.132 (0.054) **	0.195 (0.052) ***	0.395 (0.083) ***	0.605 (0.081) ***
Title deed ownership	0.026 (0.056)	-0.016 (0.043)	0.055 (0.039) **	-0.045 (0.050)
Agricultural group membership	0.105 (0.060) **	0.002 (0.049)	0.001 (0.064)	0.131(0.073) *
Credit access	0.060 (0.051)	0.057 (0.041)	0.009 (0.054)	0.092 (0.069) *
_cons	-0.179 (0.134)	-0.151 (0.117)	-0.078 (0.135)	-0.220 (0.153)

*** is 1% level of significance, ** is 5% level of significance, * is 10% level of significance
Values in parenthesis are standard errors

In Tharaka-Nithi, the gender of the household head was important in explaining the adoption intensity of intercropping ($\beta = 0.102$, $p < 0.05$) (Table 4.7). The education level of the household head influenced the adoption intensity of manure + fertilizer ($\beta = 0.058$, $p < 0.05$) (Table 4.7). The size of the household was significant and positive in explaining the adoption intensity of mulch ($\beta = 0.132$, $p < 0.01$) and manure ($\beta = 0.134$, $p < 0.05$) (Table 4.7).

Household access to external labour was significant and positively influenced the adoption of mulch ($\beta = 0.066$, $p < 0.05$) and manure ($\beta = 0.057$, $p < 0.01$) (Table 4.7). Years of farming experience of the household head had a positive and significant influence on the adoption intensity of manure + fertilizer ($\beta = 0.006$, $p < 0.05$) (Table 4.7). Training of the household head on organic based technology positive and significantly impacted the adoption intensity of mulch ($\beta = 0.092$, $p < 0.05$), and manure + fertilizer ($\beta = 0.097$, $p < 0.05$) (Table 4.7).

The TLU owned by the household was important in positively explaining the adoption intensity of intercropping ($\beta = 0.004$, $p < 0.05$), manure ($\beta = 0.053$, $p < 0.01$), and manure + fertilizer ($\beta = 0.022$, $p < 0.1$) (Table 4.7). The land under cultivation was positively significant in explaining the adoption intensity of intercropping ($\beta = 0.222$, $p < 0.01$), manure ($\beta = 0.341$, $p < 0.01$), manure+ fertilizer ($\beta = 0.435$, $p < 0.01$) (Table 4.7).

Household title deed ownership positively and significantly influenced the adoption intensity of mulch ($\beta = 0.084$, $p < 0.05$) and intercropping ($\beta = 0.138$, $p < 0.05$) (Table 4.7). Household head agricultural group membership affected positively and significantly the adoption intensity of mulch ($\beta = 0.090$, $p < 0.05$), manure ($\beta = 0.120$, $p<0.05$), and manure + fertilizer ($\beta = 0.321$, $p<0.01$) (Table 4.7). Household access to credit was an important factor that positively and significantly affected the adoption intensity of intercropping ($\beta = 0.205$, $p<0.01$), manure ($\beta = 0.073$, $p<0.1$), and manure + fertilizer ($\beta = 0.069$, $p<0.05$) (Table 4.7).

Table 4.7: Tobit regression estimates of determinants of selected organic based technology adoption intensity in Tharaka-Nithi

	Mulch	Intercropping	Manure	Manure + Fertilizer
Gender	-0.011 (0.037)	0.102(0.050) **	0.001 (0.044)	0.046 (0.040)
Age	-0.001 (0.002)	-0.010 (0.003)	-0.001 (0.003)	-0.002 (0.002)
Education level	0.015 (0.023)	0.021 (0.038)	0.001 (0.030)	0.058 (0.025) ***
Household size	0.132 (0.011) ***	0.013 (0.014)	0.134 (0.013) **	-0.004 (0.011)
Hiring labour	0.066 (0.031) **	-0.039 (0.047)	0.057 (0.039*)	0.033 (0.029)
Farming experience	0.001 (0.002)	0.001 (0.003)	0.001 (0.002)	0.006 (0.002) ***
Training	0.092 (0.044) **	0.045 (0.059)	-0.010 (0.054)	0.097 (0.047)
TLU	0.019 (0.014)	0.004 (0.002) **	0.053 (0.015) ***	0.022 (0.012)
Cultivated land	0.019 (0.051)	0.222 (0.073) ***	0.341 (0.104) ***	0.435 (0.074) ***
Title deed ownership	0.084 (0.044) **	0.130 (0.058) **	0.046 (0.058)	0.026 (0.051)
Agricultural group membership	0.090 (0.040) **	-0.043 (0.059)	0.120 (0.045) ***	0.132 (0.041) ***
Credit access	0.037 (0.041)	0.205 (0.063) ***	0.073 (0.044) *	0.069 (0.046) **
_cons	0.044 (0.082)	0.109 (0.168)	-0.031 (0.147)	-0.137 (0.102)

*** is 1% level of significance, ** is 5% level of significance, * is 10% level of significance
The values in parenthesis are standard errors

Gender of the household head was found to influence the adoption of the selected organic based positively (Table 4.6&Table 4.7). This finding implies that male households were more likely to have a higher adoption intensity of organic based technologies than female-headed households. The gender of the household head is important in assessing the decision-making process of adoption intensity (Mai et al., 2011). Literature suggests that the household authority and subsequent input into the household adoption intensity decision-making process is majorly based on the economic power (Bradshaw, 2013). Bradshaw (2013) implies that households are hierarchies in nature which are based on gender and unequal distribution of resources, and males tend to benefit more than females. This trend is seen in small scale farming system where male-headed households are more likely to have more resources to facilitate the adoption of organic based technologies compared to their female counterparts. The unequal access to resources can hinder women from adopting organic based technologies. This corroborates with Getachew and Tilahun's (2017) findings, which show that women are disadvantaged in adoption because they lack access to resources.

The age of the household head had a negative effect on the adoption intensity of organic-based technologies (Table 4.6&Table 4.7). This finding implied that households headed by elderly farmers are less likely to have a high adoption intensity of selected organic based technologies than the younger household head. As household heads advance in age, their risk aversion abilities increase, unlike their younger farmer counterparts, with low-risk aversion (Odendo et al., 2010). Therefore, elderly farmers are less likely to adopt new technologies

(Odendo et al., 2010). Additionally, the age of the household head indicates their capacity to work (Mbagaya & Anjichi, 2008), implying that as the age of the farmer advances, they are less likely to participate in strenuous farming activities and this reduces the possibility of adoption of labour-intensive technologies (Odendo et al., 2010).

In contrast, other studies, for example, Abdulai and Huffman, (2004) reported that elderly household head adopted dairy cattle compared to younger household heads. This was attributed to the heavy capital requirement; older households may have accumulated more capital over time (Abdulai & Huffman, 2013). Further, the credit institution may prefer the elderly than the young households head.

Years of farming experience positively influenced the adoption intensity of selected organic based technologies (Table 4.6&Table 4.7). This means that as the years of experience increases, the household head is more likely to have a higher adoption intensity of selected organic based technologies. It is expected that a long farming experience would increase the likelihood of a higher adoption intensity of selected organic-based technologies. According to Edmeades et al. (2008), many years of farming experience expose farmers to more knowledge and are more likely to adopt. A possible explanation to this finding is that farmers face complex constraints and as the farmer delves into solving the low soil fertility problem, he/she gains more experience. Farming experience increases the farmer's ability to decide which technologies meet their complex constraints and consequently adopt those technologies (Shiferaw et al., 2009). This result corroborates with Edmeades et al. (2008) found out in the study of the adoption of banana varieties in Uganda.

The household size had a significant positive effect on the adoption intensity of selected organic based technologies (Table 4.6&Table 4.7). This denotes that larger households are more likely to have a higher adoption intensity of selected organic-based technologies than smaller households. Household size is used as a proxy for labour availability in the household (Staal et al., 2002). The use of organic-based technologies has a high labour demand; thus, larger households are able to supply family labour and as a result, they are able to adopt organic based technologies (Kalinda et al., 2000). Thuo et al. (2005) found out that the household's size increases the probability of adoption of technologies.

Access to external labour had a significant positive influence on the adoption intensity of selected organic based technologies (Table 4.6&Table 4.7). This suggests that households that hired labour were more likely to have greater adoption of selected organic based technologies than households who did not hire labour. Employment of external labour promotes efficient utilization of resources in the farm (Mburu et al., 2007). Farmers may employ labour to supplement the available family labour. Additionally, access to external labour is a proxy of farmers' willingness to invest in replenishing the soil (Udayakumara et al., 2010). Therefore, farmers will adopt and invest in greater extends technologies they perceive to be worthwhile in relation to short-term income (Corbera and Brown, 2010).

The coefficient of education variable was positive and significant indicating the importance of education in adopting organic based technologies (Table 4.6&Table 4.7). This implied that household heads who had attained a higher level of education were more likely to adopt the selected organic based technologies in a higher intensity than the household heads who had a lower level of education. Education is broadly defined as the process of learning and is used as a proxy of human capital (Asfaw and Admassie, 2004). Education indicates the capacity to make adoption decisions. For example, Udayakumara et al., (2010) suggested that education creates awareness of soil conversation technologies. Additionally, farmers with high levels of education are more likely to apply new technologies in an efficient way (Asfaw and Admassie, 2004).

The coefficient of household training on organic based technology was also positive and significant in influencing the extent of adoption of selected organic based technologies (Table 4.6&Table 4.7). This result implied that household heads who were trained on organic based technologies were more likely to adopt organic based technologies in a greater extent compared to the non-trained household heads. Training is a critical component in instilling skills of low soil fertility correction (Asfaw and Admassie, 2004). A study conducted in the Central Highlands of Kenya by Macharia et al. (2014) found that training led to high level of knowledge. Farmers who had higher levels of knowledge were more likely to adopt organic ways of replenishing soils compared to household heads who had a moderate or low level of knowledge.

Household agricultural group membership coefficient positively influenced the adoption intensity of selected organic based technologies (Table 4.6&Table 4.7). Participation in a group is a proxy of knowledge acquisition (Macharia et al., 2014). Further, when farmers participate in an agricultural group they have higher bargaining power in the purchase of inputs such a mineral fertilizer which are unaffordable to individual farmer (Macharia et al., 2014). The positive effect of group membership on the extent of adoption may be explained by the fact that when farmers form an agricultural group, they get incentives when buying inputs such as inorganic fertilizers and hence they are more likely to adopt the combination of manure and fertilizer compared to the household heads that are not in agricultural groups and as a result they do not have a similar incentive to purchase inorganic fertilizer (Njuki et al., 2008).

As anticipated, the coefficient of land under cultivation showed a positive significant influence on the adoption intensity of selected organic based technologies (Table 4.6&Table 4.7). This finding implied that as the households that had large pieces of land were more likely to have a high adoption intensity compared to the farmers who had small pieces of land. Land is a surrogate of many factors in agriculture such as the capacity to carry risk, size of wealth and collateral in access of credit (Enki et al., 2001). A probable explanation of the positive effect on the decision to adopt is that farmers who have larger land under cultivation may earn more from crop production and livestock keeping. The income they obtain from the activity help in hiring labour to apply the organic based technologies (Enki et al., 2001). This finding agrees with what Danso-Abbeam et al., (2017) reported. Also, land under cultivation is a measure of available economic resources and the willingness to adopt new technology (Nigussie et al., 2017).

The coefficient of land title deed ownership was positive and significant in influencing the extent of adoption of the selected organic based technologies (Table 4.6&Table 4.7). This finding implies that household heads who had title deeds for their lands were more likely to have a greater extent of adoption intensity of selected organic based technologies than household heads who did not possess title deeds. Title deed is an imperative proxy of security and land rights. The security and the land rights have been identified as the key component that encourages long term investments on the soil (Adimassu *et al*., 2013). Therefore, farmers who have a secure tenure system will have an incentive to invest on long term soil replenishment strategies such as the organic based technologies (Adimassu *et al*., 2015).

Access to credit had a positive influence on the adoption intensity of selected organic based technologies (Table 4.6&Table 4.7). Households who had access to credit were more likely to adopt the selected organic based technologies to a greater extent than those that did not have credit access. Access to credit enhances the purchasing power of the farmer (Waithaka et al., 2007). With a higher purchasing power, the farmer may be able to purchase inputs such as tree seedlings, inorganic fertilizer, and manure. Conversely, the high purchasing power will allow the farmer to use maize talk as soil correction materials and incorporate them in the soil and buy livestock feed for his/her livestock. The purchase of livestock feed reduces the competition of maize stalks and other farmer litters and allows the farmer to use these materials to correct soil fertility.

TLU had a significant positive effect on the extent of adoption of the selected number of technologies a farmer adopted (Table 4.6&Table 4.7). This suggests that households that owned a higher TLU were more likely to adopt selected organic based technologies to a greater extent than households with a lower TLU. Livestock ownership is an essential livelihood strategy in social-ecological systems (Crane, 2015). Livestock keeping is both a cultural and a social symbol. However, the challenge attributed to TLU is the insufficiency of manure in the Central Highlands of Kenya that was reported by Mugwe et al. (2009). Cattle are an important source of animal manure. Therefore, it is expected that as the number of cattle per household increase then the adoption of cattle manure and other organic based technologies are likely to increase. This study found out that each household had at least two herds of cattle (Table 4.2). This finding is consistent with Macharia et al. (2014), who found out that 80% of all households in the study area had cattle and were more likely to adopt organic based technologies.

4.5 Farmers' perceptions of organic based technologies potential to improve yields

Majority of the respondents in Murang'a (115, 76.7%) and Tharaka-Nithi (104, 69.3%) strongly agreed that the use of organic based technologies improved soil fertility (Table 4.8). However, in Murang'a 2% (3) of the respondents disagreed with the statement while none of the respondents in Tharaka-Nithi disagreed with the statement.

Most of the respondents in Murang'a (100, 66.7%) and in Tharaka-Nithi (85, 56.7%) strongly agreed that the use of organic based technologies increases crop yields (Table 4.8). This implied that majority of the respondents perceived the use of organic based technologies increases crop yields.

Regarding the profitability of using organic based technologies, the majority of the responds in Murang'a (67, 44.7%) and in Tharaka-Nithi 53 (35.3%) agreed that the use of organic based technologies was profitable (Table 4.8). This meant that majority of the respondents in Murang'a and Tharaka-Nithi perceived the use of organic based technologies as profitable.

Many of the respondents in Murang'a (79, 52.7%) disagreed that organic based technologies have low labour requirement (Table 4.8). In Tharaka-Nithi, most (54, 36.0%) of the respondents strongly disagreed that organic based technologies had low labour requirements (Table 4.8). However, 22 (14.7%) of the respondents in Murang'a and 32 (21.3%) in Tharaka-Nithi agreed that organic based technologies had a low labour requirement.

Table 4.8: Farmers' perception of organic based technologies in Murang'a and Tharaka-Nithi counties

Perception question	County	Strongly agree (5)	Agree (4)	Indifferent (3)	Disagree (2)	Strongly disagree (1)
Organic based technologies improve soil fertility	Murang'a	115 (76.7%)	32 (21.3%)	0 (0%)	3 (2.0%)	0 (0%)
	Tharaka-Nithi	104 (69.3%)	45 (30.0%)	1 (0.7%)	0 (0.0%)	0 (0%)
Organic based technologies increase crop yields	Murang'a	100 (66.7%)	29 (19.3%)	4 (2.7%)	12 (8.0%)	5 (3.3%)
	Tharaka-Nithi	85 (56.7%)	59 (39.3%)	6 (4.0%)	0 (0.0%)	0 (0.0%)
Organic based technology is profitable	Murang'a	45 (30.0%)	67 (44.7%)	25 (16.7%)	12 (8.0%)	1 (0.7%)
	Tharaka-Nithi	46 (30.7%)	53 (35.3%)	47 (31.3%)	4 (2.7%)	0 (0.0%)
Organic based technologies have low labour requirement	Murang'a	18 (12.0%)	22 (14.7%)	4 (2.7%)	79 (52.7%)	27 (18.0%)
	Tharaka-Nithi	3 (2.0%)	32 (21.3%)	15 (10.0%)	46 (30.7%)	54 (36.0%)

Murang'a N=150
Tharaka-Nithi N=150
Values in parenthesis are percentages

The perceived technology-attributes such as potential to improve soil fertility, potential to improve yields, profitability and labour requirement are important to the farmer and they influence the attitude of the farmers towards the technologies (Mucheru-Muna *et al*., 2014). The attitude towards the technologies is a key driver of the technology demand by the farmer. Farmers' agree more on the technology they perceive as important in addressing their farming constrained, which is conditioned by the subjective preference of the technology attributes (Sinja *et al*., 2004).

4.6 Farmers' perceptions on the potential of organic based technologies to improve yields

The ordinal logistic regression model results indicate that gender, TLU, land under cultivation, and years of farming experience significantly influence the respondents' perception (Table 4.9).

Table 4.9: Farmers' perceptions of organic based technologies potential to increase in yield

	Murang'a			Tharaka-Nithi			Pooled		
Variable	Coef.	Std. Err.	p-value	Coef.	Std. Err.	p-value	Coef.	Std. Err.	p-value
Gender	0.576	0.434	0.184	-0.959	0.462	0.038	-0.269	0.282	0.341
Age	-0.018	0.024	0.454	-0.008	0.021	0.689	-0.007	0.014	0.633
Education level	0.091	0.306	0.766	0.148	0.273	0.588	0.064	0.186	0.732
Household size	-0.059	0.127	0.640	0.072	0.138	0.601	0.068	0.081	0.400
Hiring labour	-0.219	0.458	0.633	-0.108	0.409	0.792	-0.137	0.274	0.617
Training	-0.141	0.558	0.800	0.236	0.493	0.632	-0.039	0.334	0.907
TLU	0.728	0.254	0.004	0.872	0.225	0.000	0.768	0.147	0.000
Title deed ownership	-0.287	0.515	0.577	-0.330	0.538	0.540	-0.548	0.340	0.107
Agricultural group membership	0.416	0.587	0.479	0.909	0.476	0.056	0.345	0.323	0.285
Credit access	0.483	0.519	0.352	1.721	0.531	0.001	0.543	0.326	0.096
Cultivated land	-0.259	0.697	0.710	-1.310	0.656	0.046	-0.460	0.417	0.071
Farming experience	-0.123	0.022	0.029	-0.028	0.008	0.039	-0.054	0.014	0.048
	Model summary			*Model summary*			*Model summary*		
	Wald chi^2 22.49(14)			Wald chi^2 41.34 (14)			Wald chi^2 49.85 (14)		
	Prob > chi^2 0.0691			Prob > chi^2 0.0002			Prob > chi^2 0.0000		
	N=150			N=150			N=300		

Gender of the household had a negative and significant (p=0.038) influence on the perception of the potential of the organic based organic to increase yields in Tharaka-Nithi (Table 4.9). Gender was not significant in Murang'a and in the pooled data (Table 4.9). This means that female household heads who resided in Tharaka-Nithi perceived that organic based technologies had the potential to improve yield. Female households are constrained in access to resources (Diiro *et al*., 2018). This may condition them only to use organic based options. On the other hand, male-headed households are well endowed with resources. Therefore, male-headed households can access high input inorganic fertilizers and may not perceive the role of organic based technologies in increasing yields (Mutuma, 2013; Ndiritu *et al*., 2014).

TLU had a positive impact on the perception of organic based technologies' potential to improve crop yields (Table 4.9). Households who had a small herd size of cattle obtain small quantities of manure for use in the farm (Mugwe *et al*., 2009a). However, household heads that had larger herd size perceived an increase on yield as a result of using organic and the organic based technologies compared to the households with small herd size. Larger herd size provides an adequate amount of manure to be used in the farmer and therefore the household heads perceived increased yields (Macharia *et al*., 2014)

Access to credit had a positive influence at (p=0.001) in Tharaka-Nithi county (Table 4.9). This means that household heads who had access to credit had a positive perception on the potential of organic based technologies to increase yields. Access to credit provides the household with money to carry out household farming activities and purchase of inputs that are not available in the farm.

Land under cultivation negatively influenced the perception of organic based technology potential to improve yields at p=0.046 in Tharaka-Nithi and at p=0.71 in the pooled data (Table 4.9). As the land under cultivation is increased, the result suggested that the household heads have a negative perception on the potential of the organic based technologies to improve yields. A plausible explanation would be that smallholder farmers are constrained in resources such as manure (Mugwe *et al*., 2009b). Hence, households with larger pieces of land under cultivation cannot supply adequate amounts of manure to their farmer, which may lead to lower yields compared to when adequate quantities of manure are used (Macharia *et al*., 2014). This leads to a negative perception of the household heads that have larger pieces of land under cultivation.

In regard to the years of farming experience of the household head, the study found out that the probability of household heads with a long farming experience to perceive potential to improve yields was less than household head who had fewer years of experience at $p<0.05$ (Table 4.9). It was anticipated that more years of farming experience would lead to a positive perception of organic based technology's potential to increase yield. Nhemachena and Hassan (2007) argue that a long farming experience endows the farmer with knowledge and information on soil, crop, and livestock management practices. However, farmers with many years of farming experience may not be willing to change their farming behaviour, including the inputs they use (Mutuma, 2013). This may explain the negative perception on the potential of the organic based technologies to improve yields.

4.7 Farmers' perceptions of organic based technologies potential to improve soil fertility

The ordinal regression model results showed that the gender of the household head, household size herd size, farming experience, cattle ownership, access to credit, and land under cultivation had a significant influence on the perception of the potential of the organic based technologies (Table 4.10).

Gender of the household was a negatively significant (p=0.070) factor in explaining the perceived potential of the organic based technologies to improve soil fertility (Table 4.10). This means that female households are more likely to perceive organic based technologies' potentials to improve soil fertility than male-headed households are. A plausible explanation for the negative influence may relate to the fact that women in developing countries are highly attached to household farming activities compared to their male counterparts. Additionally, Devine-wright (2007) demonstrated that women were willing to pay for new technologies that influenced household welfare.

Household size had a significant positive influence on the perception of the organic based technologies' potential to improve soil fertility in Tharaka-Nithi (p=0.042) and pooled data (p=0.007) (Table 4.10). This implies that relatively larger households were more likely to have a positive perception of the organic based technologies potential to improve soil fertility. The application of organic based technologies requires labour to adopt successfully. Larger households may have family labour at their disposal. When these households use the organic based technologies, they are able to perceive the benefits that are accrued from the organic based technologies (Mucheru-Muna *et al*., 2014).

Table 4.10: Farmers' perceptions of organic based technologies potential to improve soil fertility

Variable	Murang'a			Tharaka-Nithi			Pooled		
	Coef.	Std. Err.	p-value	Coef.	Std. Err.	p-value	Coef.	Std. Err.	p-value
Gender	0.450	0.451	0.318	-1.018	0.562	0.070	-0.300	0.311	0.334
Age	-0.035	0.025	0.169	0.009	0.024	0.706	-0.010	0.016	0.520
Education level	0.312	0.313	0.319	-0.090	0.308	0.769	0.141	0.204	0.489
Household size	0.068	0.134	0.610	0.380	0.187	0.042	0.266	0.098	0.007
Hiring labour	0.309	0.485	0.525	0.758	0.466	0.103	0.669	0.302	0.027
Training	0.362	0.591	0.541	0.127	0.553	0.818	0.281	0.366	0.442
TLU	0.470	0.232	0.042	0.679	0.230	0.003	0.519	0.140	0.0001
Title deed ownership	0.170	0.544	0.755	-1.174	0.741	0.113	-0.579	0.389	0.137
Agricultural group membership	-0.135	0.594	0.820	0.407	0.562	0.469	-0.035	0.352	0.921
Credit access	0.114	0.538	0.832	1.443	0.567	0.011	-0.684	0.347	0.048
Cultivated land	-0.890	0.700	0.093	-1.640	0.774	0.034	-0.964	0.451	0.033
Farming experience	0.039	0.023	0.095	0.025	0.025	0.312	0.024	0.015	0.116
	Model summary			*Model summary*			*Model summary*		
	Wald chi^2 18.43 (14)			Wald chi^2 44.56 (14)			Wald chi^2 39.06 (14)		
	Prob > chi^2 0.1879			Prob > chi^2 0.0000			Prob > chi^2 0.0004		
	N=150			N=150			N=300		

TLU owned by the household has a significant positive influence on the perception of the potential of the organic based technologies to improve soil fertility in Murang'a (p=0.042), Tharaka-Nithi (p=0.03), and the pooled data (p=0.001) (Table 4.10). This meant that households that own high numbers of TLU were more likely to perceive the potential of organic based technologies in improving soil fertility than households that smaller TLU. As the TLU increases, the quantity of animal manure increases; hence the households have a positive perception.

Access to credit had a significant influence on the perception of the potential of organic based technologies to improve soil fertility Tharaka-Nithi (p=0.011) and pooled data (p=0.48) (Table 4.100). This implied that households that had access to credit were more likely to perceive that organic based technologies can improve soil fertility. Credit is important in alleviating financial constraint of the household and thereby influential in the perception of the potential of organic based technologies to improve soil (Erenstein and Farooq, 2009).

The coefficient of labour was significantly and positively influenced the perception of the potential of the organic based technologies to improve soil fertility in the pooled data (p=0.027) (Table 4.100). The hiring of labour is likely to reflect underlying household characteristics such as wealth, the commercial orientation of the farming enterprise, and perhaps the human capital. The factors mentioned above are crucial in the perception of organic based technologies (Erenstein and Farooq, 2009).

The coefficient of land under cultivation had a significant and negative influence on the perception of the potential of the organic based technologies to improve soil fertility in Murang'a (p=0.093), Tharaka-Nithi (p=0.034) and pooled data (p=0.033) (Table 4.100). This finding suggested that households with larger land pieces under cultivation were more likely to have a negative perception of the potential of organic based technologies to improve soil fertility. This may be explained by the negative correlation that may exist between the size of land under cultivation and farmer investment in the organic based technologies (Adimassu *et al*., 2015). This negative correlation exists because when more land is available, farmers may not be concerned about the loss of land fertility and reduce their willingness to invest in the use of organic based technologies (Adimassu *et al*., 2015).

4.8 Farmers' perceptions on the profitability of organic based technologies

Table 4.11 presents results on the profitability potential of organic based technologies in Murang'a and Tharaka-Nithi counties. The age of the household head, the level of education, training, title deed, credit, and land under cultivation were significant factors in explaining the perception of organic based technologies' profitability.

Table 4.11: Farmers' perceptions on the profitability potential of organic based technologies

Variable	Murang'a			Tharaka-Nithi			Pooled		
	Coef.	Std. Err.	p-value	Coef.	Std. Err.	p-value	Coef.	Std. Err.	p-value
Gender	0.092	0.351	0.794	0.278	0.378	0.463	0.103	0.232	0.658
Age	-0.006	0.018	0.742	-0.024	0.020	0.233	-0.021	0.012	0.085
Education level	0.368	0.236	0.119	0.747	0.260	0.004	-0.114	0.162	0.482
Household size	-0.057	0.103	0.577	-0.061	0.113	0.587	-0.112	0.068	0.101
Hiring labour	0.575	0.370	0.120	0.194	0.367	0.598	0.154	0.239	0.519
Training	0.121	0.420	0.773	1.182	0.428	0.006	0.464	0.280	0.097
TLU	0.135	0.113	0.232	0.199	0.154	0.197	0.122	0.084	0.149
Title deed ownership	-0.155	0.416	0.709	1.480	0.481	0.002	0.555	0.292	0.057
Agricultural group membership	0.412	0.424	0.332	-0.618	0.412	0.134	-0.012	0.269	0.964
Credit access	-0.190	0.396	0.631	1.589	0.463	0.001	0.613	0.277	0.027
Cultivated land	-0.982	0.479	0.040	-0.531	0.271	0.041	-0.326	0.116	0.023
Farming experience	0.028	0.017	0.106	0.000	0.019	0.989	0.010	0.011	0.388
	Model summary			*Model summary*			*Model summary*		
	Wald chi^2 23.77 (14)			Wald chi^2 55.37 (14)			Wald chi^2 37.95 (14)		
	Prob > chi^2 0.0489			Prob > chi^2 0.0000			Prob > chi^2 0.0005		
	N=150			N=150			N=300		

The coefficient of the household head's age had a significant negative influence on the perception on the profitability of organic based technologies on the pooled data (p=0.085) (Table 4.11). This finding implied that households headed by older people are less likely to perceive organic based technology as profitable than the younger household head. The age of the farmer has been used as a measure of how risk-averse the household head is. For example, a study by Odendo *et al*. (2010) found out that household heads that had advanced in age were more risk-averse than their younger counterparts. Due to this, elderly household heads are more likely to have a negative perception of the organic based technologies than their younger household heads counterparts, who are less risk-averse.

The household head level of education had a significant and positive influence on the perception of the profitability of organic-based technologies in Tharaka-Nithi at (p=0.004) (Table 4.11). This meant that educated household heads had a positive perception of the profitability of organic based technologies. Training of the household on organic based technologies had a positive and significant influence on the perception of organic based technologies in Tharaka-Nithi (p=0.006) and pooled data (p=0.097) (Table 4.11). This implied that household heads that had participated in organic based training had a positive perception of organic based technologies than farmers who did not participate in the training. Education and training are crucial processes of instilling skills and knowledge to the farmers. Additionally, education and training is acknowledged as a process of building human capital (Asfaw and Admassie, 2004). Education and training are vehicles through which awareness of technologies and their benefits are realized (Udayakumara *et al*., 2010).

The coefficient of land title deed ownership was positive and significant in influencing the perception of the profitability of organic based technologies in Tharaka-Nithi (p=0.002) and the pooled data at (p=0.057) (Table 4.11). This finding implied that household heads who had title deeds for their lands had a positive perception of organic based technologies' profitability than household heads who did not possess title deeds. Title deed is an imperative proxy of security and land rights. The security and the land rights have been identified as the key component that encourages long term investments on the soil (Adimassu *et al*., 2013). Therefore, farmers who have a secure tenure system have a positive perception on the profitability of organic based technologies (Adimassu *et al*., 2015).

The coefficient of credit access had a significant and positive effect on the perception of the profitability of organic based technologies in Tharaka-Nithi (p=0.027) and the pooled data (p=0.001) (Table 4.11). This finding indicated that household heads that obtained credit had a positive perception of organic based technologies' profitability than household head heads with no access to credit. Farmers that obtain credit are financially empowered to obtain other resources such as labour in the farm compared to farmers that do not obtain credit (Ndiritu *et al*., 2014). Hence, a household with such financial ability may have a positive perception of the organic based technologies.

Land under cultivation was found to have a significant and negative influence on the perception of profitability of organic based technologies in Murang'a (p=0.040), Tharaka-Nithi (p=0.04) and in the pooled data (p=0.023) (Table 4.11). This finding implied that households with larger land pieces under cultivation perceive organic based technologies as unprofitable compared to households with smaller portions of land under cultivation. Larger pieces of land under cultivation require more inputs to carry out farming, which are expensive (Glendining *et al*., 2009). Due to the inadequate financial empowerment, farmers cannot obtain inputs, which results in the use of inputs below the recommended rates (Moser & Barrett, 2003). Therefore, the farmers may not break even and hence perceive organic bases technologies as non-profitable (Adusumilli *et al*., 2019).

4.9 Farmers' perceptions of organic based technologies labour requirement

Gender of the household, household size, external labour, training, TLU, title deed, and access to credit influenced the perception of the farmers on the labour requirement of the organic based technologies in Murang'a and Tharaka-Nithi (Table 4.12

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Table 4.12: Farmers' perceptions on the labour requirements of organic based technologies

Variable	Murang'a			Tharaka-Nithi			Pooled		
	Coef.	Std. Err.	p-value	Coef.	Std. Err.	p-value	Coef.	Std. Err	p-value
Gender	-1.261	0.377	0.001	0.020	0.372	0.958	-0.252	0.233	0.281
Age	0.016	0.018	0.383	-0.004	0.018	0.808	0.003	0.012	0.819
Education level	-0.064	0.238	0.787	0.033	0.233	0.889	-0.034	0.155	0.827
Household size	-0.208	0.101	0.040	-0.213	0.121	0.079	-0.049	0.070	0.480
Hiring labour	-0.497	0.372	0.182	-0.285	0.351	0.417	0.469	0.236	0.047
Training	-0.791	0.412	0.055	-0.230	0.416	0.580	-0.392	0.270	0.047
TLU	0.053	0.099	0.594	-0.250	0.150	0.095	-0.142	0.072	0.049
Title deed ownership	-0.001	0.402	0.999	0.718	0.443	0.105	-0.599	0.287	0.037
Agricultural group membership	0.655	0.444	0.140	-0.525	0.403	0.193	0.170	0.268	0.525
Credit access	-0.176	0.404	0.662	2.122	0.460	0.0001	0.988	0.285	0.001
Cultivated land	0.629	0.495	0.204	0.459	0.529	0.386	0.296	0.322	0.358
Farming experience	-0.017	0.017	0.306	-0.007	0.016	0.648	-0.007	0.011	0.494
	Model summary Wald chi^2 30.55 (14) Prob > chi^2 0.0064 N=150			*Model summary* Wald chi^2 51.46 (14) Prob > chi^2 0.0000 N=150			*Model summary* Wald chi^2 38.6 (14) Prob > chi^2 0.0004 N=300		

The coefficient of gender was significant and negative in influencing the perception of the labour requirement of the organic based technologies in Murang'a county (p=0.001) (Table 4.12). This result suggested that males were more likely to perceive a lower labour requirement of the organic based technologies compared to their female counter parts. This result can also mean that females perceived organic based technologies to have a higher labour requirement. Women are the main source of labour in the smallholder setting (Diiro *et al*., 2018), while males tend to play the supervisory role (Ndiritu *et al*., 2014). The supervisory role assumed by males' household heads may affect their perception of how laborious it is to use organic based technologies (Diiro *et al*., 2018). However, the female heads may not have the luxury of assuming the supervisory role in the farm, and hence they perceive a high labour requirement of organic based technologies.

The ordered log-odds estimate of the household size was significant and negatively influenced the perception of labour requirement of the organic based technologies in Murang'a (p=0.040) and Tharaka-Nithi at (p=0.079) (Table 4.12). This meant larger household hold perceive organic based technologies as less laborious compared to their smaller household counterparts. This could be because the household has family labour at their disposal and may not suffer labour constraint as much as smaller households (Harris and Orr, 2012).

The coefficient of access to external labour was significant and positively influenced that perception of labour requirement of the organic based technologies in the pooled data at (p=0.047) (Table 4.12). This meant that households who employ labour perceive organic based technologies as labour intensive. In smallholder farming system in sub-Saharan Africa, labour is hired to supplement family labour (Harris and Orr, 2012). Therefore, households that hire labour perceive the use of organic based technologies laborious.

The household head training on the organic based technologies had a significant influence in Murang'a (p=0.055) and the pooled data (p=0.047) (Table 4.12). This result implied that household head who were trained on the organic based technologies were less likely to perceive organic based technologies as having a high labour requirement. Training instils skills and builds human capital of the farmers' capital (Asfaw and Admassie, 2004). Trained farmers are more aware of the technologies are able to critically examine the attributes of the technologies such as the labour requirement (Udayakumara *et al*., 2010).

The ordered log-odds estimate of TLU owned by a household was significant and negatively influenced the perception of labour requirement on the organic based technologies in Tharaka-Nithi (p=0.095) and pooled data (p=0.049) (Table 4.12). This suggested that if the household would increase the livestock, they own by one unit then that household's ordered log-odds of being in a higher high labour requirement agreement category would increase by 0.142 while the other variables in the model are held constant. This implied that as households increase their livestock units, they perceive organic based technologies as more laborious. This can be attributed to more labour requirement for livestock husbandry.

The household head with a title deed ownership had significant and negative influence on the perception of the labour requirement of the organic based technologies in the pooled data (p=0.037) (Table 4.12). This meant that household heads that own a title deed perceive organic based technologies as having a low labour requirement as compared to household heads who do not own a title deed. Title deed is a measure of land security and rights (Adimassu *et al*., 2013). Therefore, having security right influences how one perceives investments in the land. Farmers who have land security will consider long-term investment in their soil using organic based technologies as a burden (Adimassu *et al*., 2015).

The coefficient of credit access had a significant and positive effect on the perception of labour requirement of the organic based technologies in Tharaka-Nithi (p=0.0001) and in the pooled data (p=0.001) (Table 4.12). This meant that household heads who had access to credit were more likely to perceive that organic based technologies were more labour intensive than households that had not obtained credit. Credit obtained may help alleviate the household's financial burden and facilitate farming activities such as hiring labour to apply organic based technologies (Ndiritu *et al*., 2014).

4.10 Profitability of sole manure, manure plus fertilizer and inorganic fertilizer s in Murang'a and Tharaka-Nithi

The profitability analysis using the gross margins showed that in Murang'a, manure +fertilizer yielded 1962 Kg ha^{-1}, manure yielded 1820 Kg $ha^{-1,}$ while sole inorganic fertilizer yielded 1483 Kg ha^{-1} of maize grain yield (Table 4.13). This meant that manure + fertilizer yielded more maize grain yield compared to manure and sole inorganic fertilizer. The differences in means between the maize grain yields was statistically significant ($F_{(2, 66)}$ = 2.93, p = 0.012) (Table 4.13).

In Tharaka-Nithi, manure + fertilizer yielded 1940 Kg ha^{-1}, manure yielded 1723 Kg ha^{-1}, 1689 Kg ha^{-1} of maize grain yields (Table 4.13). This result showed that manure+ fertilizer yielded more maize grain yields in contrast to manure and sole inorganic fertilizer. The differences in the means of manure + fertilizer, manure and sole inorganic fertilizer were statistically significant ($F_{(2, 65)}$ = 3.79, p = 0.016) (Table 4.133).

In Murang'a, the total revenue per hectare for manure + fertilizer, manure and sole inorganic fertilizer was Kes 64680, Kes 60444 and Kes 42776, respectively (Table 4.13). This meant that manure + fertilizer had the highest total revenue compared to manure and sole inorganic fertilizer. There was a statistically significant difference between the means of revenue generated between manure + fertilizer, manure and sole inorganic fertilizer ($F_{(2, 66)}$ = 3.67, p = 0.002) (Table 4.13).

In Tharaka-Nithi manure + fertilizer generated a total revenue of Kes 69865, manure generated Kes 60131 while sole inorganic fertilizer generated Kes 53259 (Table 4.13). This showed that manure + fertilizer generated the highest revenue compared to manure and sole inorganic fertilizer. The differences between the revenue generated by manure + fertilizer, manure, and sole inorganic fertilizer in Tharaka-Nithi was statistically significant ($F_{(2, 65)}$ = 4.40, p = 0.010) (Table 4.13).

The total variable cost per hectare in Murang'a was Kes 26770 for manure + fertilizer, Kes 16370 for manure and Kes 18297 for sole inorganic fertilizer (Table 4.13). This implied that manure + fertilizer had a higher total variable compared to the total variable cost of manure and sole inorganic fertilizer. Also, sole inorganic fertilizer had Kes 1927 more than manure and Kes 8473 less than manure + fertilizer (Table 4.13). There was a statistically significant difference in mean total variable cost between manure + fertilizer, manure, and sole inorganic fertilizer ($F_{(2, 66)} = 7.86$, $p = 0.001$) (Table 4.13).

In Tharaka-Nithi, the total variable cost for manure + fertilizer was Kes 24240, Kes 22892 for manure, and Kes 21063 for sole inorganic fertilizer (Table 4.13). Manure + fertilizer had a higher total variable cost compared to manure and sole inorganic fertilizer. The difference in mean total variable cost between manure + fertilizer, manure, and sole inorganic fertilizer was statistically significant ($F_{(2, 65)} = 4.57$, $p = 0.019$) (Table 4.13).

In Murang'a, the gross margin for manure + fertilizer was Kes 37907, for manure was Kes 44074 and for sole inorganic fertilizer was Kes 24479 (Table 4.13). This meant that manure had the highest gross margin compared to manure + fertilizer and sole inorganic fertilizer. There was a statistically significant difference in mean gross margins between manure + fertilizer, manure, and sole inorganic fertilizer ($F_{(2, 66)} = 3.56$, $p = 0.026$) (Table 4.13).

In Tharaka-Nithi, the gross margin for manure + fertilizer was Kes 45625, for manure was Kes 37235, and Kes 32191 for sole inorganic fertilizer (Table 4.13). These results showed that manure + fertilizer had the highest gross margin compared to manure and sole inorganic fertilizer. Additionally, the difference in mean gross margins between manure + fertilizer, manure, and sole inorganic fertilizer was statistically significant fertilizer ($F_{(2, 65)} = 9.80$, $p = 0.002$) (Table 4.13).

Table 4.13: Gross margins for maize for users of manure, manure and fertilizer, and inorganic fertilizer in Murang'a and Tharaka-Nithi

		Murang'a					Tharaka-Nithi				
	Variable	Manure + Fertilizer (N=41)	Manure (N=18)	Inorganic fertilizer (N=10)	F-value	p-value	Manure + Fertilizer (N=41)	Manure (N=18)	Inorganic fertilizer (N=10)	F-value	p-value
		Mean (SD)	Mean (SD)	Mean (SD)			Mean (SD)	Mean (SD)	Mean (SD)		
Output	Yield Kg ha^{-1}	1962 (1002)	1820 (924)	1483 (1160)	2.93	0.012**	1940 (940)	1723 (788)	1689 (1194)	3.79	0.016**
	Returns ha^{-1}	64680 (35730)	60444 (27579)	42776 (36560)	3.67	0.002***	69865 (32007)	60131 (27605)	53259 (40027)	4.40	0.010***
Variable Cost ha^{-1}	Seed	1784 (895)	700 (340)	2702 (1267)	19.09	0.000***	1943 (1213)	1748 (913)	1774 (942)	1.26	0.273
	Nutrient source	12012 (8150)	6538 (5844)	3167(2480)	8.65	0.001***	13322 (8353)	8166 (5976)	8040 (7003)	3.99	0.023**
Labour	Land preparation	4874 (41.13)	1172 (349)	2523(1639)	8.65	0.001***	4532 (1825)	4218 (2692)	2456 (1365)	5.02	0.009***
	Planting	20.40 (10.89)	1172 (349)	2306 (1228)	5.35	0.007***	1474 (1229)	2323 (1194)	2420 (1155)	4.51	0.015**
	Weeding	30.30 (25.24)	3305 (1760)	5253 (1699)	3.96	0.023**	1629 (1074)	2861 (1844)	4374 (1888)	14.90	0.000***
	Harvesting	30.31 (1477)	3483 (1881)	2346 (1076)	1.76	0.183	1340 (1107)	3576 (1755)	2003 (915)	18.43	0.000***
	Total variable Cost (ha^{-1})	26770 (11615)	16370 (7620)	18297 (5807)	7.86	0.001***	24240 (9499)	22892 (9524)	21063 (8891)	4.57	0.019**
	Gross Margins ha^{-1}	37907 (35618)	44074 (33510)	24479 (20610)	3.56	0.026**	45625 (33873)	37235 (32512)	32191 (30046)	9.80	0.002***
	N= 69						N= 68				

*, **, and ***: Coefficients are significant at the 10%, 5%, and 1% levels, respectively

The application of manure + fertilizer and sole manure gave the highest maize grain yields compared to sole inorganic fertilizer in both study sites. The higher maize yields under the combination of manure and inorganic fertilizer could be attributed to the balanced supply of nutrients for the maize. According to Partey et al., (2013) application of organics in combination with fertilizer improves the synchrony between the supply and demand of the nutrients. However, the gross margins associated with manure + fertilizer was highest in Tharaka-Nithi and second highest in Murang'a. The result could be explained by the high variable cost associated with the application of manure + fertilizer.

In on-station experiments, lower grain maize yields have been reported where sole fertilizer was used compared to where sole organic or organic combined with mineral fertilizer (Mugwe *et al*., 2009a; Mucheru-Muna *et al*., 2014). Maize grown using manure and integration of manure and fertilizer showed high profitability compared to sole inorganic fertilizer (Mucheru-Muna *et al*., 2014). The higher profits may be associated with the higher yield reported in the use of sole organic or organic combined with mineral fertilizer in Kenya's Central Highlands (Kimetu *et al*., 2004).

Positive financial returns on maize production system by using from organic based inputs has reported in Zimbabwe by Mutiro and Murwira, (2004). The organic based input used in the study was manure in combination with inorganic fertilizer. In the experiment, the returns obtained from the sole manure was \$122.8 ha^{-1} more compared to the control (no input). While manure + fertilizer reported \$184 ha^{-1} more compared to sole animal manure. These results showed that smallholder farmers can get higher positive financial returns by using organic based inputs solely or in combination with inorganic fertilizer in maize production.

CHAPTER FIVE

SUMMARY OF FINDINGS, CONCLUSIONS, AND RECOMMENDATIONS

5.1 Summary of findings

The first objective sought to determine socio-economic factors that influenced the adoption intensity of organic based technologies in Murang'a and Tharaka-Nithi counties. The socio-economic determinants of the adoption intensity of organic based technologies were estimated using a Tobit regression model. The socio-economic factors that significantly influenced adoption intensity of organic based technologies were gender of the household head, age, level of education, size of the household, access to external labour, access to credit, land under cultivation, training, TLU owned by the household, household agricultural group membership and years of farming.

The second objective aimed at determining the socio-economic factors that influenced the perception of organic based technologies in Murang'a and Tharaka-Nithi counties. This objective examined how farmers perceive the potential of organic based technologies to improve yields, improve soil fertility, profitability and the labour requirement. This was done using ordinal logistic regression model. The socio-economic factors that influenced the perception of organic based technology potential to improve yields were gender of the household heads, TLU, land under cultivation, and years of farming experience. The socio-economic factors that influenced the perception of organic based technology potential to improve soil fertility were gender of the household head, household size, TLU, farming experience, access to credit, land under cultivation. The socio-economic factors that influenced the perception of the profitability of organic based technology were age of the household head, the level of education, training, title deed, access to credit, and land under cultivation. The socio-economic factors that influenced the perception of organic based technology labour requirement were gender of the household, household size, external labour, training, TLU, title deed, and access to credit.

The third objective sought to determine the profitability of using organic based technologies in Murang'a and Tharaka-Nithi counties. This was done using a gross margin analysis. Only two organic based technologies were used because they had significant data for the gross margin analysis. Inorganic fertilizer was used for comparison. Manure + fertilizer reported the highest grain yields in both counties compared to sole animal manure and sole inorganic fertilizer. The total variable cost for manure+fertilizer was higher compared to the other inputs. The major contributor to the total variable cost was the cost of the inputs. Sole animal manure had higher gross margins in Murang'a compared to other inputs. Manure+fertilizer had higher gross margins in Tharaka-Nithi County.

5.2 Conclusions

1. Nine organic-based techniques were used in the central highlands of Kenya. Out of the nine technologies, manure and manure combined with fertiliser were adopted by the majority of households in Murang'a and Tharaka-Nithi, respectively. On the other hand, agroforestry, compost

and residue incorporation in Murang'a and compost, residue incorporation and cover crop in Tharaka-Nithi were poorly adopted.

Results also revealed that socioeconomic determinants of intensity of adoption were gender, age of the household head, level of education, household size, access to external labour, training, TLU, agriculture group membership, access to credit, land cultivated, title deed ownership and farming experience. Gender influenced positively the adoption intensity of manure +fertiliser, which implied women-headed households were disadvantaged. The age of the household head had a negative effect on the adoption intensity of organic based technologies, especially compost and crop rotation meaning that older household heads will have low adoption intensity. The education level had a significant positive relationship with the intensity of adoption. Household size had a significant positive effect on the adoption intensity of selected organic-based technologies, suggesting that larger households are more likely to have a higher adoption intensity compared to smaller households. Access to external labour had a significant positive influence on the adoption intensity of selected organic-based technologies. Household training was positive and significant in influencing the extent of adoption of selected organic-based technologies. Tropical Livestock Unit had a positive and significant effect on the extent of adoption. Agricultural group membership positively influenced the adoption intensity. Access to credit had a positive influence on the adoption. Land under cultivation had a significant positive influence on the adoption intensity. Land title deed ownership had a positive and significant influence on the adoption intensity. Years of farming experience had a significant positive influence on the adoption intensity of organic-based technologies.

2. Findings demonstrate that farmers positively perceive the use of organic based technologies improve soil fertility, increases crop yields and results in higher financial returns (profitable). However, the farmers perceived the technologies to be labour intensive. Gender of the household head, household size, TLU, access to external labour, access to credit, total land cultivated, age, and years of farming experience are the socioeconomic drivers that significantly influence farmers' perception of organic based technologies.
3. The use of animal manure combined with inorganic fertiliser showed the highest total variable cost compared to other inputs in the two study areas. Highest financial returns are achieved under sole animal manure in Murang'a and in manure combined with inorganic fertiliser in Tharaka-Nithi.

5.3 Recommendations for Policy Action

Several policy recommendations arise from the findings of this study:

1. The results imply that the adoption intensity of organic based technologies could be enhanced by targeting younger and large families, farmers with bigger farms sizes, training farmers on organic based technologies and encouraging farmers to join agricultural groups where they can learn from each other.

2. This study recommends that farmers should be included in developing organic based technologies. Farmers' subjective assessment and subsequent perception of the technologies attributes such as potential to improve yields, improve soil fertility, profitability and the labour requirement are important technology attributes that can hinder or accelerate decision to adopt a technology.
3. Both national and county governments should promote the use of organic based technologies not only for their sustainable attribute but also because higher profitability margins than the use of sole inorganic inputs.

5.4 Recommendations for further research

This study recommends future research on the role of the interdependency of agricultural technologies in the adoption process and the intensity of adoption of organic based input technologies in the Central Highlands of Kenya. This information will be useful in informing future research on a holistic approach to adoption and its dynamics.

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APPENDICES

Appendix 1: Household questionnaire

Interview No: ……….   Date: …..../……/ 2018
Name of enumerator: ……………
County: ………………………………   Sub-county: ………………….
Location: ……………………………...   Sub-location………………….
Village………………………………….
GPS co-ordinates: S: ………… °.…………………”. ……………”
                           E: ………… °.…………………”. ……………”
Altitude (meters above sea level) ……………………….

A. HOUSEHOLD AND FARM CHARACTERISTICS

1. Name of household head ………………………
2. Mobile number………………………………
3.Name of respondent ……………………? (if not household head)
   (b)Mobile number…………………………….
4. Gender of household head (*Tick where applicable*)
   1=☐ Male   2=☐ Female
5. House-hold type (*Tick where applicable*)
   1= ☐ Nuclear   2= ☐ Extended 3= ☐ Polygamous
   4= ☐ female headed (widow, never married, divorced)
   5= ☐ male headed (widow, never married, divorced)
6.What is the age of the household head……………………... (Exact age)
7. How long has the household head practiced farming…………………. (Number of years)
8. What is your total land size……………………… (write in ha/acres)
9. What size of land have you hired……………………. (Indicate the units in the next space: points, acres or Ha)
10. What is total land that is cultivated…………………. (Indicate the units in the next space: points, acres or Ha)
11. Total land occupied by homestead……………………. (Indicate the units in the next space: points, acres or Ha)

12. What type of livestock and how many of each do you keep on your farm?

Type of livestock	*Number*
Cattle	
Goats	
Donkey	
Sheep	
Chicken	
Oxen	
Pigs	
Other (specify)	

13. Which four main crops are important to you? (List in the order of importance/ preference and show the area covered in acres)

	Type of crop	*area under cultivation*
1		
2		
3		

B. LAND TENURE SYSTEM

14. Do you hold a formal title deed of the land you farm on?
1=Yes 0=No

15. what tillage method do you use for cultivation?
Manual with hoe =1, Animal traction =2, Tractor tillage =3

16. Would you invest more amount of resources (e.g. labour or capital) in the land you are currently farming on?
1=Yes 0=No

16.b If yes, what is the motivation? *1=Profit orientation 2=Environmental orientation 3=Risk orientation 4=Enterprise scale 5=Management horizon 6=Short-term constraints*

C. WORKFORCE AND FAMILY SIZE

17. How many people live in your household (eat from the same pot including those who are currently living here but you support them while excluding visitors)?
- *Number of males: ………………*
- *Number of females: ………………*

18. How many adults live in this household (Aged 18)
- *Number of males: ………………*
- *Number of females: ………………*

19. How many children live in this household (Aged below 18 years)?
- *Number of males: ………………*
- *Number of females: ………………*

20. How many adult members of your household work mainly on the farm?
- *Number of males: ………………*
- *Number of females: ………………*

21. How many adult members of your household work mainly outside the farm?
- *Number of males: ………………*
- *Number of females: ………………*

22. Do you hire labour from outside the farm?
- Number (per season) ………….
- Wage rate…….

D. ADOPTION OF TECHNOLOGIES AND SOURCE OF INFORMATION

23. Are you aware of and use the following organic based technologies

Technology	Are you aware of the following technologies? 1=Yes 0=No	Which of these technologies do you use?	When did you first learn about these technologies (Year)	When did you first implement on your farm?	If implemented what was the motivation CODE A	Do you still implement on your farm?	How much area are you currently applying the technology?	How did you first learn about the technology? CODE B
Use of animal manure								
Composting								
Crop residue incorporation								
Plant based organic fertilizer								
Agroforestry (Nitrogen fixing trees, shrubs, food and fodder crops)								
Intercropping systems								
Biomass Transfer								
Crop rotation								
Cover crops								

Erosion control and soil conservation								
Green fallow periods								
Management of animal and farm yard manure								
Management and application of organic fertilizers								
Legume inoculation								

CODE A
1=Profits 2=Environmental considerations 3=To minimize crop failure related risks 4=Enterprise expansion, 5=Ease of management/implementation 6=Lack of alternative due accessibility related constraints

CODE B
1=Farmer field school 2=Extension officers 3=Demonstrations 4=Farmer-farmer 5=Field days,
6=Workshop/seminar 7=Media channels-TV, radio, 8=Brochure, 9=others (specify)

24. Which technology(s) are you currently practicing and why? (*List in order of preference)*

Technology	*Reason*

1=Use of animal manure 2=Composting 3=Crop residue incorporation 5=Agro-forestry 6 =Plant based organic fertilizer 7= Inorganic fertilizer 8= Legume inoculation 9= Crop rotation 10= Green fallow periods

E. GROUP MEMBERSHIP, SOCIETY AND CULTURE

25. Are you currently a member of any farmers' group or local association in this village?

1=Yes 0=No

26. Which type of group?

(tick where appropriate)

1= ☐ Farmer group 2 = ☐ saving group 3= ☐ Cooperatives 4 = ☐ Religious group

5 = ☐ Youth group 6= ☐ Women group 7 = ☐ CBOs, NGO 8 = ☐ If another group, please specify: ……………………

27. Does your culture support or hinder the adoption of listed ORM technologies in any specific ways?

1=Yes 0=No

If yes, please explain your answer and specify which technology by ticking appropriately

………………………………………………………………………………

(1=Use of animal manure 2=Composting 3=Crop residue as mulch 4=Organic+ inorganic fertilizer 5=Agroforestry 6 =Plant based organic fertilizer)

28. What do you think can be done at community level to restore soil fertility?

………………………………………………………………………………

29. Is your culture has a specific role in the adoption of the listed ORM compared to other cultures you know?

……………………………………………………………………………

30. Do you have any special customs related to soil fertility management techniques in your culture?

1=Yes 0=No

If yes, please explain your answer

………………………………………………………………………………

31. Which group in the society do you feel is more receptive to change and innovation in soil fertility management?

1 = ☐ Men (above 35) 2= ☐ Women (above 35) 3= ☐ Male youth (18-35)

4= ☐ Female youth (18-35)

F. PERCEPTION ON SOIL FERTILITY

32. Do you perceive soil fertility as a problem on your farm?

1= ☐ Yes, it is a major problem 2 = ☐ Yes, it is only a minor problem 3 = ☐ No, it is not 4= ☐ I do not know

33. In your opinion, which soil fertility improvement technology combination work best for you

CODE A

1= Manure and fertilizer 2= Tithonia and fertilizer 3= Tithonia and manure 4=others specify

34. How would you rate the level of soil fertility in your farm*? (Tick one of the options, give reason for the response, especially the indicators of the fertility status like the colour of crops, soil colour etc.…)*

Soil fertility is very good on my farm	*Soil fertility is good*	*Soil fertility is not good /not bad*	*Soil fertility is bad*	*Soil fertility is very bad*
5	4	3	2	1

Please give reasons for your answer:
…………………………………………………………………………………

35. Have you seen a change in soil fertility over the last 5 to 10 years? *Tick one*
1=*Yes, soil fertility has declined tremendously*
2=*Yes, soil fertility has declined*
3=*No change, soil fertility has remained stable*
4=*Yes, soil fertility has somewhat improved*
5=*Yes, soil fertility has improved tremendously*
Give indicators for change noticed: ……………………………………………..
36. Have you ever had soil test done on the soil? 1=Yes 0=No

G. FARMERS PERCEPTION ON ORGANIC BASED TECHNOLOGIES

37 *What is your perception of the following technologies on soil fertility improvement*						
		Strongly agree	*Agree*	*Undecided*	*Disagree*	*Strongly disagree*
		5	*4*	*3*	*2*	*1*
a	Application of animal manure improves soil fertility					
b	Animal manure is easily available for use on my farm					
c	Application of animal manure leads to high crop yields					
d	Animal manure is not labour intensive					
e	Use of crop residue as mulch improves soil fertility					
f	Using crop residue as animal feed is more economical than using as mulch					

g	Application of inorganic fertilizer alone gives better crop yield					
h	Application of inorganic ferilizer improves soil fertility					
i	Animal manure+ fertilizer application leads to high crop yields					
j	Agroforestry trees improve soil fertility					
k	*Tithonia divesofolia* is an important shrub in improving soil fertility					
l	Soil fertility is not a problem on my farm					

38. After how long do you think the impact of using ORM is felt? (time in years)
39. Do you think that the use of ORM can expose your farming enterprise to risk?

<u>H. CHALLENGES IN TECHNOLOGIES-GENERAL WHETHER PRACTICED OR NOT </u>(*Several answers possible. Rank challenges in the order of their importance*)

40. What challenges are faced in application of sole animal manure? (Tick the most significant challenge)

1 = *Labour intensive 2=Transportation difficulties (bulkiness, weight problems) 3=Insufficient number of animals to produce manure 4=Lack of machinery/equipment to use 5=Non-availability of Animal manure from external sources 6=Animal manure is too expensive to buy 7= others (please specify)*

41. What challenges are faced in the use of compost? (Tick the most significant challenge)

1=Labour intensive 2=Transportation difficulties (bulkiness, weight problems) 3=Insufficient amount of material to make compost 4=Lack of machinery/equipment to use 5=Non-availability of Compost 6=Compost is too *expensive to buy 7=Inadequate knowledge about compost making 8=others (please specify): ……………………………………………….*

42. What challenges are faced in the use of crop residue as soil cover (mulch) or as organic material (incorporation)? (Tick the most significant challenge)

1=Crop residues is used as fodder 2=Crop residues are used as fuel wood 3=Free grazing animals just feed on it 4=Too much labour needed to collect and distribute crop residues 5=Not many crop residues available 6=Crop residues are not available to buy (for sale) 7=others (please specify): ……………………………………………

43. What is the challenge to using *Tithonia diversifolia*? (Tick the most significant challenge)

1=Never heard of Tithonia diversifolia 2=Lack of knowledge on how to use it 3=lack of knowledge on benefits 4=lack of planting material to plant on our farm 5=others (please specify): ……………………………………………….

44. What are the challenges faced in applying sole inorganic fertilizer?

1=Fertilizer is too costly 2=Fertilizer harms the soil 3=Appropriate fertilizer is not available 4=Yields are not convincing 5=Fertilizer does not pay off 6=Don't know the recommended rates to use 7=Other reasons (please specify): ……………………………………………….

45. What are the challenges to using trees to improve soil fertility?

1=Lack of knowledge on which species to use 2=Non-availability of planting material 3=Competition to use tree leaves as fodder 4=Trees compete for water with crops 5=Limited availability of land 6=others (please specify): ……………………………………………….

46. What are the challenges to using plant based organic fertilizer? (Tick the most significant challenge)

1=The fertilizer is too costly 2=Never heard of it 3=Lack of knowledge on how to use it 4=Yields are not convincing 5=Do not know the recommended rates to use 6=other reasons (please specify): ……………………………………………….

48. Do you think that the impact from using ORM is reversible?

<u>I. INNOVATIVENESS</u>

Farmers self-Assessment concerning willingness for innovation and to solve soil infertility problems

49. Have you introduced any soil fertility enhancement technology in your farm in the last three years?

1=Yes 2=No

Give a reason for answer:
…………………………………………………………………………………………

J. PERCEPTION ON PROFITABILITY

50. In your view, do you think implementing the following technologies in your farm profitable?

Technology	1=YES	2=NO	Reasons for Yes	Reasons for No
Use of animal manure				
Composting				
Crop residue incorporation				
Plant based organic fertilizer				
Agro-forestry				

51. In your view is the first/starting cost of the following technologies high?

Technology	1=YES	2=NO	Reasons for Yes	Reasons for No
Use of animal manure				
Composting				
Crop residue incorporation				
Plant based organic fertilizer				
Agro-forestry				

52. In your view, what is the expected time to start realizing profits from the use of ORMs (Time in years)
53. In your view, do you think if you start using ORM technology today you will end up being profitable in the future?
57. Do you have final remarks? ………………………………………
58. Remarks by enumerator …………………………………….

………………………………………………………………………

Thank you for taking part.

Appendix 2: Profitability questionnaire

Name of the farmer-----------------------------, County-------------------
Land size under technology-------------------------, Gender-----------------------,
Mobile phone--------------------
GPS Lat GPS Long Alt
Date…………………………………………………………
Please fill in the following table relating to the last season of maize production
Variable costs

Activity	Number of persons	Unit cost	Days to complete	Total cost
Transport				
1st ploughing				
2nd ploughing				
Planting				
1st weeding				
2nd weeding				
Spraying				
Harvesting				
Threshing				
Drying				
Bulking				
Sorting				
Packaging				
Other (Chasing birds)				

Fixed costs

Inputs	Unit Cost	Quantity	Total Cost
Seed			
Inoculant			
Fertilizer			
Fungicide			
Land rent			

Total yield realized_____________________________
Crop Value (Yield x Crop value per Kg) --------------------------
Total production cost ----------------------------------- Profit------------------------

JOURNAL ARTICLES PUBLISHED FROM THIS THESIS

1. **Adoption Intensity of Selected Organic-Based Soil Fertility Management Technologies in the Central Highlands of Kenya**

   Authors: George G. Mwaura*, Milka N. Kiboi, Eric K. Bett, Jayne N. Mugwe, Anne Muriuki, Gian Nicolay, and Felix K. Ngetich

   Published in Frontiers in Sustainable Food Systems Journal

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2. **Financial Analysis And Determinants Of Perceived Benefits Of Using Manure And Manure Combined With Inorganic Inputs For Soil Fertility Improvement In The Central Highlands Of Kenya (Under Review)**

   Authors: George G. Mwaura*, Milka N. Kiboi, Eric K. Bett, Jayne N. Mugwe, Anne Muriuki, Gian Nicolay, and Felix K. Ngetich

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