GENDER INFLUENCE ON SOIL FERTILITY AND WATER MANAGEMENT TECHNOLOGIES UPTAKE AMONG SMALLHOLDER FARMERS IN THARAKA NITHI COUNTY

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DECLARATION

This thesis is my original work and has not been presented elsewhere for a degree or any other award.

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DEDICATION

This work is dedicated to my parents Mr. and Mrs. Ndeke, thank you for the incessant love and backing.

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ABBREVIATIONS AND ACRONYMS

AEZs	:	Agro-Ecological Zones
ANOVA	:	Analysis of Variance
FFHs	:	Female Headed Households
FGDs	:	Focus Group Discussions
HH	:	Household Head
IL	:	inner/Intermediate Lowland
IMR	:	Inverse Mill’s Ratio
ISFM	:	Integrated Soil Fertility Management
IPCC	:	Intergovernmental Panel on Climate Change
LM	:	Lower Midland
MLE	:	Maximum Likelihood Estimation
MMHs	:	Male Headed Households
ODK	:	Open Data Kit
SPSS	:	Statistical Packages for Social Scientists
SSA	:	Sub-Saharan Africa
SWC	:	Soil and Water Conservation
TLU	:	Tropical Livestock Units

ABSTRACT

Degraded landscapes and soil water stress are long-standing problems to smallholder agriculture in the drylands. Despite the important roles of soil and water conservation in restoring degraded landscapes and improving agricultural productivity, the technologies are yet to be adopted to their fullest extent. This can be attributed to gender-linked disparities in agricultural technology utilization. This study, therefore, sought to evaluate gender-specific choice and use-intensity determinants of soil and water management technologies and preference for technology attributes by women and men farmers. Mixed-methods approach was employed to collect two sets of data; quantitative and qualitative data. Quantitative data were collected in a cross-sectional survey using an interviewer-administered questionnaire in Tharaka South sub-county. A multistage sampling technique was employed in randomly selecting 133 female-headed households and 267 male-headed households. Purposively, across the study sites, three Focus Group Discussions were engaged to gather qualitative data on most preferred technology attributes. Using sex-disaggregated data, Chi-square and t-test statistic were employed to test the statistical significance of dummy and mean value of continuous variables, respectively. Gender influence in preference for soil and water conservation technologies specific-attributes was measured in a ten-point scoring scale. T-test was used to determine if there were significant differences between the average scores of each attribute among male-headed households and female-headed households. One-way analysis of variance was run to determine presence of statistical evidence that associated attributes average scores were significantly different with respect to household headship. Tukey’s Honestly Significant Difference test was used to compare all possible pairs of means. Gender specific determinants of zai technology choice and use-intensity were determined using the Heckman-two-step econometric model. The results revealed that, significant gender differences existed in preference, choice and use-intensity of zai technology and mineral fertiliser. In regard to preference, women farmers are more sensitive to soil fertility and information availability characteristics when considering soil and water conservation measures whereas male farmers are more inclined towards technologies that increase yields and improve soil fertility. Among women farmers, total cultivated land, access to animal-drawn farm implements, and group membership had an influence on zai technology and mineral fertiliser choice. For men, total cultivated land, group membership and access to extension services positively influenced choice of zai technology and mineral fertiliser. With regard to zai technology and mineral fertiliser use-intensity, total land cultivated, livestock densities, group membership and frequency of trainings on soil and water management were important determinants among women farmers. For men, total cultivated land and farmers’ perceptions on soil erosion were significant drivers for zai and mineral fertiliser use intensity. The study recommends that, gender-sensitive farm-level policies oriented towards farmer socioeconomic profiles are important deliberations towards choice and intense application of preferred soil and water conservation strategies such as the zai technology and mineral fertiliser.

CHAPTER ONE

INTRODUCTION

1.1 Background of the study

Climate change exacerbates food insecurity as variations in agroclimatic conditions impinge sustainable food production, especially in the dryland systems (IPCC, 2014; Farooq & Siddique, 2017). As was noted by White et al. (2002), arid and semi-arid lands cover about 40% of land surface globally, but most extensive in Africa ($13\times l0^6$ km^2). Correspondingly, in sub-Sahara Africa (SSA), there is a high incidence of food insecurity where rain-fed subsistence agriculture remains a predominant livelihood strategy for most people residing in the drylands (Shahid & Al-Shankiti, 2013; Barbier & Hochard, 2018). These regions experience erratic rainfall, recurrent dry spells, increasing temperatures, and infertile lands characterized by; diminishing organic matter and reduced biological activity, and this poses limitations for intensifying agricultural productivity (Bradford et al., 2017; Bradford et al., 2019; Issahaku & Abdul-Rahaman, 2019). Upper Eastern Kenya faces similar challenges of soil moisture stress, declining soil fertility, and reduced agricultural yields promoting various research and development efforts on soil and water conservation (Mucheru-Muna et al., 2010; Ngetich et al., 2014; Muriu Ng'ang'a et al., 2017; Kiboi et al., 2019; Kimaru-Muchai et al., 2020). In response to these challenges, smallholder farmers usually apply various soil fertility and soil water conservation strategies, but often at lower rates (Mugwe et al., 2009; Kiboi et al., 2017; Mwaura et al., 2021). This aggravates production volatility heightening the food crisis in the rural economies (Mganga et al., 2015; Rojas et al., 2016; Sinyolo et al., 2020).

The growing risk of vulnerability to climate shocks is not gender-neutral (Djoudi & Brockhau 2011; Beuchelt & Badstue et al., 2013). Women farmers face different challenges in utilizing agricultural innovations to avert climate-related risks when compared to their male counterparts (Diouf et al., 2019; Rola-Rubzen et al., 2020). Furthermore, gender inequalities and lack of attention to men and women's specific preferences and needs is associated with low use of agricultural innovations (Huyer, 2016;

Kawarazuka et al., 2018; Rola-Rubzen et al., 2020). The disparities exist in form of land tenure insecurities, to which women farmers are underprivileged in use and decision making; gender differences in access to education and extension trainings; rationing out of credit markets; greater difficulties in access and control to assets including, livestock and farm implements and machinery; limited access to education and agricultural training, and other social and cultural forms of inequalities linked to social perceptions on differentiated roles for men and women (Njuki et al., 2011; Kassie, 2014; Quisumbing et al., 2014; Doss et al., 2018). Moreover, patriarchal systems are oppressive to women, perhaps not allowing women farmers to participate more effectively in decision-making (Sultana, 2012; Colfer et al., 2015; Mukoni, 2018). Consequently, the inequalities have implications for technology use and pose a significant drawback to the effective utilization of agricultural innovations (Rola-Rubzen et al., 2020). In the pursuit for women's empowerment in agriculture, aligning the design and implementation of agricultural technologies to specific gender preferences is imperative.

Soil fertility depletion, interseasonal dry spells and degraded landscapes are the main causes of low agricultural productivity in the dry lands (Ngetich et al., 2014; Farooq & Siddique, 2017). The impacts of soil moisture stress and soil nutrient deficiencies are severe when farmers have no adaptation alternatives and perhaps utilize these adaptation strategies at lower rates than recommended (Mugwe et al., 2019; Mwaura et al., 2021). Kiboi et al. (2017) and Partey et al. (2018) reported that regenerative agriculture strategies such as use of organic and mineral fertilizers, zai technology, tied ridges, mulching and legume-intercropping are possible solutions for enhancing soil water conservation and soil nutrient replenishment. For example, the zai technology remains a dependable choice for improving soil water conservation in the drylands (Danso-Abbeam et al., 2019; Kimaru-Muchai et al., 2020) and the restoration and rehabilitation of completely denuded, encrusted and degraded landscapes. The zai technology offers multiple benefits when incorporated with organic and mineral fertilisers. Precisely, as an effort to bridge intraseasonal dry spells, development agencies in the drylands of upper Eastern Kenya introduced and incessantly promoted the use of zai technology (Kimaru-Muchai et al., 2020). Zai technology is recommended for drier agro-ecological zones receiving 300-800 mm annual rainfall (Roose et al., 1999), hence best-fitting the region. Furthermore, water conservation structures achieve dual purposes of increased spatial extent and duration of plant-available moisture and controlling soil erosion by trapping and altering sediment distribution (Nichols et al., 2021).

Recently, several studies that consider agricultural technology use have reported imperfect information and institutions among other demographic and socioeconomic characteristics to be constraining factors to utilization of agrarian technologies (Mango et al., 2017; Wekesa et al., 2018; Thinda et al., 2020). On the other hand, empirical evidence has proven that gender inequalities exist in utilization of agricultural technologies owing to inadequate access to key productive assets, education and relevant training among other fairly obvious and largely overlooked technical constraints (Ndiritu et al., 2011; Meinzen-Dick et al., 2019; Rola-Rubzen et al., 2020). Integrating gender in understanding the synergies between factors underlying preferences, choice and use-intensity of the soil fertility and soil water management technologies is crucial in crafting, diffusion and intensification.

1.2 Statement of the problem

Despite the progressive development and promotion of soil fertility and soil water conservation technologies in the drylands of Tharaka Nithi county, uptake of these technologies has remained low over time. As a result, soil fertility decline and soil water stress are the primary challenges facing smallholder farmers in this region. The low uptake is attributable to lack of gender considerations when promoting agricultural innovations. Additionally, there is a dearth of knowledge on the preferred soil and water conservation technologies attributes and the drivers of technology choice and use intensity by gender. Thus, disparities exist in opportunities for male and female farmers to participate and equitably benefit from the technologies. Therefore, this study was geared towards reducing the gender technology-use gap by determining the soil and water management technologies preferred attributes, choice and use-intensity determinants among female and male farmers.

1.3 Research objectives

1.3.1 General objective

To evaluate the influence of gender on uptake of selected soil fertility and water management technologies among smallholder farmers in the dry lands of Tharaka Nithi County.

1.3.2 Specific objectives

1. To assess farmers' preference for selected soil fertility and water management technologies attributes among male-headed and female-headed households in the dry lands of Tharaka Nithi County.
2. To examine socio-economic characteristics influencing choice of selected soil fertility and water management technologies among male headed and female headed households in the dry lands of Tharaka Nithi County.
3. To establish the determinants of selected soil fertility and water management technologies use intensity among male-headed and female-headed households in the dry lands of Tharaka Nithi County.

1.4 Research questions

1. What soil fertility and water management technologies attributes do male-headed and female-headed households prefer?
2. What socio-economic characteristics influence the choice of soil fertility and water management technologies among male-headed and female-headed households?
3. What are the determinants of soil fertility and water management technologies use intensity among male-headed and female-headed households?

1.5 Justification of the study

The arid and semi-arid lands of Tharaka Nithi County and at large the lower Eastern Kenya are particularly hard hit by climate related hazards putting the lives and livelihoods of millions of households at risk (Muriu-Ng’ang’a et al., 2017; Kimaru-Muchai et al., 2020). Besides, the major livelihood activity in this regions is smallholder farming majorly dominated by women who provide over 80% of farm labour and are more vulnerable to climate related risks with the lowest adoption of climate responsive farming technologies (Onyalo, 2019). Therefore, the knowledge on preferred soil and water technologies, drivers of choice and use intensity of these technologies among women and men farmers is one step towards scaling out climate smart technologies uptake. This would advance the country’s big four agenda by contributing towards a food secure nation.

Furthermore, the results will be shared with the community and relevant stakeholders through convenient, accessible and cost effective channels. This will facilitate the review of the existing evidence on gender and uptake of climate smart strategies and their effectiveness in agricultural production. In addition, development partners and policy makers who have taken gender analysis as an important aspect in the design, implementation and evaluation of development projects can adopt the results to guide their decisions for effective and efficient delivery. Finally, it’s the desire of the researcher to contribute to the body of knowledge for future research and act as a source of reference to all stakeholders in agricultural industry.

1.6 Scope and limitation of the study

The study was carried out in the dry parts of Tharaka Nithi county, Tharaka South sub-county, targeting all smallholder farmers. It captured information regarding farmer’s socio-economic profiles and the strategies farmers were using to enhance soil fertility and soil water conservation in both male-headed households and female-headed households. The study was limited to household and farm level analysis. Only the selected soil fertility and soil water management technologies were considered for this study yet farmers practice a myriad of soil and water conservation technologies.

CHAPTER TWO

LITERATURE REVIEW

2.1 Overview

In this section, literature of past studies on soil and water conservation, determinants of preference, choice and use intensity of agricultural innovations and gender integration in agricultural technology uptake were reviewed. The reviews led to identification of knowledge gaps in existing literature which this study sought to bridge. Finally, a random utility maximization theory on which this study was anchored was reviewed and a conceptual framework presented.

2.2 The concept of soil and water conservation

Soil and water conservation is characterized by minimal soil exposure and disturbance, wide-ranging crop rotations, application of regenerative agriculture practices that entail crop residue retention and use of organic and inorganic fertilisation methods to reduce soil degeneration while improving crop production sustainably (Farooq et al., 2017). Although adoption of soil and water conservation strategies is increasing globally and especially in the dry lands, in some regions its either slow or non-existent. For example, in SSA, utilization of soil and water conservation strategies has remained low despite the envisioned benefits (Mango et al., 2017; Nyamekye et al., 2018).

Continuous tillage among other conventional practices have significantly degraded fertile lands (Farooq et al 2017), with a concomitant drop in crop and livestock productivity. To reverse these conditions, soil and water conservation strategies that have the ability to reduce and/or revert many undesirable effects of principal types of farming such as prevalent surface runoff, soil organic matter (SOM) loss, soil water stress and soil aggregation degradation have been recommended (Serraj & Siddique, 2012). Similarly, in the drylands of Eastern Kenya, a number of integrated soil and water management options have been developed and tested in the region (Mugwe et al., 2009; Mwaura et al., 2021). For instance, tied ridging, mulching/crop residue retention, minimum tillage, legume-intercropping and use of animal manure are some of the technologies that have the prospective to boost soil fertility and soil water management for sustained crop growth. Kiboi et al. (2017) found that, tied ridges doubled maize yields with use of manure and minimum tillage having significant effect on maize yields. Also, zai technology is one of most effectual strategy in harvesting runoff and at the same time enhancing crop productivity in the dryland regions (Kimaru-Muchai et al., 2020). Moreover, efficient use of mineral fertilisers in restoring and maintaining soil fertility as proven relevant in most severe infertile and degraded landscapes (Lambrecht et al., 2016).

Despite the positive impacts achieved through soil fertility improvement and soil water management, slow adoption of these technologies remains a big challenge particularly among rural resource poor farmers (Mugwe et al., 2009; Mponela et al., 2016; Mwaura et al., 2021). This is associated with negative economic externalities such as disruption of livelihoods, low returns to agricultural investments and a threat to food security in the drylands. Feder et al. (1985) found technology intensification decisions to depend on socio-economic factors, technology characteristics, institutional factors and farmer intrinsic attributes. Over the years, a wide-ranging body of literature has studied the factors driving agricultural innovations use and intensification (Zeng et al., 2018; Beshir &Wagary, 2014). On the other hand, a considerable amount of empirical studies has premeditated the gender differences in agricultural innovations choice anwd use levels using sex of the household head as the gender pointer (Gebre et al., 2019; Lambretch et al., 2016). Most notably, there is a clear need to understand the economic, cultural and institutional profiles that would fast-track intense use of soil and water conservation techniques at household or farm level among other agrarian technologies.

2.3 Soil and water conservation strategies

2.3.1 The zai technology

In the restoration practice, the zai pits of dimensions 20-40 cm diameter and 10-15 cm deep are implemented early before the onset of rains (Roose et al., 1999; Sawadogo et al., 2001).

The pit size is subject to variations; deeper pits in shallow horizons and shallow pits on the watertight soils (Slingerland & Stork, 2000). For example, in Kenya, most farmers observe 60 cm × 60 cm × 60 cm dimensions in width, length and height when executing zai (Peter & Itabari, 2014). On average, with a spacing of 60-80 cm apart, 8000 pits fit ha^{-1} (Fatondji et al., 2006; Kimaru-Muchai et al., 2020), and are applied in alternating rows to increase runoff collection. In most cases, on average, farmers incorporate zai pits with about 2 Mg ha^{-1} of well decomposed manure or crop residues (Roose et al., 1999; Mwangi, 2020). Moreover, some farmers incorporate mineral fertilizer in the pits (Kimaru-Muchai et al., 2020). The addition of organic matter improves runoff water infiltration, thus creating deep moisture pockets in the planting hole, protected from quick evaporation (Danso-Abbeam et al., 2019).

The incorporation of manure and other organic residues also helps in maintaining soil structure. Decomposition of organic manure by soil organisms enrich the soils and runoff water with nutrients (Roose et al., 1999). Subject to rainfall and soil fertility conditions, on average, well-executed zai pits can lead to about 750 kg ha^{-1} of grain yields and about 3 Mg ha^{-1} of crop residue for mulching and livestock feed (Fatondji et al., 2006). Also, zai harvests 25% of surface runoff from 5 times its area (Malesu, 2006) and can increases soil water holding capacity by over 500% (Danjuma & Mohammed, 2015). Furthermore, water conservation structures achieve dual purposes of increased spatial extent and duration of plant-available moisture and controlling soil erosion by trapping and altering sediment distribution (Nichols et al., 2021). Conversely, the use of the technology among other soil and water management technologies has stagnated over time in spite of its diffusion (Mugwe et al., 2019; Kimaru-Muchai et al., 2020).

2.3.2 Mineral fertiliser use

Notably, across the globe, approximately 50 percent of the population depends on mineral fertilisation methods for their food intake (Ogada et al., 2014; Vanlauwe et al., 2014). The emphasis on mineral fertiliser utilisation is important in SSA and the drylands in general.

Apparently, mineral fertiliser use is indispensable in the long-run sustained soil health and for ensuring sufficient food supply for the exponentially increasing populations (Lambrecht et al., 2015). Interventions that increase preference, choice and use of mineral fertiliser intensely among the rural poor farmers can advance food sufficiency, nutritional security and empower them shift from poverty trap (Donkor et al., 2019). However, in SSA, the use of mineral fertiliser is negligible with the consumption ratio being 0.03:0.97 when compared to total world mineral fertiliser consumption (Kelly, 2006; Lambrecht et al., 2015). In such a setting of trivial mineral fertiliser application, it is expressly imperative to empirically unravel the drivers of preference, choice and intensification decisions so as to inform better on diffusion and adoption.

The crux is in the use of the fertilisers, not the fertilisers themselves. There exists a depth of antagonising messages on mineral fertiliser application and its long-term implications on soils health among rural smallholders (Vanlauwe & Giller, 2006). These myths need to be countered for effectual role of research and science in achieving the main goal of supporting smallholders to tackle the dire hitches of soil fertility loss especially in the drylands. Fertiliser, preferably combined organic and inorganic when applied in the recommended amounts and appropriate fertiliser type can have a boundless and progressive sustained impact on crop growth and food production (Ogada et al., 2014). Contrariwise, uniformed fertiliser application patterns may become a cause of soil degradation. Proper fertiliser recommendation should consider three distinguished objectives namely; maximum capacities in yield level, rate of return and crop response that is utmost yield response per amount of fertiliser applied (Smil, 2011). In addition, for most developing countries the fourth objective when recommending mineral fertiliser is to attain the highest adoption level possible (Vanlauwe et al., 2014).

According to literature, there are several factors that impinge sustainable adoption and application of mineral fertilisers in the developing countries (Kassie et al., 2013; Pircher et al., 2013; Teklewold et al., 2013). Citing back the adopters’ theory, only 15 percent of the population can be regarded as innovators and early adopters and the theory explains that 100 percent adoption will never be achieved because of different farmer realities and intrinsic characteristics such a personality among others (Rogers et al., 2014). In addition, an enabling environment is a prerequisite for mineral fertiliser adoption (Pircher et al., 2013). This factor contains the tools, skills and the extent to which farmers are motivated and supported to access the inputs and utilize them.

2.4 Preference, choice and use intensity of agricultural technologies

Agricultural technology preference has widely been examined for various aspects. For example, farmers' preference for various technology characteristics so as to offer better pointing of resources in best possible adaptation strategy. Wale & Yalew, (2007), following the empirical analysis, attributed low uptake of agricultural innovations to the incongruity between the consumers "farmers'" felt needs and the inherent characteristics of innovations disseminated. The findings revealed that resource poor smallholders preferred coffee seeds malleable to their environments and varieties with steady yields attributes and marketable. A variety of literature has adopted dissimilar methodologies in measuring stated preferences for technologies and technology attributes. For instance, Murage et al. (2010) employed weighted score index and ordered probit regression to sequentially rank information dissemination pathways and determine the probabilities of farmers ranking the pathways differently. On the other hand, Blasch et al. (2020) adopted choice experiments to elicit farmers' willingness to adopt precision farming technologies as well as their preferences for specific attributes such as increased yields, reduced fertiliser input and improved ground water quality. These studies demonstrate the importance of policy-makers formulating context specific technology developments.

Past studies have conceptualized choice as a binary variable where a farmer either choses to use a certain technology or not (Chianu & Tsujii, 2004; Belachew et al., 2020). Empirically, many studies analysing the determinants of choice have employed a wide range of econometric models in determining factors influencing choice decisions. For example, Mango et al. (2017) employed the logit models to examine the factors that influenced farmer’s knowledge and choice of land conservation strategies. The study revealed that, age of the household head years of schooling, agricultural extension reception and participation in farmer organizations and groups, acreage of land owned and land-to-man ratio to be critical in raising awareness and choice decisions. Similarly, Mugwe et al. (2009) adopted the logistic regression models in evaluating the determinants of decision to adopt integrated soil fertility management options in the Central Highlands of Kenya. The results revealed that farm management, hired labour, and household food security status positively and significantly influenced adoption.

On the other hand, age of household head and total livestock units (cattle) negatively influenced adoption. Also, the probit models have been adopted extensively in literature in estimating choice decisions. Ndiritu et al. (2014) employed a multivariate probit to investigate differences in adoption of sustainable agricultural intensification with regard to gender and reported that differences in use of some technologies do exist among male and women farmers. The model revealed that women farmers had higher likelihood of using maize-legume intercropping, and largely unlikely to choose minimum tillage and apply animal manure when compared to men. Further, the results indicated that choice of agrarian innovations is dependably driven by land and household characteristics such as size, ownership and headship, fertility status, access to extension services, availability of credit and age of the farmer.

Technology use intensity has been measured distinctively in literature. Many studies have conceptualized use intensity as the level of application of a given innovation. For instance, some studies theorized use intensity as the land size under improved seeds or amount of fertilizer applied per acre (Feder et al., 1985). Other studies define use intensity as the degree or extent of application of a technology. Nkoya et al. (1997) measured use-intensity as the land size under improved seeds. Mensah-Bonsu et al. (2017), defines use-intensity as the number of technologies a farmer is using. Other researchers conceptualize use-intensity as the proportion of land under improved crop varieties (Asfaw et al., 2011; Nchinda et al., 2010). Count econometric models have been widely employed in determining the drivers and probabilities of technology use intensity. For example, Mwaura et al. (2021) employed the Tobit model Tobin, (1958) to estimate the effects of socioeconomic characteristics on use-intensity of organic-based innovations among smallholders. The model results revealed that socioeconomic characteristics were important determinants influencing use of organic-based technologies intensely.

Lambretch et al. (2014) employed the Heckman model Heckman, (1979), to empirically examine the determinants of mineral fertiliser intensification among smallholder farmers in Congo. The study revealed that drivers of agrarian innovations use and use-intensity have different impacts on the different stages in the adoption process. On the other hand, double hurdle models Cragg, (1971), have been employed in explaining determinants of technology intensification. For example, Gebre et al. (2019) used the double hurdle approach to determine the gender differences in adoption of improved maize varieties in Ethiopia. The results revealed use-intensity of improved maize varieties was lower among women farmers when compared to male farmers. The wide application of econometric models in measuring technology use intensity as adopted in literature can be explored with key note on the nature of the explained variable observing that different count models estimate the effects on the limited variable distinctively.

2.5 Determinants of choice and use intensity

Notably, a wide-ranging body of literature has reported on the drivers of agrarian innovations and use intensity (Beshir &Wagary, 2014; Asfaw & Neka, 2017; Zeng et al., 2018). For example, Feder et al. (1985) found socioeconomic aspects, technology attributes and institutional factors to influence farmers’ decision to use agricultural innovations as well as the intensification of the technology at the farm level. The farm and farmer characteristics that can potentially influence choice and use intensity decisions include age, education attainment, gender, household size, farming experience, farmer’s perceptions towards the specific technologies attributes, soil fertility status and soil water holding capacity, size of the farm, total cultivated land, ownership of key productive resources, access to key institutions and services.

Age of the farmer is presumed to positively or negatively influence choice and agricultural technology use-intensity. Many studies have reported that the probability of choosing and using soil and water conservation practices intensely is higher among younger farmers as compared to ageing farmers (Asfaw & Neka, 2017). Conversely, other studies have found age to positively influence choice of soil management practices (Adesina & Forson, 1995). This was largely attributed to older farmers being more risk averse and experienced in farming and with better ability to access the characteristics of modern technologies than younger farmers. Related to age, years a farmer has been involved in making key farming decisions has been found to have mixed effects on choice and use-intensity of agricultural innovations. More experienced farmers are reputed to have a better knowledge of conservation agriculture hence a higher likelihood of adopting soil and water conservation technologies (Knowler & Bradshaw, 2007). Conversely, veteran farmers may resolve to opt out from farming for other off-farm undertakings with more returns.

Household size designates the number of people living in a household. An important factor influencing use of labour-intensive agricultural technologies. Larger households have more human capital in terms of labour employed in application of labour demanding soil and water conservation technologies (Belachew et al., 2020). Predominantly, the majority of labor for most farming activities in SSA is entirely provided by the family members and more so females and this may constrain preference, choice and use of labour demanding agricultural technologies intensely. Nonetheless, part of larger households may opt out from farming activities in an attempt to diversify their income to ease the consumption budget imposed by higher food demand in larger households (Wekesa et al., 2018).

Education has been found to positively and negatively influence utilization of agrarian innovations. Many studies conceptualize education as the years of schooling or the levels attained (Wekesa et al., 2020). Educated farmers are presumed to be more informed on soil water conservation technologies application modalities and hence being more receptive to new and improved technologies (Mango et al., 2017). Contrariwise, educated farmers may opt out from farming for off-farm activities that are more rewarding (Alwang et al., 2019).

Access to extension services and contact with development agents with farmers play a great role in creating awareness on soil and water conservation technologies (Mponela et al., 2016). Many studies have hypothesized access to extension to positively and significantly influence zai technology choice and use-intensity (Awotide et al., 2016; Wekesa et al., 2020). Similarly, participating in farmer trainings increases farmers' knowledge of soil and water conservation technologies, hence positively influencing choice and use-intensity of soil and water conservation technologies (Okeyo et al., 2020).

Ownership of key productive assets for example livestock, land, farm implements and farm machinery and credit facilities is assumed to increase the likelihood of taking up new agricultural innovations. Livestock densities are an essential factor in explaining adoption of conservation agriculture technologies at household level (Ndiritu et al., 2014). This can be attributed to livestock providing manure that is a key input in conservation agriculture. In addition, livestock also provide animal drawn labor and also a source of income. Land ownership is an indicator of secure land tenure system and increases the likelihood of farmers adopting long-term agricultural innovations (Awotide et al., 2016). In addition, total land owned and cultivated is often correlated with farm income and wealth. Therefore, farmers with large farm size could have the ability to pay wages while undertaking soil and water conservation. Moreover, farmers with large farm size have the flexibility of experimenting with new technologies (Thinda et al., 2020). Also, technology adoption likelihood is positively driven by access to and ownership of farm implements (Melesse, 2018). Farmers with access and the ability to timely access and hire farm hands have a higher probability of adopting soil water management innovations, among other agricultural technologies that are labour demanding (Mugwe et al., 2009; Teshome et al., 2016).

On the other hand, institutional factors are important determinants of choice and use of agricultural technologies intensely. Farmers receiving relief in form of inputs, farm implements or cash from the government and other development agencies act as incentives to technology adoption. Awotide et al. (2016) found that farmers who had received relief in the form of improved seeds largely commercialized rice production in Nigeria as compared to those who did not receive the support. Group membership which tends to create social capital increases the likelihood of adopting agricultural innovations (Kassie et al., 2014). Besides, agricultural development agencies who work closely with farmers' in disseminating the technologies to target groups have higher success rates. Access to agricultural credit promotes the adoption of labour-intensive climate-smart innovations, among other technologies, that require high initial investment capital (Obisesan et al., 2016; Yigezu et al., 2018). Selling farm output is a proxy of farm income and positively predicts choice and use-intensity of soil and water conservation technologies (Kuehne et al., 2017). This is attributable to the increased ability of the farmer to purchase inputs and also hire labour. Distance to produce and input market may positively as well as negatively influence choice and use-intensity of agricultural technologies (Muriithi et al., 2018; Wekesa et al., 2018). Proximal access to markets lowers the transactional costs incurred during transportation of inputs to the farm and outputs to the markets.

Intrinsic farmer characteristics such as attitudes and perceptions towards conservation agriculture influence adoption patterns of soil and water conservation strategies. Additionally, farmers’ perspicacity is deliberated as distinctive influence on new technologies choice decisions (D’Antoni et al., 2012). For example, farmers perceiving soil erosion to be more severe has been found to positively influence the likelihood of using soil and water conservation technologies (Biratu & Asmamaw, 2016). This was attributed to severe soil erosion increasing nutrient and surface water loss hence the need for application of soil and water practices that reduce surface runoff. Also, farmers perceiving their soils as infertile have higher likelihood of using soil fertility enhancing and conservation strategies (Belachew et al., 2020).

2.6 Gender integration in agricultural technology uptake

At the household level, understanding technology choice patterns is very important when up-scaling use of successful agricultural interventions. Empirical studies have extensively examined gender difference in agrarian innovations choice using sex of the household head as the gender indicator (Gebre et al., 2019; Lambretch et al., 2016). Despite evidence from gender analysis studies suggesting that when women farmers have a larger role in decision-making and control of productive assets, household wellbeing improves (Doss, 2014), gender gap in agricultural technology use persists in developing countries. 43 percent of unindustrialized labour in emergent nations comes from women, producing about 80 percent of locally consumed food in Africa (Palacios-Lopez et al., 2017). Also, studies analyzing gender integration in agriculture have highlighted gender gaps in asset ownership, education, access to a credit facility and extension trainings, which constrain women farmers agricultural productivity (Quisumbing et al., 2014; Sell & Minot, 2018). An implication is that, gender gap in agriculture may have long term inferences both at households economic welfare and agricultural technological progress (Kantor et al., 2015; Manfre et al., 2013).

Recent studies consider technology choice and use intensity decisions jointly made by men and women in the same household (Diiro et al., 2018; Gebre et al., 2019; Muriithi et al., 2018). Additionally, in the recent literature, joint farm management and decision making has been reported to positively drive technology use at household level (Lambrecht et al., 2016; Marenya et al., 2015). Contrariwise, other studies reported that there is no gender disparity in agricultural technology utilization (Muriithi et al., 2018). Moreover, gender is a factor of influence to farmers’ perceptions on uptake of new technologies as women and men experience their social, economic, cultural and environmental realities (Obiero et al., 2019). Therefore, household resource endowment among other socioeconomic characteristics and farmer intrinsic attributes are key factors when assessing gender effects on uptake of new technologies.

2.7 Gaps in literature review

Extensively, literature has covered the possible impacts of soil fertility loss and soil water stress on agricultural production especially in the drylands (Bradford et al., 2017; Bradford et al., 2019; Issahaku & Abdul-Rahaman, 2019). These studies generally indicate that smallholder farmers have the choice of addressing soil moisture stress and soil fertility loss by implementing climate smart options. Much of the literature on soil and water conservation has drawn consideration to a variety of factors driving choice and use intensity of such strategies by smallholders (Mango et al., 2017; Wekesa et al., 2018; Thinda et al., 2020). However, a lot of these literature merely disaggregate households, farm characteristics and institutional services as key technology uptake drivers with respect to gender. Therefore, there is dearth of information on the preferred technology attributes and drivers of choice and use intensity among men and women farmers. Further still, many studies targeting promotion of soil and water conservation consider gender as a demographic indicator, which may not evidently reveal household's characterisation with regard to adoption drivers. This study therefore focused on undertaking a gendered household and farm level analysis on the preference, choice and use intensity of soil and water conservation strategies.

2.8 Theoretical framework

The study followed random utility maximization theory, which postulates that, a rational farmer will choose a given innovation or a bundle of innovations if the benefits derived from their choice exceed the benefits derived from not choosing (Feder & Umali, 1993). The utility *(u)* that an individual *(m)* gains from utilizing *(n)* soil and water conservation technologies can be defined by Eq 2, where (v) is the utility determinants and ($\mathcal{E}$)is the error term.

$$u_{mn} = v_{mn} + \varepsilon_{mn} \tag{2.1}$$

The assumption is that (u) depends on individual preferences from a package of (n) soil and water management alternatives Cascetta (2009). Thus, the utility function can further be expressed as Eq 2.2.

$$u_{mn} = V(x_m, z_n) \tag{2.2}$$

x_m is the soil and water conservation strategy, and z_n are farmers' desired technology-specific attributes and farmer characteristics.

A farmer with the intention of maximizing present farm productivity through increased soil and water conservation will select preferred strategy among a set of (n) soil and water conservation innovations. The choice of innovation (n) is dependent on expected higher benefits when compared to other innovations (q) ; if $u_n >. \, u_q$. Among other factors, specific characteristics of an innovation influence levels of satisfaction an individual derives from utilizing an innovation. Chances that an individual (m) will choose innovation (n) from a set of selected innovations (q) could be defined by Eq 2.3.

$$p\left[(v_n - v_q) > u\right] + \mathcal{E} \tag{2.3}$$

Variations in choice are accounted for by a random element ($\mathcal{E}$), included in the utility function.

2.9 Conceptual framework

Figure 2.1 shows the conceptual framework which explains the link between key variables and the problem. Identifying gendered preferences for technology attributes and understanding of the effects of socio-economic characteristics driving choice and use intensity of soil management options promotes development and use of gender friendly soil and water management technologies intensely leading to improved agricultural productivity. Farmer specific needs with regard to technology and their intrinsic characteristics (perceptions) are intervening in the framework to influence the preferences, choice and intense application decisions of soil and water conservation strategies. Improved soil fertility and soil water conservation is indicated as a responsive measure to low agricultural productivity.

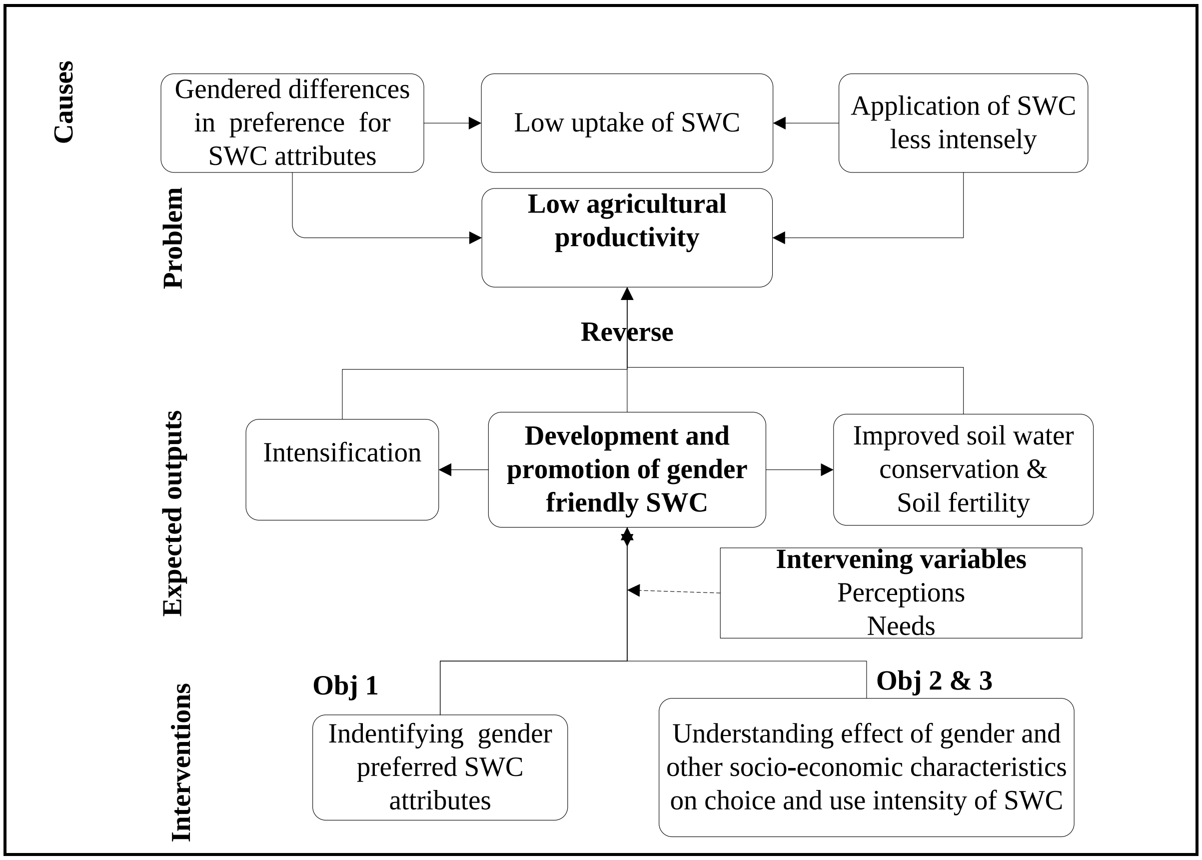

Figure 2. 1 Conceptual framework

2.10 Operationalizing variables

2.10.1 Choice of dependent and independent variables

Choice of variables was guided by relevant theories and past studies (Feder et al., 1985; Chianu & Tsujii, 2004; Belachew et al., 2020). However, some variables were selected with regard to theorized relationship with the explained variable (Table 2.1). Studies included in the choice of variables demonstrate that farm characteristics and farmer attributes mostly influenced choice and use-intensity of agricultural innovations (Kassie et al., 2014; Mango et al., 2017; Thinda et al., 2020). The influence of these variables was tested in the empirical models.

The first stage dependent variable was a dummy variable (whether a farmer chose to use zai technology or not). Similarly, for mineral fertiliser choice, the first stage dependent variable was a dummy variable (whether a farmer chose to use mineral fertiliser technology or not) (Table 2.1). It takes the value of 1 if yes and 0 otherwise. The second stage dependent variable was a continuous variable and defined as the proportion of cultivated land (ha) dedicated to zai technology and fertiliser application rates (kg ha^{-1}). Past studies have conceptualized intensification as the area of land in hectares planted with improved seeds, fertilizer application rate per acre and number of technologies adopted (Feder et al., 1985; Nkonya et al. 1997; Mensah-Bonsu et al. 2017). Additionally, other studies conceptualize use-intensity as the amount of land under a technology (Nchinda et al., 2010; Asfaw et al., 2011).

Table 2.1 Descriptions and units of measurement of hypothesized variables

Variable	Variable description and measurement	Expected sign
Dependent variables		
Zai technology choice	Household head decision to use zai technology is a dummy variable: 1=Yes; 0=Otherwise	
Zai use-intensity	Proportion of total cultivated land allocated to zai technology in hectares (continuous)	
Fertiliser choice	Household head decision to use mineral fertiliser is a dummy variable: 1=Yes; 0=Otherwise	
Fertiliser use-intensity	Mineral fertiliser application rate (Kg/ha) (continuous)	
Independent variables		
HHAGE	Age of the household head was measured in years (continuous)	-
HHEDUC	Education of the household head was measured in years of decision making (continuous)	+/-
HHSIZE	Household size was measured in number (continuous)	+
EXTENSION	Access to extension services is a binary variable: 1= Received extension; 0= otherwise	+
LIVSTCK	Livestock densities was measured in number (continuous)	+
PERCSOILERSN	Perception on soil erosion is a dummy variable:1= Not severe; 2= Moderate; 3= Very severe	+
FAMEXP	Household head farming experience is a continuous variable measured in years	+
MKTDST	Distance in walking to the nearest input/output market (continuous)	-
LAND	Total land cultivated is a continuous variable measured in hectares	+/-
CREDIT	Access to credit is a binary variable: 1= Household head received credit; 0= Otherwise	+
TRAINING	Farmers training is a binary variable: 1= Household head received training; 0= Otherwise	+
GRPMBR	Group membership is a binary variable:1= Farmer had group membership; 0=Otherwise	+
LANDOWN	Land ownership is a binary variable: 1= Ownership with a formal title deed; 0=Otherwise	+
LABOUR	Access to timely labour is a binary variable: 1= Farmer had access to labour; 0=Otherwise	+
FAMIMPLNT	Access to animal-drawn farm implement is a binary variable: 1= access to implement; 0=Otherwise	+
RELIEF	Access to relief is a binary variable: 1= Farmer received relief; 0=Otherwise	+
SELLOUTPUT	Selling output is a binary variable: 1= Farmer sold output; 0=Otherwise	+
PERSOILFERT	Perception on soil fertility status is a dummy variable: 1= Fertile; 0=Otherwise	+

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Description of the study area

The study was conducted in Tharaka Nithi County, Kenya, covering three wards in Tharaka South sub-county: Chiakariga, Marimanti, and Nkondi (Figure 1). The sub-county covers about 637 km^2 with a population of 75,250 persons, and a population count of approximately 118 persons per square kilometre (Kenya National Bureau of Statistics, 2019). The Agro-Ecological Zones (AEZs) covering the area range from the wetter Lower Midland (LM)4 to the drier Intermediate Lowland (IL)6 (Jaetzold et al., 2007). The area receives bi-modal rainfall: March-May "long rains" and October-December "short rains" (Jaetzold al., 2007; Recha et al., 2012). The annual rainfall amount ranges from 1100 mm in the LM4 to less than 800 mm in the IL6. Farmers in the region prefer the October-December season for its reliability and accurate predictability. The annual temperature ranges from 21 to 25 ℃ (Smucker & Wisner, 2008). Shallow, highly weathered, and leached Ferrasols are the main soils in Tharaka South sub-county (Jaetzold et al., 2007). As a semiarid sub-county, rainfall is highly variable, affecting the community livelihood strategies, which is primarily agro-pastoralism (Smucker & Wisner, 2008; Recha et al., 2012). The sub-county's erratic rainfall has contributed to wide variability in crop and livestock production, escalating poverty levels and overdependence on relief from government and development agencies (Muriu Ng'ang'a et al., 2017; Kimaru-Muchai et al., 2020). Ongoing development efforts in the area along with devolution target diversification of livelihood options that are responsive to climate change. The choice of the sub-county was guided by earlier research efforts in the area and the understanding that being a semiarid area, livelihood options are limited and vulnerability levels differ across gender and households.

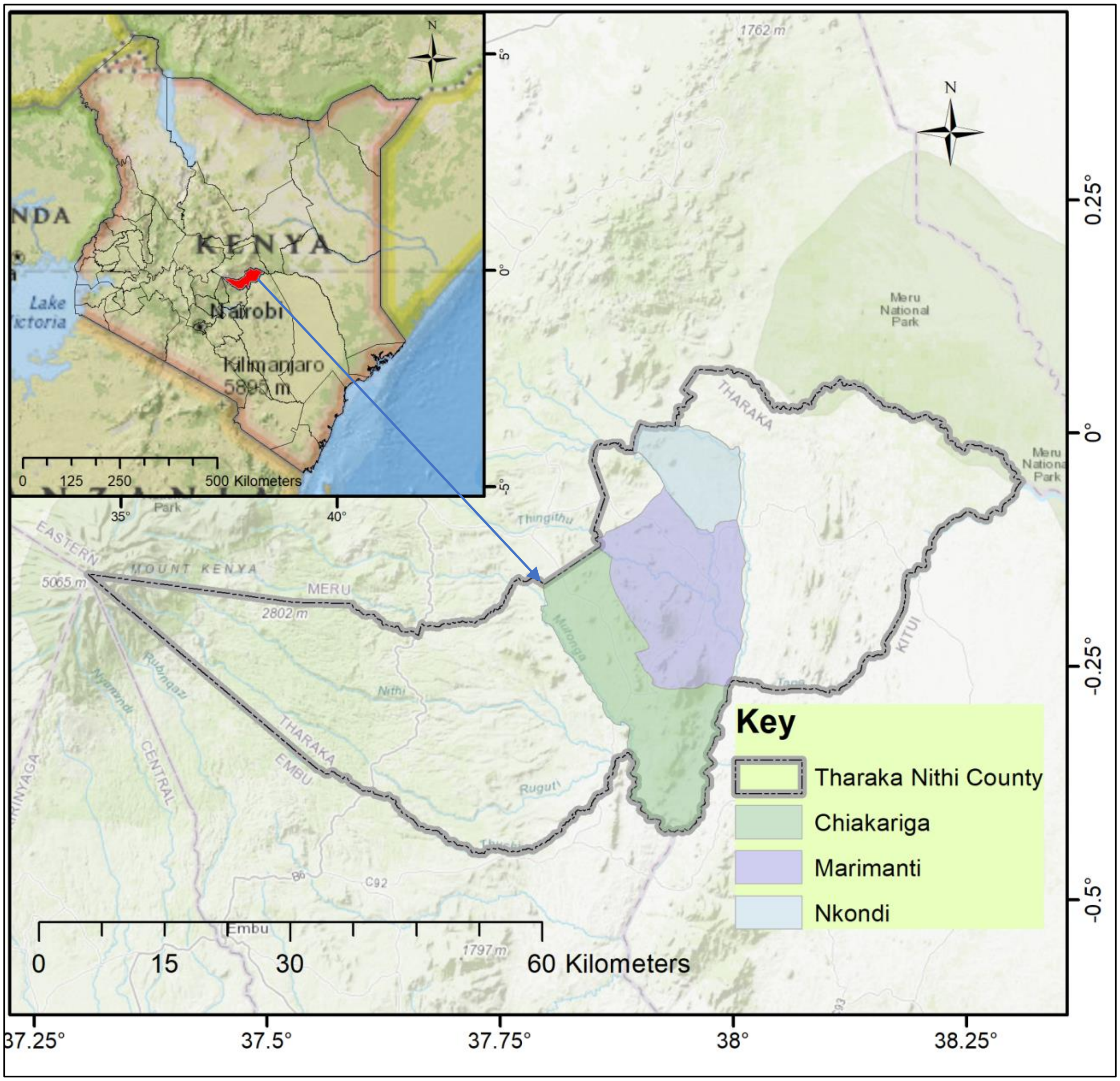

Figure 3.1 Map of the study area

3.2 Research design

The study applied mixed-methods approach to collect two sets of data; qualitative and quantitative data. Quantitative and qualitative approaches in combination provides better understanding of research, and complex phenomena than either of the approaches alone (Timans et al., 2019).

3.3 Target population and sample size

The target population comprised the smallholder farming households. The sample size was determined using Cochran (2007) formula (Eq 3.1) as given below:

$$n = \frac{Z^2 \, pq}{d^2} \approx \frac{1.96^2 * (0.5) * (1-0.5)}{0.049^2} \approx 400 \qquad (3.1)$$

Where n = sample size, Z= 1.96 the standard normal deviate at the required confidence level, p = (0.5) the proportion in the target population estimated to have the characteristic under observation, q =1-p =0.5 = the proportion of the population without the characteristics being measured d = 0.049 = the desired level of precision. In total, 400 farmers were sampled.

3.4 Sampling strategy

Sampling units for quantitative data were drawn using multistage sampling procedures. Tharaka South Sub-county was pre-defined because farmers in that region were already implementing soil and water conservation. In the second stage, all the three wards (Chiakariga, Marimanti and Nkondi) (Fig 3.1) in the Tharaka South sub-county were selected using a sampling framework. In the third stage; at ward level, sample households were randomly selected. A list of 4,000 farmers was obtained from Tharaka South Sub-county agricultural office. The basic element in the sampling frame was the farm household. A probability proportional to size sampling technique was employed to determine the number of households sampled per ward (Table 3.1). A sample of 400 farming households was randomly selected. Random numbers were generated to reduce the chances of sample selection bias.

The second set of data was collected in two sex-separated Focus Group Discussions (FGDs) and one mixed (men and women) FGD in each of the three study wards (Table 3.1). A total of 36 respondents were purposively sampled to participate in the three FGDs. Sampling of participants was carried out with the assistance of agricultural extension officers and service providers working for development agencies in the region. Selection criterion was based on gender, age, perceived levels of knowledge, participation in farmer group activities implementing conservation agriculture and leadership in community organizations.

Table 3.1 Sampled wards and their number of respondents

Ward	Male-headed households	Female-headed households	Total	FGDs
Chiakariga	117	67	184	12
Marimanti	97	38	135	12
Nkondi	53	28	81	12
Total	267	133	400	36

FGDs represents Focus Groups Discussions

3.5 Data collection methods and instruments and ethical considerations

Before the actual data collection exercise, an exploratory survey was conducted in all the study wards in Tharaka South sub-county, during which primary data was collected to understand the major livelihood strategies, household socioeconomic profiles and soil water conservation practices farmers were implementing in the area. Informal discussions with model farmers and key informants (extension agents) were conducted to provide more insights on soil and water conservation strategies practiced in the region.

A check list was used to seek information from FGDs participants. The choice of questions facilitated spontaneous opinions and avoided restrictions. The discussions were facilitated in Swahili and where necessary translation was done in the local language. The purpose of FGDs was to generate more in depth information on gendered preference for soil and water conservation technologies.

At the household level, the interviewer administered questionnaires with modules on farm and farmer's socioeconomic characteristics. Institutional factors were used to collect quantitative data in a cross-sectional survey. The tool was programmed into an electronic format using Open Data Kit (ODK) software and sufficiently pre-tested for reliability and validity and corrected for errors. Trained enumerators were used in administering the questionnaires.

All participants gave informed consent to their involvement and were aware that they can withdraw their consent at any point.

3.6 Data processing and statistical analysis

Livestock densities were determined for each unit following Musafiri et al. (2020). For every cow, sheep, goat, and chicken, Total Livestock Unit (TLU) of 0.7, 0.1,0.1, and 0.01, was assigned respectively. Area of land was converted to hectares. Secondly, data was cleaned, organized in Microsoft Excel, and analysed using STATA and SPSS softwares'. The analyses disaggregated the results by sex of the household head based on key indicators of the study. Chi-square and t-test were used to test statistical relationships for categorical and continuous variables respectively. Comparisons were made between zai technology and mineral fertiliser users and non-users in male-headed households and female-headed households. Heckman's two step selection model was employed in estimating the determinants of zai technology and mineral fertiliser choice and use-intensity.

3.7 Model diagnostics

Preliminary diagnostics were conducted for statistical problems of multicollinearity. Inter-correlation among dependent variables was tested using the Variance Inflation Factor (VIF). The VIF values obtained were below 10, hence the conclusion that, their existed weak inter-association among the explanatory variables. To validate Heckman's 2-stage selection model viability, golden standards in applying the model were observed. Inverse Mills Ratio (Lambda), a function of the correlation coefficient between first and second stage error terms (rho) that accounts for potential sample selection bias was significant; an indication that sample selection bias was resolved for (Wooldridge, 2010; Certo et al., 2016). Therefore, the study concluded that Heckman 2-stage model was sufficient in determining zai technology choice and use-intensity from the sample.

3.8 Methods of analysis

3.8.1 Objective one: Gendered preference for technologies attributes

To determine the soil and water management technologies preferred attributes by gender, farmers were asked to list attributes of specific soil and water management technologies from a list of soil and water management technologies characteristics. The list of attributes was generated in FGDs with a random sample of farmers prior to the household survey. Most frequently mentioned positive attributes were; ability of the technologies to increase soil fertility, conserve soil water, increase economic returns (yields) and availability of sufficient extension information and trainings on the technologies application modalities. On the other hand, negative attributes that were frequently mentioned were labor intensive and high input cost associated with soil and water management technologies.

Farmer’s stated preferences for the attributes were scored in a ten-point scale where, 0 was the least score and 10 was the highest score. A t-test was run to determine if there were significance differences between the average scores of each attribute with respect to gender of the household head. For each household type, one-way Analysis of Variance (ANOVA) was used to determine whether there was statistical evidence that the associated attributes average scores were significantly different. Tukey’s honestly significant difference test was used to compare all possible pairs of means.

Qualitative data was transcribed and translated into generative themes “salient recurrent ideas” in evaluating whether and how the research illuminated the research questions. The analytical process entailed reducing the volumes of information “narratives”, sorting out significant facts, identifying patterns and trends and constructing a framework for a plausible and coherent interpretation. Themes were coded to create order out of the different patterns of transcribed participants’ narratives. The data was reduced into small manageable set of themes.

3.8.2 Objective two and three: Examining the determinants of choice and use intensity of selected technologies

3.8.2.1The analytical framework: Heckman's two-step procedure

To determine the choice and use intensity of the selected soil and water conservation technologies, the study employed the Heckman's two step selection model to obtain unbiased estimates at the second stage (use intensity) of decision making. In the Heckman's selection model, we presumed that, sample selection bias existed necessitating unbiased estimation in the second stage (use-intensity) (Jaleta et al., 2013; Lambrecht et al., 2014; Rabbi et al., 2019). Furthermore, when employing the Heckman's selection model, the assumption is that choice and use-intensity are not determined with exactly a similar set of dependent variables. In this study, frequency of training and farmers' perceptions of soil fertility were the identifier variables that only influenced the first stage (probability of choice) but not the second-stage (use-intensity) of the selected technologies.

A two-step estimation procedure was followed. In the first step, we estimated the probability of choice and obtained the Inverse Mill's Ratio (IMR). The IMR was incorporated in estimating the second step as a remedy for sample selection bias. Heckman's model is anchored on two latent variables (Heckman, 1979). The first step expressed as a hypothetical construct, Z_i^*, representing the choice in our study, and hinges on a set of independent variables, W_i, as given in Eq 3.2.

$$Z_i^* = W_i'\alpha + \mathcal{E}_i \tag{3.2}$$

Where, α denotes a k-vector of the independent variables, and $\mathcal{E}_i$ represents the error term.

Hypothetical variable (Z_i^*) is not observed, however, we observe a dichotomous variable (Z_i) whether a farmer was using zai technology or not. Then, the binary variable is given in Eq 3.3.

$$Z_i = \begin{cases} 1, \ if\ Z_i^* > 0 \\ 0, otherwise \end{cases} \tag{3.3}$$

The second equation is linear representing the use-intensity (Y_i), and is given by Eq 3.4.

$$Y_i = X_i'\theta + u_i \tag{3.4}$$

Where, θ is a k-vector of the explanatory variables, and u_i is the error term.

The error terms $\mathcal{E}_i$ (selection equation) and u_i(outcome equation) are independent of α and θ.

The use-intensity Y_i is observed when a farmer is using zai technology ($Z_i = 1$), prompting inconsistent and biased parameter estimates using Ordinary Least Square (OLS). To correct for the inconsistencies in parameter estimates, the following conditional regression function is used (Eq 3.5):

$$E = \left(\frac{Y_i}{Z_i} > 0\right) = X_i'\theta + \theta_\lambda + \lambda_i \qquad (3.5)$$

Where λ_i is the IMR and given as (Eq 3.6):

$$\lambda_i = \frac{\phi W_i'\alpha}{\varphi W_i'\alpha} \qquad (3.6)$$

Where ϕ is the standard normal, probability density function and φ represents the cumulative distribution function for a standard random variable. Lambda is unknown, nevertheless, the variables α can be assessed in a probit model with regard to the observed binary outcome (Z_i).

In estimating the second stage, IMR, $\lambda_i = \frac{\phi W_i'\alpha}{\varphi W_i'\alpha}$ is interleaved into outcome equation as independent variable and given as (Eq 3.7).

$$Y_i = X_i'\theta + \theta_\lambda \lambda_i + u_i \qquad (3.7)$$

This gives rise to self-selection bias when θ is non-zero. To avoid self-selection bias and obtain consistent estimators, the model parameters were estimated using the maximum likelihood criterion.

3.8.2.2 Empirical model specification

In Heckman's selection model, the first step dependent variable was dummy in nature (whether a farmer was using zai technology or not); (whether a farmer was using mineral fertiliser technology or not) and was explained using a set of independent variables, namely age, education, household size, off-farm income, total land cultivated, land ownership, access to farm implements, livestock densities, perceptions on soil fertility and soil erosion, farmer training, group membership, access to relief, frequency of training, the number of groups, household head received credit, access to labour, distance to main market and frequency of extension services. The algebraic representation of Heckman's probit selection model was given in Eq 3.8.

$$Z_i = \alpha X_i + \cdots + \alpha X_n + \mathcal{E} \tag{3.8}$$

Where:

Z_i= the decision of the ith farmer to use zai/mineral fertiliser technology.

X_i= the vector of independent variables of probability using zai/mineral fertiliser technology by the ith farmer.

α= the vector of the parameter estimates of the explained variables hypothesized to effect the chances of ith farmer choosing zai technology/mineral fertiliser.

In Heckman's outcome model, the dependent variable was continuous (proportion of cultivated land under zai/mineral fertiliser technology). It was also explained using a set of relevant independent variables, namely age, education, household size, off-farm income, total land cultivated, land ownership, access to farm implements, livestock densities, farmer perceptions on soil erosion, access to training, group membership, access to relief, number of groups, household received credit, access to labour, distance to main market and frequency of extension (Eq 12):

$$Y_i = \theta X_i + \cdots + \theta X_n + u_i \tag{3.9}$$

Where:

Y_i = area of land under the technology (zai or mineral fertiliser)/ Total area of land cultivated

X_i= the vector of independent variables of zai/mineral fertiliser technology by the ith farmer use-intensity

θ= the vector of the parameter estimates of the independent variables conjectured to effect the outcome stage.

CHAPTER FOUR

RESULTS

4.1 Overview

For purposes of this study, male-headed households (MHHs) (267) were those in which husband was present and was the final decision-maker on most activities pertaining to the household welfare. Only *De jure* female-headed households (FHHs) (133) were considered where they are run and represented by a widow, divorced or single woman (Table 4.1). *De facto* female-headed households where the wife assumes headship in absence of a male migrant were not considered due to the temporary nature of household headship, as the husband assumed headship whenever present.

Table 4.1 Demographic characteristics of sample households

	Female-headed households (n=133)	Male-headed households (n=267)	
Variable	Mean	Mean	*T*-test
HH age (years)	47	45	-1.30
Education (years of schooling)	7.41	8.67	2.56**
HH farming experience (years)	19.44	18.60	-0.68
Total family size (number)	5	6	1.97**

** represents 5% significance levels, respectively. HH represents Household Head.

Education varied significantly between male-headed households and female-headed households with men being more educated (Table 4.1). Similarly, total family size was larger in male-headed households.

4.2 Gender differences in soil and water conservation technology use

The soil and water conservation technologies considered were zai technology, use of mineral fertiliser, mulch application/ crop residue retention and legume intercropping. (Table 4.2). The results in table 4.2 revealed that there were no significant differences in use of the selected soil and water conservation technologies in either of the households.

However, the technology use levels for mineral fertiliser (53%) in female-headed households and (52%) in male-headed households and zai technology (44%) in female-headed households and (38%) in male-headed households, were considered low when compared to other technologies (Fig 4.1).

Table 4.2 Household level soil and water conservation technology uptake by gender

	FHHs		MHHs		χ^2
Technology	Users	Non-users	Users	Non-users	
Animal manure	111(83)	22(17)	219(82)	48(18)	0.418
Mulch/crop residue retention	109(82)	24(18)	214(80)	53(20)	0.121
Mineral fertilizer use	70 (53)	63(47)	138(52)	129(48)	0.471
Zai technology	58(44)	75(56)	102(38)	165(62)	0.112
Legume-intercropping	114(86)	44(14)	233(87)	19(13)	0.340

No significant association observed, χ^2 = Chi Square value. % are in parentheses.
MHHs represent Male-headed households, FHHs represents Female-headed households

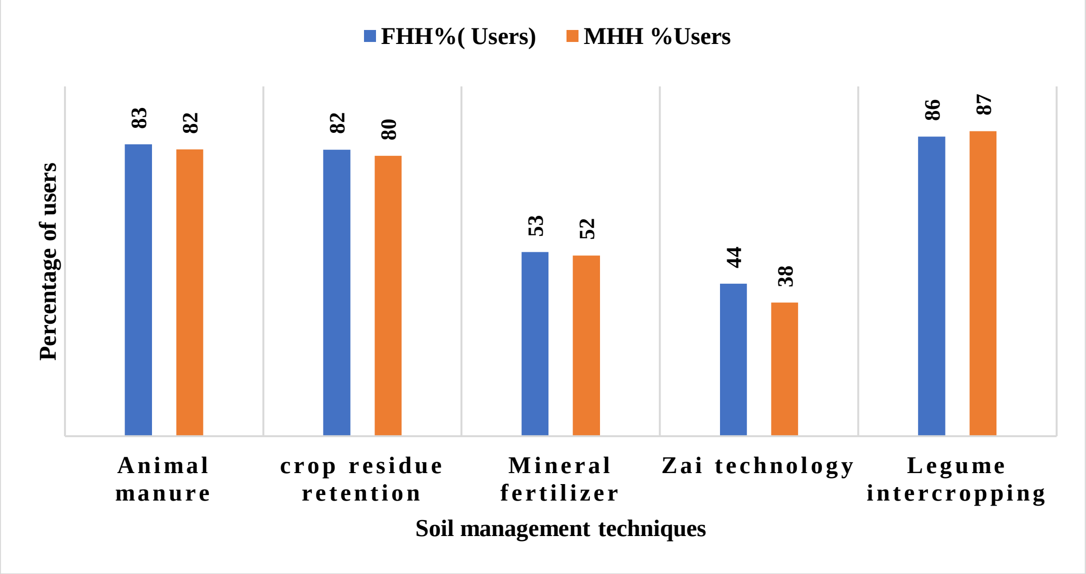

Figure 4.1 Farmers level of usage of soil and water management techniques

4.3 Gender differences in land under technologies

On average, male-headed households have dedicated more land to legume-intercrop 0.92 ha, in comparison to 0.67ha in female-headed households (Table 4.3). A possible implication that, male-headed households own and control more land than do female-headed households.

Table 4.3 Land allocation under different technologies by gender

	FHHs		MHHs		*T*-test
Technology	Mean	Std. Dev.	Mean	Std. Dev.	
Land under animal manure (ha)	0.37	0.34	0.43	0.48	1.53
Land under mulch (ha)	0.62	0.70	0.61	0.65	-0.14
Land under fertilizer (ha)	0.34	0.60	0.38	0.81	0.17
Land under Zai pits (ha)	0.12	0.21	0.11	0.24	-0.24
Land under legume-intercrops (ha)	0.67	0.57	0.92	0.97	3.199**

***, ** and * represents 1%, 5% and 10% significance levels, respectively. MHHs represent Male-headed households, FHHs represents Female-headed households

Largely, trends in land allocation under different technologies depicted that men allocated more land to the technologies when compared to female farmers (Fig 4.2).

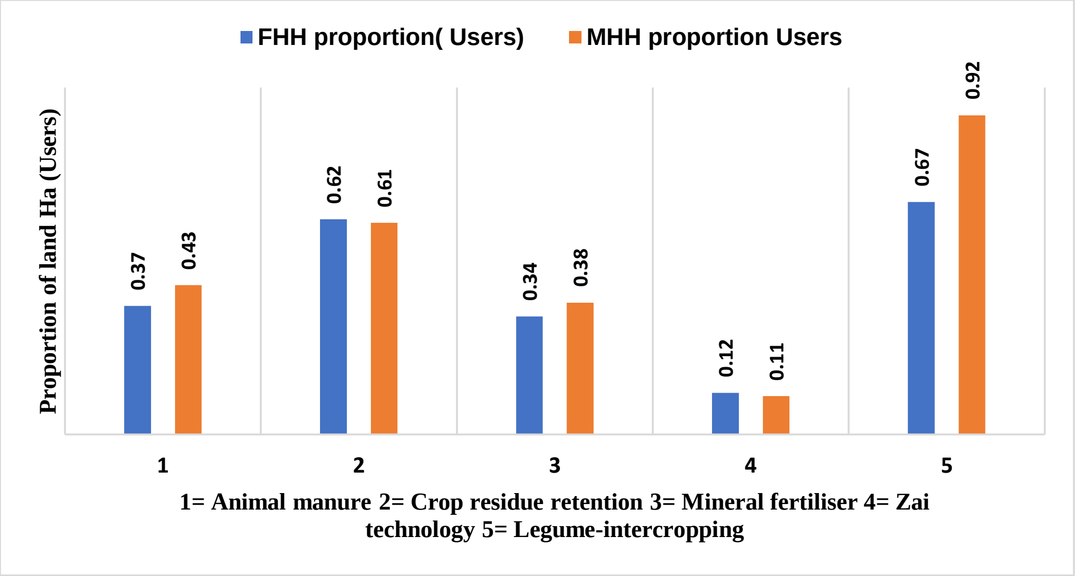

Figure 4.2 Trends in land allocation under different soil management techniques

4.4 Preference for zai technology and mineral fertilizer attributes by gender

Preferences for zai technology and mineral fertilizer technologies attributes were disaggregated by sex of the household head. Gender emerged as a significant determinant of preference for zai technology and mineral fertilizer various specific-attributes (Table 4.4). With regard to zai technology, the results revealed significant differences among male-headed and female-headed households' perceptions on soil fertility improvement and information availability characteristics. On average, female-headed households perceived that zai technology improved soil fertility and information and training on the technology was readily available than did male-headed households. Moreover, ease of application, soil water conservation and soil fertility improvement attributes for mineral fertilizer were perceived differently among men and women farmers. Men indicated more frequently than women that mineral fertilizers were easy to apply, improved soil fertility and improved soil water conservation.

Table 4.4 Farmers perceptions of zai technology and mineral fertilizers attributes

	Zai technology			Mineral fertiliser		
Attributes	MHHs	FHHs	*T*-test	MHHs	FHHs	*T*-test
Ease of application	3.71^{b}	3.57^{c}	0.60	4.55^{c}	3.96^{b}	2.61**
Soil water conservation	4.60^{b}	4.76^{ab}	-0.60	4.33^{cd}	3.89^{b}	1.97**
Soil fertility improvement	4.67^{b}	5.11^{a}	-1.68*	5.31^{a}	4.64^{ab}	2.49**
Labour intensive	3.66^{b}	4.07^{bc}	-1.56	4.34^{cd}	4.21^{b}	0.52
Economic returns (yields)	5.04^{a}	5.26^{a}	-0.81	5.25^{b}	5.17^{a}	0.54
Information availability	3.60^{b}	4.00^{bc}	-1.68*	3.99^{d}	3.87^{b}	0.52
Cost of inputs	4.12^{b}	4.40^{abc}	-1.05	4.19^{cd}	4.11^{b}	0.32
P value	*<0.0001*	*<0.0001*		*<0.0001*	*<0.0001*	

Means with same letter within a column are not significantly different at p = 0.05.

***, ** and * represents 1%, 5% and 10% significance levels, respectively across the column. MHHs represent Male-headed households, FHHs represents Female-headed households

Overall, the results indicate that, within female-headed and male-headed households, the technology attributes were significant determinants of preference at less than 1%. One-way ANOVA results indicated that, the means of the attributes within the households were unequal (p=< 0.0001) (Table 4.4). Further, results show that the most preferred zai technology attributes in female-headed households were the ability to improve soil fertility (5.11) and increase economic returns (5.26) whereas in male-headed households' ability to increase economic returns (5.04) was the most preferred attribute. With regard to mineral fertilizer, within female-headed households, ability to increase economic returns (5.17) was the most preferred attribute while among male-headed households, ability to improve soil fertility (5.31) was the most preferred technology attribute.

4.4.1 Preference for zai technology and mineral fertiliser

Four major themes were important in terms of preference for zai pits and mineral fertilizer (Table4.5). These were; technology awareness, participants' expressions about the technologies, gendered roles in technology use and technology needs and concerns intrinsic to each participant.

Table 4.5 Four themes emerging from the analyses of the qualitative data

	Theme	Description
1	Awareness of selected soil and water management technologies and their benefits.	Both genders reported that they were aware of mineral fertiliser, legume-intercropping, use of animal manure and zai technology and their benefits in soil and water conservation. Largely, they reported that they were using most of the technologies in their farms.
2	Participants expressions about each technology attributes.	With regard to mineral fertiliser the most cited positive technology attribute was ability to improve yields and improve soil fertility. Farmers also frequently cited that mineral fertiliser require high capital (negative attribute). For zai technology its ability to conserve soil water was the most cited positive attribute followed by yields improvement and ability to improve soil fertility. Farmers also noted that zai technology was laborious.
3	Gendered roles and technology use.	Women farmers frequently reported that it was their role to till land and apply the technologies. Men hardly participate in land preparation.
4	Technology needs and concerns intrinsic to each participant.	Women farmers reported that they preferred technologies that improved yields and were less laborious and extension information was readily available. For men, improvement of soil fertility was a key concern when choosing soil and water management technologies.

4.5 Comparison of zai technology users and non-users by gender

Among the interviewed households, (44%) female-headed households and (38%) male-headed households were utilizing zai technology (Table 4.6). On average, within female-headed households, the farming experience was significantly different at 10% level, with non-users of zai technology being more experienced in farming (21) when likened to users (17.28) (Table 4.6). The number of females in male-headed households varied significantly at 5% level, with user households having more females (2.93) as compared to non-users (2.53) (Table 4.6).

Table 4.6 Demographic factors influencing zai technology choice and use-intensity disaggregated by gender of the household head

	Female-headed households			Male-headed households		
	Mean			Mean		
Variable	Non- users (n=75)	Users (n=58)	*T*-test	Non- users (n=165)	Users (n=102)	*T*-test
HH age	48.00	45.16	1.19	45.53	43.73	1.02
Farming experience	21.00	17.28	1.89[c]	18.78	17.71	0.68
Education	7.36	7.48	-0.16	8.41	9.10	-1.18
Household size						
Males	2.19	2.29	-0.41	2.75	2.81	-0.34
Females	2.71	2.79	-0.37	2.53	2.93	2.16[b]

b and **c** represents 5% and 10% significance levels, respectively. HH represents Household Head.

There existed a significant relationship between group membership and choice and use-intensity of zai technology in male-headed households and female-headed households at 1% level. About (53%) of zai technology users in female-headed households were members of a farmer group compared to (47%) non-users. For male-headed households, (46%) users had group membership compared to (54%) of non-users (Table 4.7). Within male-headed households, users and non-users also differed significantly at 1% in levels of participation in farmer training. About (51%) of users participated in farmer training, whereas (49%) non-users participated in training (Table 4.7). Also, results suggest a significant association at 1% level between choice and use-intensity of zai technology and access to extension services among male-headed households (Table 4.7).

Results also showed a significant relationship at 5% level between access to relief and use of zai technology in male-headed households. Some (47%) non-users of zai technology had received government relief compared with (53%) users (Table 4). On average, total landholding significantly differed at 5% level within male-headed households, with users of zai technology having a larger land size compared with non-users (Table 4.5). Similarly, total cultivated land significantly differed within male-headed households at 1% level, with users of zai technology cultivating more land than non-users. Averagely, the frequency of training and extension contacts varied markedly for users and non-users of zai in male-headed households. Users of zai technology had more extension contacts and training as compared to non-users (Table 4.7).

Table 4.7 Socioeconomic factors influencing zai technology choice and use-intensity disaggregated by gender of the household head

Variable	Female-headed households			Male-headed households		
	Non-users (n=75)	Users (n=58)	χ^2	Non-users (n=165)	Users (n=102)	χ^2
Off farm income	22(49)	23(51)	0.21	63(59)	44(41)	0.42
Sell output	64(56)	50(44)	0.88	138(61)	87(39)	0.72
Land ownership	51(59)	35(41)	0.36	107(62)	67(38)	0.90
Soil fertility perception						
Fertile	44(57)	33(43)	0.84	84(61)	54(39)	0.74
Otherwise	31(55)	25(45)		81(63)	48(37)	
Soil erosion severity						
Not severe	14(64)	8(36)	0.26	65(64)	20(36)	0.88
Moderate	59(57)	45(43)		115(61)	74(39)	
Very severe	2(29)	5(71)		15(65)	8(35)	
Participation in trainings	31(51)	30(49)	0.23	59(49)	65(51)	0.00 [a]
Group membership	46(47)	53(53)	0.00[a]	95(54)	80(46)	0.00 [a]
Group leadership	33(46)	39(54)	0.70	66(57)	50(43)	0.15
HH has received relief	14(52)	13(48)	0.59	35(53)	31(47)	0.09[b]
Received credit	19(50)	19(50)	0.35	44(61)	28(39)	0.89
Access to labour	63(56)	49(44)	0.94	138(60)	92(40)	0.13
Access to extension	23(49)	24(51)	0.20	31(37)	52(63)	0.00 [a]
Farm implements	45(52)	41(48)	0.20	123(62)	77(38)	0.86
	Mean		*t*-test	mean		*t*-test
TLU	1.32	1.19	0.49	2.11	2.38	-0.67
Total land holding ha	1.59	1.63	-0.15	1.83	2.30	-2.04[b]
Total cultivated land ha	1.10	1.22	-0.99	1.26	1.75	-3.32 [a]
Frequency of Trainings	1.03	0.97	0.30	0.62	1.28	-3.18 [a]
Number of groups	0.75	1.26	-3.63[a]	0.76	1.13	-3.44 [a]
Frequency of extension	0.45	0.67	-1.29	0.30	0.82	-4.37 [a]
Market distance	56.00	63.02	-0.93	59.42	63.07	2.24

a and **b** represents 1% and 5% significance levels, respectively. % are in parentheses, HH represents household head, TLU represents Tropical Livestock Units

4.6 Determinants of zai technology choice by gender

Table 4.8 shows the Heckman 2-step model results of the determinants of zai technology choice and use-intensity. Findings revealed that, for both gender, land under cultivation significantly determined zai technology choice at the 5% level. A unit change in land under cultivation increased the likelihood of zai technology choice by 12.2% and 6.8% in female-headed households and male-headed households, respectively. Ownership and access to higher-value agricultural farm implement significantly influenced zai technology choice by women farmers at the 10% level. A unit change in access and ownership of farm implements increased the likelihood of choosing zai technology by 15.8% in female-headed households. Membership to a farmer group significantly influenced zai technology's choice in female-headed households and male-headed households at the 5% level. Specifically, group membership increased the likelihood of choosing zai technology by 26.8% and 8.8% among female-headed households and male-headed households, respectively. Within Male-headed households, an increase in agricultural extension access increased the likelihood of selecting zai technology by 5.9%.

4.7 Determinants of zai technology use-intensity by gender

Further, the results indicated that, age of the household head negatively and significantly (= -0.026, p<0.01) and (= -0.019, p<0.01) influenced zai technology use-intensity among female-headed households and male-headed households, respectively. Years of education negatively predicted zai technology use-intensity within female-headed households (= -0.048, p<0.10). The study found a significant and positive relationship with zai technology use-intensity concerning livestock densities within female-headed households (= 0.111, p<0.01). The coefficient of farmers' perception of soil erosion severity was significantly and positively associated with zai technology use-intensity among male-headed households (= 0.250, p<0.10). The study also established a positive and significant relationship within female-headed households (= 0.140, p<0.10) between the frequency of training on conservation practices and zai technology use-intensity.

Table 4.8 Estimated coefficient and the marginal effects of the Heckman 2-stage model on determinants of zai technology choice and use-intensity disaggregated by gender of the household head

	Pooled		Female-headed households		Male-headed households	
	step I	step II	step I	step II	step I	step II
Variable	dy/dx	Coefficients	dy/dx	Coefficients	dy/dx	Coefficients
Age	-0.003 (0.002)	-0.011)^{b} (0.005)	-0.005 (0.004)	-0.026 ^{a} (0.007)	-0.004 (0.003)	-0.019^{a}(0.006)
Education	-0.009 (0.007)	-0.042 ^{b} (0.016)	-0.009 (0.011)	-0.048^{c} (0.028)	-0.001 (0.006)	-0.003 (0.020)
Household size	-0.005 (0.010)	-0.003 (0.032)	-0.003 (0.019)	-0.014 (0.069)	0.007 (0.011)	0.012 (0.041)
Off farm income	0.029 (0.046)	0.120 (0.150)	0.057 (0.88)	0.285 (0.297)	0.005 (0.048)	0.019 (0.181)
Sell output	-0.024 (0.058)	-0.120 (0.184)	-0.047 (0.114)	-0.220 (0.371)	0.003 (0.071)	-0.067 (0.239)
Cultivated land (ha)	-0.028 (0.031)	-0.101 (0.099)	0.122^{b} (0.062)	0.596^{c} (0.207)	0.068^{b} (0.037)	0.361^{a} (0.107)
Land ownership	0.027 (0.047)	0.119 (0.154)	-0.053 (0.084)	-0.247 (0.287)	-0.004 (0.055)	0.009 (0.201)
Access to farm implements	-0.013 (0.051)	-0.061 (0.163)	0.158^{c} (0.093)	-0.742 (0.276)	-0.010 (0.061)	-0.065 (0.218)
Livestock densities	-0.005 (0.012)	-0.021 (0.037)	0.023 (0.025)	0.111^{a} (0.091)	-0.014 (0.012)	-0.052 (0.044)
Perception on soil fertility	-0.043 (0.047)	-	0.018 (0.074)	-	-0.016 (0.053)	-
Perception on soil erosion	0.055 (0.036)	0.209^{c} (0.125)	-0.030 (0.082)	-0.135 (0.250)	-0.035 (0.060)	0.250^{c} (0.159)
Farmer received training	0.086 (0.057)	0.349^{b} (0.180)	0.054 (0.093)	0.240 (0.359)	0.076 (0.062)	0.311 (0.230)
Group membership	0.142^{b} (0.072)	0.488^{b} (0.221)	0.268 ^{b} (0.111)	1.109 ^{a} (0.388)	0.088^{b} (0.087)	0.488 (0.221)
Received relief	0.127^{b} (0.061)	0.535^{a} (0.168)	-0.021(0.086)	0.125 (0.342)	0.045 (0.058)	-0.208 (0.206)
Frequency of Trainings	-0.013 (0.017)	-0.056 (0.057)	0.027 (0.026)	0.140^{c} (0.081)	0.000 (0.017)	-0.003 (0.078)
Number of groups	0.019 (0.033)	0.083 (0.115)	-0.055 (0.050)	-0.291 (0.192)	-0.009 (0.040)	0.041 (0.153)
Access to agricultural credit	-0.033 (0.053)	-0.138 (0.163)	0.033 (0.082)	0.126 (0.318)	-0.032 (0.060)	0.189 (0.213)
Access to labour	0.074 (0.067)	0.324^{c} (0.191)	0.093 (0.111)	0.519 (0.335)	0.042 (0.072)	0.144 (0.254)
Distance to nearest market	0.000 (0.000)	0.001 (0.001)	0.000 (0.002)	0.002 (0.003)	0.000 (0.000)	0.001 (0.001)
Access to extension services	0.050^{c} (0.028)	-	0.022 (0.037)	-	0.059^{b} (0.037)	-
Statistic						
IMR(λ)	1.049 ^{b} (0.387)		0.989 ^{b} (0.499)		0.913 ^{b} (0.441)	
Number of observation	400		133		267	

a, b and c represents 1%, 5% and 10% significance levels, respectively. Standard errors are in parentheses

4.8 Comparison of mineral fertiliser users and non-users by gender

Among the interviewed households, (53%) female-headed households and (52%) male-headed households were using mineral fertiliser (Table 4.9).

Table 4.9 Demographic factors influencing mineral fertiliser choice and use-intensity disaggregated by gender of the household head

Variable	Female-headed households			Male-headed households		
	Mean			Mean		
	Non- users (n=63)	Users (n=70)	*T*-test	Non- users (n=129)	Users (n=138)	*T*-test
HH age	47.00	46.00	0.27	45.00	45	0.11
Farming experience	19.87	18.93	0.48	18.36	18.38	-1.55
Education	7.84	7.03	1.03	8.74	8.61	0.22
Household size						
Males	2	2	0.51	3	3	-0.60
Females	3	3	-0.76	3	3	-1.72

No significant difference observed.

There existed a significant relationship between group membership and choice and use-intensity of mineral fertiliser in male-headed households and female-headed households at the 10% and 1% levels respectively. About (62%) of mineral fertiliser users in female-headed households were members of a farmer group compared to (38%) non-users. For male-headed households, (61%) users had group membership compared to (39%) of non-users (Table 4.8). Within male-headed households and female-headed households, users and non-users also differed significantly at 5% in levels of participation in farmer trainings. About (61%) and (60%) of users participated in farmer training within female-headed and male-headed households respectively (Table 4.10). Also, within female-headed households and male-headed households, results suggested a significant association at 5% and 1% levels respectively, between choice and use-intensity of mineral fertiliser and access to extension services among (Table 4.10). Within female-headed households, a larger number (86%) of mineral fertilizer users perceived that soil erosion in their farms was very severe in comparison to non-users (14%). An implication is that, farmers who perceived soil erosion to be severe had higher chances of utilizing mineral fertilizer.

Table 4.10 Socioeconomic factors influencing mineral fertiliser choice and use-intensity disaggregated by gender of the household head

	Female-headed households			Male-headed households		
Variable	Non-users (n=63)	Users (n=70)	χ^2	Non-users (n=129)	Users (n=138)	χ^2
Off farm income	22(49)	23(51)	0.80	47(44)	60(56)	0.24
Sell output	56(49)	58(51)	0.32	114(51)	111(49)	0.08^{b}
Land ownership	42(49)	44(51)	0.65	85(49)	89(51)	0.81
Soil fertility perception						
Fertile	33(43)	44(57)	0.22	60(44)	78(56)	0.10^{a}
Otherwise	30(54)	26(46)		69(54)	60(46)	
Soil erosion severity						
Not severe	8(36)	14(34)	0.08^{b}	28(51)	27(49)	0.08^{b}
Moderate	54(52)	50(48)		85(45)	104(55)	
Very severe	1(14)	6(86)		16(70)	7(30)	
Participation in trainings	24(39)	37(61)	0.08^{b}	48(40)	73(60)	0.01^{b}
Group membership	38(38)	61(62)	0.00^{c}	68(39)	107(61)	0.00^{a}
Group leadership	33(46)	39(54)	0.70	46(40)	70(60)	0.01^{b}
HH has received relief	3(11)	24(89)	0.40	27(41)	39(59)	0.17
Received credit	19(50)	19(50)	0.70	26(36)	46(64)	0.02^{b}
Access to labour	54(48)	58(52)	0.65	109(47)	12(53)	0.45
Access to extension	17(36)	30(64)	0.06^{b}	28(34)	55(66)	0.00^{a}
Farm implements	48(56)	38(44)	0.01^{b}	98(49)	102(51)	0.70
	Mean		*t*-test	mean		*t*-test
TLU	1.31	1.22	0.34	2.18	2.34	-0.59
Total land holding ha	1.65	1.57	0.32	1.97	2.04	-0.35
Total cultivated land ha	1.05	1.25	-1.77	1.35	1.55	-1.63
Frequency of Trainings	1.06	0.94	0.40	0.75	0.99	-1.30
Number of groups	0.84	1.09	-1.66^{c}	0.74	1.05	-2.95^{a}
Frequency of extension	0.48	0.61	-0.82	0.41	0.58	-1.50
Market distance	57.70	60.29	-0.34	67.91	54.19	2.24^{b}

a and **b** represents 1% and 5% significance levels, respectively. % are in parentheses, HH represents household head, TLU represents Tropical Livestock Units

There existed a significant relationship between sale of farm output and choice and use intensity of mineral fertiliser at 5% level in male headed households. A majority of mineral fertilizer non-users (51%) sold farm produce compared to users (49%). This implies that selling of outputs negatively influenced use of mineral fertilizer. Further explanation is that, farmers abandoned use of mineral fertilizers and perhaps this could be as a result of low returns. Regarding soil fertility, within male headed-households, a majority of mineral fertilizer users (56%) perceived their soils to be fertile compared to non-users (44%), an implication is that, farmers perceiving their soils to be fertile were more likely to use mineral fertilizers.

Within male-headed households, there existed a significant relationship between access to credit and mineral fertilizer choice and use intensity at 5% level. More users in male-headed households (64%) had access to credit facility in comparison to non-users (36%). At 5% and 1% significance levels, access to extension services influenced mineral fertiliser choice and use intensity within female-headed and male-headed households. More user's (64%) and (66%) within female-headed and male-headed households respectively, had access to extension services, a positive indication that access to extension positively influenced mineral fertilizers use. Within female-headed households, the study also found a significant relationship at 5% level regarding access to farm implement and mineral fertiliser choice and use intensity

Among male-headed households, on average, distance to the nearest input/output market significantly varied at 5% level with mineral fertiliser non-users walking longer distances (67.91 walking minutes) to access the nearest market facility when compared to users (54.19 walking minutes). The same trend was observed with group membership. Users of mineral fertiliser in male-headed households had more group membership when compared to non-users. Group membership varied significantly at 1% level (Table 4.10).

Table 4.11 Estimated coefficient and the marginal effects of the Heckman 2-stage model on determinants of mineral fertiliser choice and use-intensity disaggregated by gender of the household head

	Pooled		Female-headed households		Male-headed households	
Variable	step I dy/dx	step II Coefficients	step I dy/dx	step II Coefficients	step I dy/dx	step II Coefficients
Age	0.001[a] (0.000)	-0.006 (0.007)	5.000 (0.002)	-0.004 (0.009)	0.000 (0.002)	0.006 (0.006)
Education	0.002[a] (0.000)	0.005 (0.022)	-0.000 (0.007)	-0.006 (0.031)	-0.002 (0.006)	-0.008 (0.019)
Household size	0.003[a] (0.001)	0.078[c] (0.045)	-0.000 (0.014)	0.001 (0.068)	0.008 (0.012)	0.027[c] (0.040)
Off farm income	0.002 (0.005)	0.235 (0.207)	-0.009 (0.014)	-0.023 (0.286)	-0.047 (0.054)	-0.193 (0.177)
Sell output	0.020[a] (0.006	-0.454[c] (0.249)	0.085 (0.096)	-0.545[c] (0.378)	0.036 (0.071)	0.173 (0.228)
Cultivated land (ha)	-0.001 (0.003)	-0.157 (0.159)	0.135[c] (0.101)	0.819[a] (0.266)	-0.044 (0.040)	-0.157[c] (0.159)
Land ownership	0.001 (0.005)	0.119 (0.154)	0.001 (0.058)	-0.018 (0.299)	-0.047 (0.061)	-0.201 (0.131)
Access to farm implements	-0.001 (0.005)	0.248[b] (0.217)	0.042 (0.065)	0.308 (0.293)	0.011 (0.063)	0.039 (0.218)
Livestock densities	0.005 (0.012)	-0.068 (0.059)	0.011 (0.021)	0.043 (0.089)	-0.008 (0.013)	-0.036 (0.044)
Perception on soil fertility	0.010[b] (0.005)	-	-0.034 (0.057)	-	-0.059 (0.059)	-
Perception on soil erosion	0.034[a] (0.004)	-0.273 (0.182)	0.055 (0.036)	0.105 (0.252)	0.045 (0.063)	0.217 (0.157)
Farmer received training	0.008 (0.006)	-0.306 (0.302)	0.080 (0.087)	0.446 (0.365)	0.065 (0.067)	0.246 (0.223)
Group membership	0.043[a] (0.008)	1.160[a] (0.287)	0.142[c] (0.072)	1.251[a] (0.416)	0.232[b] (0.112)	0.894[a] (0.275)
Received relief	0.007 (0.005)	0.535[a] (0.168)	0.024 (0.070)	0.089 (0.334)	-0.060 (0.062)	-0.245 (0.201)
Frequency of Trainings	0.001 (0.001)	0.068 (0.151)	0.045 (0.039)	0.276 [b] (0.1129)	-0.015 (0.023)	-0.065 (0.072)
Number of groups	0.001 (0.003)	-0.083 (0.115)	-0.010 (0.044)	-0.083 (0.210)	0.038 (0.047)	-0.155 (0.153)
Access to agricultural credit	0.008 (0.005)	-0.206 (0.230)	-0.072 (0.076)	-0.440 (0.310)	0.052 (0.060)	0.205 (0.207)
Access to labour	0.023[a] (0.006)	-0.244 (0.261)	-0.039 (0.075)	-0.265 (0.349)	0.003 (0.076)	-0.032 (0.240)
Distance to nearest market	-0.00[a] (0.000)	-0.006[a] (0.002)	-0.000 (0.000)	-0.001 (0.003)	-0.001 (0.001)	-0.002 (0.002)
Access to extension services	0.001 (0.003)	-	0.022 (0.033)	-	0.007 (0.034)	-
Statistic						
IMR(λ)	0.064[a] (0.021)		0.852[b] (0.491)		1.135[b] (0.4417)	
Number of observation	400		133		267	

a, b and c represents 1%, 5% and 10% significance levels, respectively. Standard errors are in parentheses

4.9 Determinants of mineral fertiliser choice by gender

Table 4.11 shows the Heckman 2-step model results of the determinants of mineral fertiliser choice and use-intensity. Findings revealed that, within female-headed households and male-headed households, group membership significantly determined zai technology choice at the 10% and 1% level respectively. Specifically, participation in farmer groups increased the likelihood of mineral fertiliser choice by 14.2% and 23.2% in female-headed households and male-headed households, respectively. For female-headed households, total cultivated land influenced mineral fertiliser choice significantly and positively. An increase in cultivated land by one acre increased the likelihood of mineral fertiliser choice by 13.5%.

4.10 Determinants of mineral fertiliser use-intensity by gender

The results also indicated that, membership to a farmer group positively and significantly (= -1.251, $p<0.01$) and (= 0.895, $p<0.01$) influenced mineral fertiliser use-intensity among female-headed households and male-headed households, respectively. Selling output negatively predicted mineral fertiliser use-intensity within female-headed households (= -0.545, $p<0.10$). The study found a significant and positive relationship with mineral fertiliser use-intensity concerning trainings on soil and water conservation within female-headed households (= 0.276, $p<0.05$). The coefficient of total cultivated land was significantly and positively associated with zai technology use-intensity among female-headed households (= 0.819, $p<0.01$) whereas in male-headed households the relationship was negative and significant (= 0.157, $p<0.10$). The study also established a positive and significant relationship within male-headed households (= 0.027, $p<0.10$) between the household size and mineral fertiliser use-intensity.

CHAPTER FIVE

DISCUSSION, CONCLUSIONS, AND RECOMMENDATIONS

5.1 Overview

This chapter provides the discussion of results for the three specific objectives, conclusions, policy and future research recommendations.

5.2 Discussion

5.2.1 Socioeconomic characteristics of zai technology and mineral fertiliser users

A majority of the interviewed households were male-headed. This finding collaborates with other studies conducted in the region by Mugwe et al. (2009) and Mwaura et al. (2021). The implication is that, men dominate major farm decision-making activities at the household level (Macharia et al., 2014). Contrariwise, the results revealed that more female farmers were using zai technology and mineral fertiliser when compared to men. This probably explains the importance of women participating in agricultural decision making at household level and having access and control over productive resources such as land and income. The finding resonates with that of Murage et al. (2015), who reported that women adopted more climate-smart strategies when compared to men to avert the overarching constraints of climate shocks that affected them more directly than men. The results further underscore the importance of larger households in driving choice and use-intensity of agricultural innovations. The propensity of choosing and using zai technology and mineral fertiliser intensely was high in larger male-headed households. Usman et al. (2021) pointed out that larger families provide voluntarily available labour required in implementing labour-intensive technologies.

This study's demographic characteristics show that, among female-headed households, non-users of zai technology were more experienced than users. Farming experience has been found to positively as well as negatively influence the likelihood of adopting agricultural technologies (Knowler & Bradshaw, 2007). This could be associated with trade-offs involved in technology choice. With time, as farmers gain more experience, they gradually shift from technologies with diminishing marginal returns to improved technologies. Further, with rapid technological advancement, experience devalues with time necessitating frequent refreshment of knowledge for effectual technology choice and implementation decisions. Previous research by Ainembabazi et al. (2014) reported that farming experience is mostly important at the try-out stage. Then, farmers may opt out when the returns to investment start decreasing. More so, farmers may abandon zai technology that is labour intensive and requires more land allocation for intensive application.

Results showed that users of zai technology and mineral fertiliser were members of farmer groups, accessed extension services, and participated in soil and water conservation training. These findings may be co-attributed to farmer groups, extension services, and training, providing capacity-building avenues to disseminate information to farmers on agricultural innovations. As was noted by Genius et al. (2014), extension agents and farmer groups link-up researchers and farmers reducing transaction costs when disseminating new and improved technologies to a larger heterogeneous group of farmers. In addition, through extension training, model farmers extend knowledge to other farmers through farmer to farmer training. Farm size is an important factor in the utilization process of agricultural technologies. Application of scale-dependent technologies determined by land size (Feder et al., 1985). User male-households had larger land size. This implies that zai technology is a lumpy technology requiring large farm sizes to maximize returns on investment.

5.2.2 Preferences for zai technology and mineral fertiliser attributes by gender

With regard to zai technology, farmers’ perceptions on ability of the technology to improve soil fertility and information availability significantly varied by gender of the household head. More female headed households perceived zai technology to improve soil fertility and sufficient extension information to be readily available than did male headed households. This is likely to be a reflection of the history of extension programmes and training on soil and water conservation in the area. The implication is that, there are strong positive associations of zai technology with high yields and improvement of soil fertility. Also, female headed households are more sensitive to soil fertility and information availability characteristics when considering soil and water conservation measures. These findings are in consonance with those of Ndiritu et al (2014) who found that women base their choices for soil and water conservation strategies on opportunity cost of realizing better yields. In another study by Andersson et al (2015), the results revealed that, extension information was an important factor in promoting continued use of conservation agriculture after tryout stage by female farmers.

According to a focus group discussion (female farmers), a participant reported that;

> *"I am able to construct zai pits in my farm because I was trained in a project on the measurements and how to incorporate manure and crop residue in the pits; Our officer demonstrated how to construct the pits and followed up what I did in my farm; Although its tiring and one cannot manage a large piece of land with zai technology, crops planted in the pits do well when compared to planting furrows and other practices."*

In relation to mineral fertilizer, female farmers cited the ability of the technology to increase yields more frequently suggesting that there are strong positive associations of mineral fertilizer with high yields. For the male farmers, the most frequently cited attribute was ability of mineral fertilizer to improve soil fertility. Misiko et al (2011) carried out a study on strengthening understanding and perceptions of mineral fertilizer use among smallholder farmers in Western Kenya and found that farmers perceive mineral fertilizer differently, especially characteristics resulting from erratic crop responses such as yields. The findings suggest that, perceptions are substantiated and calls for more research and training over a long period to enable farmers understand the effects of mineral fertilizer on yields and soil fertility. In a focus group discussion (female farmers), a participant reported that;

> *"Those who use fertilizer have money, after selling our produce we use all the money on educating our children; I used mineral fertilizer once which was given as relief through our farmer group, the produce that season was high. I was not able to buy fertilizer for the subsequent seasons due to lack of capital"*

In male FGD a farmer reported that;

> "*Mineral fertilizers improve yields but require consistency in use to maintain soil fertility. When I don't use fertilizer yields decrease and that's the risk of lack of consistency in use."*

Ease of application characteristic was least cited by both genders with regard to use of zai technology and mineral fertilizer technology. This implies that the technologies are labour demanding. These findings resonate with those of Wodon & Blackden (2006) and Komatsu et al, (2018) who found that women are more likely to be attracted to less labour intensive technologies other than zai technology due to their commitment in care work and other household.

A female farmer reported that;

> "*In my household I am the one who tills my farm, I don't have enough money to hire labour, I am only able to work on a small piece of land; I am not able to dig zai pits and all my children are grown and gone, I have nobody to help me with farm work*".

In a mixed focus group discussion (men and women), farmers agreed that;

> *"Using zai technology was laborious and was mostly applicable with hired labour; also use of fertilizer is not easy because you need the skill and you cannot use animal power in applying fertilizer."*

5.2.3 Determinants of zai technology and mineral fertiliser choice and use intensity

For both genders, membership in a farmers’ group increased the likelihood of choosing and using zai technology and mineral fertiliser intensely. Group membership and other social fora provide linkage to access agricultural information through extension contacts and other farmers' interactions where they exchange ideas and practically demonstrate agricultural innovations. Also, farmers’ groups are target points for researchers' and other development agents disseminating research findings. These results are consistent with the finding of Gido et al. (2015) and Kassie et al. (2014), who reported that farmers’ groups and other rural institutions create avenues through which information on agricultural innovations is channelled to farmers thus .reducing the cost of information delivery through increased economies of scale. Further, in a group platform, early adopters can share their testimonies (success stories), encouraging other members to adopt the technologies (Mango et al., 2017).

Among male-headed households, access to extension increased the likelihood of choosing zai technology. Extension services bridge farmers’ knowledge gaps on improved farming practices and application modalities. The study finding concurs with several other studies, for example, Gebregziabher (2018), Donkor *et al.* (2019) and Ehiakpor *et al.* (2019). These studies noted that extension contact increased smallholder farmers' probability of adopting zai technology, among other soil conservation technologies. Additionally, the results are consistent with the findings of Mponela et al. (2016), who found extension services to positively determined the choice of soil conservation practices. Also, Ndiritu et al. (2014) found that the probability of adopting chemical fertilizer increased with access to agricultural extension. Conversely, Chirwa et al. (2008) reported that extension contacts may sometimes not result in increased technology use. This may arise when extension agents have preferential approaches targeting resource-poor households who lack resources necessary for implementing new technologies.

Within male-headed and female-headed households, total land cultivated positively influenced the choice and use intensity of zai technology and mineral fertiliser. This was an indication that larger farm sizes increased the likelihood of choosing soil and water management technologies. This could be attributed to flexibility of devoting a portion of land for new technologies increasing with increase in land size. Our results corroborate with those of Kassie et al. (2010), Mwangi & Kariuki (2015) and Gebre et al. (2019), who reported that increasing land size under cultivation increases the likelihood of utilizing agrarian technologies among smallholder households with an explanation that, the land is an indicator of wealth, which relaxes capital constraints of implementing the practices. Contrariwise, Thinda et al. (2020) contend that large farms are not always a prerequisite for the choice of agrarian technologies. Farmers' with large farm size may prioritize labour-saving technologies abandoning labour-intensive technologies such as zai pits. In addition, farmers may fail to adopt zai technology as it hinders animal traction, a cheaper alternative source of farm power when compared with other ploughing mechanization for resource poor households (Kimaru-Muchai et al., 2020).

Ownership and access to farm implements (a proxy of household wealth in productive assets) within female-headed households increased the likelihood of choosing zai technology. This could be due to the availability of farm implements, which save on both time and labour costs for female farmers trapped in drudgery rural agriculture. This agrees with Johnson et al. (2016), who found that household assets could influence the use of agricultural interventions among female farmers and increase returns to productive assets. The study also noted that farmers with low-value farm assets are limited to low-impact technologies that are appropriate with low-value agricultural implements. Similarly, Peterman et al. (2014) reported that farm implements significantly determined the choice of agricultural technologies for men and women farmers.

In female-headed households, training on soil and water conservation increased the likelihood to use zai technology intensely. Similarly, trainings increased the likelihood of using mineral fertiliser intensely. Training increases farmers' knowledge on agricultural innovations application modalities. Additionally, frequent knowledge-refreshing increase the chances of continued adoption after the try-out stage. Well-versed farmers make accurate estimates of expected returns, a cushion from frustrations of returns overestimation resulting in stagnating and abandoning technologies. The results are consistent with Li et al. (2020) who found information accumulation to have a positive and significant impact on technology adoption. Another study by Okeyo et al. (2020) also found that farmer training positively influenced improved sorghum varieties' adoption among smallholders. Further, they reported that, trained farmers were better informed on varying production patterns under changing agroclimatic conditions and often they prefer climate smart agriculture. Moreover, a study by Gebre et al. (2019) reported that participation in farmer training had more effect on increasing farmers' ability to effectively apply new technologies.

Kimaru-muchai et al. (2020) pointed out that the probability of zai technology use is higher among younger farmers. The study attributed the finding to the labour-demanding nature of zai technology and younger farmers having a better understanding and up-to-date information on zai technology application modalities. In agreement with our current finding, Asfaw & Neka (2017) reported that age negatively influenced acceptance level and use of conservation practices. The negative interaction between age and use of the practices was ascribed to age decreasing farmer assertiveness, hence reducing farm care involvement. Contrary, Wekesa et al. (2018) noted that, farming experience increases with age and farmers upgrade from smaller agrarian practices packages to more rewarding options.

The study established a negative relationship between years of education and zai technology use-intensity, suggesting that more educated farmers were more inclined towards non-farming activities. The findings were consistent with those of Alwang et al. (2019) and Okeyo et al. (2020), who reported that educated farmers are more knowledgeable in predicting and analysing agricultural-related risks and uncertainties associated with biophysical and agro-ecological conditions. In addition, educated farmers may opt-out from farming, taking up secondary non-farming opportunities that are better rewarding, secure, and offer a wide range of alternatives. However, this finding is inconsistent with Mango et al. (2017) and Wordofa et al. (2020), who found the education level of the household head to influence the choice of soil and water conservation practices positively. These studies attributed their findings to the influence of education in raising farmer receptiveness on important conservation measures.

Male-headed households who perceived soil erosion to be severe were more likely to use zai technology intensely. The implication is that, zai technology has the water-holding capacity and when applied together with manure, soil water infiltration and porosity improve and, subsequently, reduces water loss. Low soil fertility occurs as a result of soil loss, among other factors; hence farmers who experience soil loss adopt zai technology more (Kimaru-Muchai et al., 2020). A study by Biratu & Asmamaw (2016) points out that farmers who perceived soil erosion on their farmland as a problem and had good motives to implement soil water conservation activities.

Within male headed households, larger households had higher likelihoods of utilizing mineral fertiliser intensely. A probable explanation is that, there is high potential for supply of family labour and high demand for food among larger households. Mensah-Bonsu et al. (2017) observed a positive association between fertilizer adoption by male headed households and household size ascribing the findings to the need for increased crop yield to cater for food demand. The results are also in line with those of Danso-Abbeam et al. (2019) and Ndiritu et al. (2014) who found that large family size was positively correlated with the adoption soil conservation measures. Similarly, Mugwe et al. (2009) found household size to have positive influence on the decision to adopt integrated soil fertility management techniques by smallholders farmers in Kenya.

Farm output sales (a proxy for farm income) significantly and negatively influenced mineral fertilizer use-intensity among female headed households. This can be ascribed to the low returns to capital intensive mineral fertiliser investment hence farmers are not able to plough back proceeds from farming. In addition, if the returns realized are far below expected returns, farmers might be discouraged on technological investment hence abandoning it at tryout stage. Moreover, female farmers when compared to their male counterparts sell only a small proportion of their produce and reserve larger proportions for household consumption. These results collaborate with those of Kijima & Sserunkuuma, (2011) who points out that farmers abandoned technologies of improved rice varieties in Uganda due to unrealistic expectations about returns. Returns to agricultural technology are subject to biophysical and agro-ecological conditions. For example, soils may vary in their responsiveness to different mineral fertilizers and this may affect intensity of use of a particular technology by farmers (Lambrecht & Vanlauwe, 2014). In another study by Olumeh et al. (2018) characterizing smallholder maize farmers' marketing in Kenya found that female headed households reserve three-fifth of their produce for home consumption, and are more concerned with household welfare hence foregoing sale of farm produce.

In terms of total livestock densities, the study found a positive relationship with zai technology use-intensity within female-headed households. Livestock ownership signifies women's empowerment in agriculture, translating to household wellbeing (Kristjanson et al., 2014). Proceeds from livestock can be ploughed back to cater for costs of labour-demanding zai technology. Most commonly, zai pits are applied in combination with animal manure; hence households with readily available animal manure are more likely to allocate more land under zai technology. These findings agree with Ndiritu et al. (2014), who found livestock ownership to influence soil conservation measures positively. Further, their study pointed out that female plot managers faced with resource constraints (livestock, credit, and labour) have reduced chances to use soil conservation measures compared with male plot managers.

5.3 Conclusions

Three conclusions emerge from this study,

1. The results indicated that preference for zai technology and mineral fertiliser specific-attributes differed for male and female farmers. Female farmers preferred soil and water conservation strategies that improved soil fertility and those with sufficient extension information whereas male farmers preferred strategies that increased yields and improved soil fertility.

2. The results further indicated that, female headed households and male headed households' choice of mineral fertiliser and zai technology was influenced by membership to a farmer group and total cultivated land. In addition, access to extension services positively predicted zai technology choice in male headed households.

3. The key finding is that, female and male farmers have the potential to use soil and water conservation strategies intensely. Specifically, within male-headed households, the study revealed that, efforts to promote zai technology and mineral fertiliser intensification should consider the total cultivated land, farmers' perceptions on soil erosion, group membership, and access to extension services. For female-headed households, total land cultivated, livestock densities, group membership, frequency of training and ownership and access to farm implements were important determinants of zai technology and mineral fertiliser use-intensity.

5.4 Recommendations

1. Researchers and extension agents should focus on needs identification to recognize women and men farmers' felt needs and preferences with regard to soil and water conservation, therefore, designing and promoting technologies that can meet their particular needs. This will encourage technology uptake among women and men farmers.

2. Male and female farmers should be encouraged to join farmer groups and other social networks. Farmer groups could provide avenues for women to participate in leadership and link up with extension services and other development agents promoting soil and water conservation. In addition, gender-sensitive farm-level policies oriented towards land use should promote equitable, secure ownership and access to land by male and female farmers.

3. There is need to develop gender-sensitive policies that advocate equitable and secure ownership of productive assets (livestock, land and extension information). Such policy frameworks could be embraced as a guideline to women’s empowerment in agriculture. Moreover, the study recommends that extension systems need to be reformed and tailored to serve male and female farmers' specific needs and preferences with regard to utilization of agricultural innovations. This will enable both female and male farmers, to choose and use zai technology and mineral fertiliser intensely as adaptation strategies to climate shocks in sub-Saharan Africa's drylands.

5.5 Areas of further research

Intra-household dynamics expound more on the preferred technology attributes and determinants of choice and intensification decisions among the different genders. As such, further studies on gender integration on soil and water conservation should be considered at plot level.

REFERENCES

Adesina, A. A., & Baidu-Forson, J. (1995). Farmers' perceptions and adoption of new agricultural technology: evidence from analysis in Burkina Faso and Guinea, West Africa. *Agricultural economics*, *13*(1), 1-9.

Ainembabazi, J. H., Mugisha, J., Ainembabazi, J. H., & Mugisha, J. (2014). The Role of Farming Experience on the Adoption of Agricultural Technologies: Evidence from Smallholder Farmers in Uganda. *The Journal of Development Studies*, *50*(5), 666–679.

Alwang, J., Gotor, E., Thiele, G., Hareau, G., Jaleta, M., & Chamberlin, J. (2019). Pathways from research on improved staple crop germplasm to poverty reduction for smallholder farmers. *Agricultural Systems*, *172*, 16–27.

Andersson, J. A., Misiko, M., Farnworth, C. R., Badstue, L., & Stirling, C. M. (2015). Gender and conservation agriculture in East and Southern Africa: towards a research agenda. 1–24.

Asfaw, D., & Neka, M. (2017). Factors affecting adoption of soil and water conservation practices: The case of Wereillu Woreda (District), South Wollo Zone, Amhara Region, Ethiopia. *International Soil and Water Conservation Research*, *5*(4), 273–279.

Asfaw, S., Shiferaw, B., Simtowe, F., & Hagos, M. (2011). Agricultural technology adoption, seed access constraints and commercialization in Ethiopia. Journal of Development and *Agricultural Economics*, *3*(9), 436-477.

Awotide, B. A., Karimov, A. A., & Diagne, A. (2016). Agricultural technology adoption, commercialization and smallholder rice farmers' welfare in rural Nigeria. *Agricultural and Food Economics*, *4*(1), 3.

Rejesus, R. M., Knight, T. O., Jaramillo, M., Coble, K. H., Patrick, G. F., & Baquet, A. (2008). Preference for risk management information sources: implications for extension and outreach programming. *Agricultural and Resource Economics Review*, *37*(1), 106-116.

Barbier, E. B., & Hochard, J. P. (2018). Poverty, rural population distribution and climate change. *Environment and Development Economics*, *23*(3), 234-256.

Belachew, A., Mekuria, W., & Nachimuthu, K. (2020). Factors influencing adoption of soil and water conservation practices in the northwest Ethiopian highlands. *International Soil and Water Conservation Research*, *8*(1), 80–89.

Beshir, B., & Wegary, D. (2014). Determinants of smallholder farmers' hybrid maize adoption in the drought prone Central Rift Valley of Ethiopia. *African Journal of Agricultural Research, 9*, 1334-1343.

Beuchelt, T. D., & Badstue, L. (2013). Gender, nutrition-and climate-smart food production: Opportunities and trade-offs. *Food Security, 5*(5), 709-721.

Biratu, A. A., & Asmamaw, D. K. (2016). Farmers' perception of soil erosion and participation in soil and water conservation activities in the Gusha Temela watershed, Arsi, Ethiopia. *International Journal of River Basin Management, 14*(3), 329–336.

Blasch, J., van der Kroon, B., van Beukering, P., Munster, R., Fabiani, S., Nino, P., & Vanino, S. (2020). Farmer preferences for adopting precision farming technologies: a case study from Italy. *European Review of Agricultural Economics,* (00), 1-49.

Bradford, J. B., Schlaepfer, D. R., Lauenroth, W. K., Palmquist, K. A., Chambers, J. C., Maestas, J. D., & Campbell, S. B. (2019). Climate-driven shifts in soil temperature and moisture regimes suggest opportunities to enhance assessments of dryland resilience and resistance. *Frontiers in Ecology and Evolution*, 7, 358.

Bradford, J. B., Schlaepfer, D. R., Lauenroth, W. K., Yackulic, C. B., Duniway, M., Hall, S., Jia, G., Jamiyansharav, K., Munson, S.M., Wilson, S.D., & Tietjen, B. (2017). Future soil moisture and temperature extremes imply expanding suitability for rainfed agriculture in temperate drylands. *Scientific reports, 7*(1), 1-11.

Cascetta, E. (2009). Transportation systems analysis: models and applications (Vol. 29). Springer Science & Business Media.

Certo, S. T., Busenbark, J. R., & Woo, H. (2016). Sample selection bias and Heckman models in strategic management research. *Strategic Management Journal,* 2657, 2639–2657.

Chianu, J. N., & Tsujii, H. (2004). Determinants of farmers' decision to adopt or not adopt inorganic fertilizer in the savannas of northern Nigeria. *Nutrient cycling in agroecosystems, 70*(3), 293-301.

Chirwa, E. W., Kumwenda, I., Jumbe, C., Chilonda, P., & Minde, I. (2008). Agricultural growth and poverty reduction in Malawi: Past performance and recent trends. *ReSAKSS-SA Working Paper, 8*.

Cochran, W. G. (2007). Sampling techniques. John Wiley & Sons.

Colfer, C. J. P., Achdiawan, R., Roshetko, J. M., Mulyoutami, E., Yuliani, E. L., Mulyana, A., Moeliono, M., Adnan, H., & Erni. (2015) The balance of power in household decision-making: encouraging news on gender in southern Sulawesi. *World Development*, 76, 147–164.

Cragg, J. G. (1971). Some statistical models for limited dependent variables with application to the demand for durable goods. *Econometrica: Journal of the Econometric Society*, 829-844.

D'Antoni, J. M., Mishra, A. K., & Joo, H. (2012). Farmers' perception of precision technology: The case of autosteer adoption by cotton farmers. *Computers and Electronics in Agriculture*, 87, 121–128.

Danjuma, M. N., & Mohammed, S. (2015). Zai pits system: a catalyst for restoration in the dry lands. *Journal of Agriculture and Veterinary Science, 8*(2), 1–4.

Danso-Abbeam, G., Dagunga, G., & Ehiakpor, D. S. (2019a). Adoption of Zai technology for soil fertility management: evidence from Upper East region, Ghana. *Journal of Economic Structures*, *8*(1), 1–14.

Diouf, N. S., Ouedraogo, I., Zougmoré, R. B., Ouedraogo, M., Partey, S. T., & Gumucio, T. (2019). Factors influencing gendered access to climate information services for farming in Senegal. *Gender, Technology and Development, 23*(2), 93-110.

Djoudi, H., & Brockhaus, M. (2011). Is adaptation to climate change gender neutral? Lessons from communities dependent on livestock and forests in northern Mali. *International Forestry Review, 13*(2), 123-135.

Donkor, E., Onakuse, S., Bogue, J., & Rios-carmenado, I. D. L. (2019). Land Use Policy Fertiliser adoption and sustainable rural livelihood improvement in Nigeria. *Land Use Policy*, 88, 104193.

Doss, C. (2014). Data needs for gender analysis in agriculture. In *Gender in agriculture* (pp. 55-68). Springer, Dordrecht.

Doss, C., Meinzen-Dick, R., Quisumbing, A., & Theis, S. (2018). Women in agriculture: Four myths. *Global food security*, *16*, 69-74.

Ehiakpor, D. S., Danso-Abbeam, G., Dagunga, G., & Ayambila, S. N. (2019). Impact of Zai technology on farmers' welfare: Evidence from northern Ghana. *Technology in Society*, 59, 101189.

Farooq, M., & Siddique, K. H. (Eds.). (2017). *Innovations in dryland agriculture*. Springer.

Fatondji, D., Martius, C., Bielders, C. L., Vlek, P. L. G., Bationo, A., & Gerard, B. (2006). Effect of planting technique and amendment type on pearl millet yield, nutrient uptake, and water use on degraded land in Niger. *Nutrient Cycling in Agroecosystems,* 76, 203-217.

Feder, G., & Umali, D. L. (1993). The adoption of agricultural innovations: a review. *Technological Forecasting and Social Change, 43*(3–4), 215–239.

Feder, G., Just, R. E., & Zilberman, D. (1985). Adoption of agricultural innovations in developing countries: A survey. *Economic Development and Cultural Change, 33*(2), 255–298.

Gebre, G. G., Isoda, H., Rahut, D. B., Amekawa, Y., & Nomura, H. (2019). Gender differences in the adoption of agricultural technology: the case of improved maize varieties in southern Ethiopia. *Women's Studies International Forum,* 76. Elsevier.

Gebregziabher, K. (2018). The impact of agricultural extension on households' welfare in Ethiopia. *International Journal of Social Economics*, 5-2014-0088.

Genius, M., Koundouri, P., Nauges, C., & Tzouvelekas, V. (2014). Information transmission in irrigation technology adoption and diffusion: Social learning, extension services, and spatial effects. *American Journal of Agricultural Economics, 96*(1), 328-344.

Gido, E. O., Sibiko, K. W., Ayuya, O. I., & Mwangi, J. K. (2015). Demand for agricultural extension services among small-scale maize farmers: Micro-level evidence from Kenya. *The Journal of Agricultural Education and Extension, 21*(2), 177–192.

Heckman, J. J. (1979). Sample selection bias as a specification error. Econometrica: *Journal of the Econometric Society*, 153–161.

Huyer, S. (2016). Closing the gender gap in agriculture. SAGE Publications Sage India: New Delhi, India.

IPCC, (2014). Climate Change 2014: Synthesis Report. Core Writing Team, R.K., Pachauri, L.A., Meyer (Eds.), In Proceedings of Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. IPCC, Geneva, Switzerland, p. 151.

Issahaku, G., & Abdul-Rahaman, A. (2019). Sustainable land management practices, off-farm work participation and vulnerability among farmers in Ghana: Is there a nexus? *International soil and water conservation research, 7*(1), 18-26.

Jaetzold, R., Schmidt, H., Hornetz, B., & Shisanya, C. (2007). Farm management handbook of Kenya: part C, East Kenya. Ministry of Agriculture, Nairobi.

Jaetzold, R., Schmidt, H., Hornetz, B., & Shisanya, C. (2007). Farm management handbook of Kenya: part C, East Kenya. *Ministry of Agriculture, Nairobi*.

Jaleta, M., Yirga, C., Kassie, M., De Groote, H., & Shiferaw, B. (2013). *Knowledge, adoption and use intensity of improved maize technologies in Ethiopia* (No. 309-2016-5268).

Johnson, N. L., Kovarik, C., Meinzen-Dick, R., Njuki, J., & Quisumbing, A. (2016). Gender, Assets, and Agricultural Development: Lessons from Eight Projects. *World Development,* 83, 295–311.

Kantor, P., Morgan, M., & Choudhury, A. (2015). Amplifying outcomes by addressing inequality: the role of gender-transformative approaches in agricultural research for development. *Gender, Technology and Development, 19*(3), 292–319.

Kassie, M., Jaleta, M., Shiferaw, B., Mmbando, F., & Mekuria, M. (2013). Adoption of interrelated sustainable agricultural practices in smallholder systems: Evidence from rural Tanzania. *Technological forecasting and social change, 80*(3), 525-540.

Kassie, M., Ndiritu, S. W., & Stage, J. (2014). What determines gender inequality in household food security in Kenya? Application of exogenous switching treatment regression. *World Development,* 56, 153–171.

Kassie, M., Zikhali, P., & Pender, J. (2010). The Economics of Sustainable Land Management Practices in the Ethiopian Highlands. *Journal of agricultural economics, 61*(3), 605–627.

Kawarazuka, N., Prain, N., Forsythe, L., Mayanja, S., Mudege, N., Babini, C., & Polar, V. (2018). Gender in Agricultural Mechanization: Key Guiding Questions.

Kelly, V. A. (2006). *Factors affecting demand for fertilizer in Sub-Saharan Africa* (No. 37060, pp. 1-89). The World Bank.

Kenya National Bureau of Statistics. (2019). *The 2019 Kenya Population and Housing Census: Population by County and Sub-county*. Kenya National Bureau of Statistics.

Kiboi, M. N., Ngetich, K. F., Diels, J., Mucheru-Muna, M., Mugwe, J., & Mugendi, D. N. (2017). Minimum tillage, tied ridging and mulching for better maize yield and yield stability in the Central Highlands of Kenya. *Soil & Tillage Research*, 170, 157–166.

Kijima, Y., Otsuka, K., & Sserunkuuma, D. (2011). An inquiry into constraints on a green revolution in Sub-Saharan Africa: the case of NERICA rice in Uganda. *World Development*, *39*(1), 77-86.

Kimaru-Muchai, S. W., Ngetich, F. K., Baaru, M., & Mucheru-Muna, M. W. (2020). Adoption and utilisation of Zai pits for improved farm productivity in drier upper Eastern Kenya. *Journal of Agriculture and Rural Development in the Tropics and Subtropics (JARTS), 121*(1), 13–22.

Knowler, D., & Bradshaw, B. (2007). Farmers' Adoption of Conservation Agriculture: A Review and Synthesis of Farmers' adoption of conservation agriculture: A review and synthesis of recent research. *Food policy, 32*(1), 25-48.

Komatsu, H., Malapit, H. J. L., & Theis, S. (2018). Does women’s time in domestic work and agriculture affect women’s and children’s dietary diversity? Evidence from Bangladesh, Nepal, Cambodia, Ghana, and Mozambique. *Food Policy*, *79*, 256-270.

Kristjanson, P., Waters-Bayer, A., Johnson, N., Tipilda, A., Njuki, J., Baltenweck, I., Grace, D., & MacMillan, S. (2014). Livestock and women's livelihoods. In *Gender in agriculture* (pp. 209-233). Springer, Dordrecht.

Kuehne, G., Llewellyn, R., Pannell, D. J., Wilkinson, R., Dolling, P., Ouzman, J., & Ewing, M. (2017). Predicting farmer uptake of new agricultural practices: A tool for research, extension and policy. *Agricultural Systems*, 156, 115–125.

Lambrecht, I., & Vanlauwe, B. (2014). Understanding the Process of Agricultural Technology Adoption: Mineral Fertilizer in Eastern DR Congo. *World development,* 59, 132–146.

Lambrecht, I., Vanlauwe, B., & Maertens, M. (2016). Agricultural extension in Eastern Democratic Republic of Congo: Does gender matter? *European Review of Agricultural Economics*, 43, 841-874.

Li, H., Huang, D., Ma, Q., Qi, W., & Li, H. (2020). Factors Influencing the Technology Adoption Behaviours of Litchi Farmers in China. *Sustainability, 12*(1), 271.

Macharia, J., Mugwe, J., Mucheru-Muna, M., & Mugendi, D. (2014). Socioeconomic factors influencing levels of knowledge in soil fertility management in the central highlands of Kenya. *Journal of Agricultural Science and Technology, 4*(9), 701-711.

Malesu, M. M. (2006). *Rainwater harvesting innovations in response to water scarcity: The Lare experience.* World Agroforestry Centre.

Manfre, C., Rubin, D., Allen, A., Summerfield, G., Colverson, K., & Akeredolu, M. (2013). Reducing the gender gap in agricultural extension and advisory services: How to find the best fit for men and women farmers. *Meas Brief*, *2*.

Mango, N., Makate, C., Tamene, L., Mponela, P., & Ndengu, G. (2017). Awareness and adoption of land, soil and water conservation practices in the Chinyanja Triangle, Southern Africa. *International Soil and Water Conservation Research, 5*(2), 122–129.

Marenya, P., Kassie, M., & Tostao, E. (2015). Fertilizer use on individually and jointly managed crop plots in Mozambique. *Journal of Gender, Agriculture and Food Security (Agri-Gender)*, 1, 62-83.

Meinzen-Dick, R., Quisumbing, A., Doss, C., & Theis, S. (2019). Women's land rights as a pathway to poverty reduction: Framework and review of available evidence. *Agricultural Systems,* 172, 72–82.

Melesse, B. (2018). A review on factors affecting adoption of agricultural new technologies in Ethiopia. *Journal of Agricultural Science and Food Research, 9*(3), 1–4.

Mensah-Bonsu, A., Sarpong, D. B., Al-Hassan, R., Egyir, I. S., Asuming-Brempong, S., Egyir, I. S., Osei-Asare, Y. B. (2017). Intensity of and factors affecting land and water management practices among smallholder maize farmers in Ghana. *African Journal of Agricultural and Resource Economics, 12*(2), 142–157.

Mganga, K. Z., Musimba, N. K. R., & Nyariki, D. M. (2015). Combining sustainable land management technologies to combat land degradation and improve rural livelihoods in semiarid lands in Kenya. *Environmental management*, *56*(6), 1538-1548.

Misiko, M., Tittonell, P., Giller, K. E., & Richards, P. (2011). Strengthening understanding and perceptions of mineral fertilizer use among smallholder farmers: evidence from collective trials in western Kenya. *Agriculture and Human Values*, *28*(1), 27-38.

Mponela, P., Tamene, L., Ndengu, G., Magreta, R., Kihara, J., & Mango, N. (2016). Land Use Policy Determinants of integrated soil fertility management technologies adoption by smallholder farmers in the Chinyanja Triangle of Southern Africa. *Land Use Policy,* 59, 38–48.

Mucheru-Muna, M., Pypers, P., Mugendi, D., Kung'u, J., Mugwe, J., Merckx, R., & Vanlauwe, B. (2010). A staggered maize–legume intercrop arrangement robustly increases crop yields and economic returns in the highlands of Central Kenya. *Field Crops Research, 115*(2), 132-139.

Mugwe, B. J., Mugendi, D., Mucheru-Muna, M., Merckx, R., Chianu, J., & Vanlauwe, B. (2009). Determinants of the decision to adopt integrated soil fertility management practices by smallholder farmers in the central highlands of Kenya. *Experimental Agriculture*, *45*(1), 61-75.

Mugwe, J., Ngetich, F., & Otieno, E. O. (2019). Integrated Soil Fertility Management in Sub-Saharan Africa: Evolving Paradigms Toward Integration. *Zero Hunger. Encyclopedia of the UN Sustainable Development Goals. Springer, Cham.*

Mukoni, M. (2018). Gender, Power and Women's Participation in Community Environmental Education. *Southern African Journal of Environmental Education*, 34(0).

Murage, A. W., Amudavi, D. M., Obare, G. A., Chianu, J., & Khan, Z. R. (2010). *Determining smallholder farmers' preferences for Push-Pull technology dissemination pathways in western Kenya* (No. 308-2016-5101, pp. i-18).

Murage, A. W., Midega, C. A. O., Pittchar, J. O., Pickett, J. A., & Khan, Z. R. (2015). Determinants of adoption of climate-smart push-pull technology for enhanced food security through integrated pest management in eastern Africa. *Food Security*, 7, 709-724.

Murage, A. W., Pittchar, J. O., Midega, C. A. O., Onyango, C. O., & Khan, Z. R. (2015). Gender specific perceptions and adoption of the climate-smart push–pull technology in eastern Africa. Crop Protection, 76, 83-91.

Muriithi, B. W., Menale, K., Diiro, G., & Muricho, G. (2018). Does gender matter in the adoption of push-pull pest management and other sustainable agricultural practices? Evidence from Western Kenya. *Food Security*, 10(2), 253–272.

Muriu-Ng'ang'a, F. W., Mucheru-Muna, M., Waswa, F., & Mairura, F. S. (2017). Socioeconomic factors influencing utilisation of rain water harvesting and saving technologies in Tharaka South, Eastern Kenya. *Agricultural Water Management*, 194, 150-159.

Musafiri, C. M., Macharia, J. M., Ng'etich, O. K., Kiboi, M. N., Okeyo, J., Shisanya, C. A., Okwuosa, E.A., Mugendi, D.N. & Ngetich, F. K. (2020). Farming systems' typologies analysis to inform agricultural greenhouse gas emissions potential from smallholder rain-fed farms in Kenya. *Scientific African*, 8, e00458.

Mwangi, M., & Kariuki, S. (2015). Factors determining adoption of new agricultural technology by smallholder farmers in developing countries. *Journal of Economics and Sustainable Development*, 6(5).

Mwangi, P. (2020). A climate-smart agriculture approach using double digging, Zai pits and Aquacrop model in rain-fed sorghum cultivation at Wiyumiririe location of Laikipia County, Kenya. *Africa Journal of Physical Sciences 2313-3317, 4.*

Mwaura, G. G., Kiboi, M. N., Bett, E. K., Mugwe, J. N., Muriuki, A., Nicolay, G., & Ngetich, F. K. (2021). Adoption intensity of selected organic-based soil fertility management technologies in the Central Highlands of Kenya. *Frontiers in Sustainable Food Systems*, 4: 570190.

Nchinda, V. P., Ambe, T. E., Holvoet, N., Leke, W., Che, M. A., Nkwate, S. P., & Ngassam, S.B., Njualem, D. K. (2010). Factors influencing the adoption intensity of improved yam (Dioscorea spp.) seed technology in the western highlands and high guinea savannah zones of Cameroon. *Journal of Applied Biosciences*, 36, 2389–2402.

Ndiritu, S Wagura, Kassie, M., & Shiferaw, B. (2014). Are there systematic gender differences in the adoption of sustainable agricultural intensification practices? Evidence from Kenya. *Food Policy*, 49, 117–127.

Ndiritu, Simon W, Kassie, M., & Shiferaw, B. (2011). Adoption of agricultural technologies in Kenya: How does gender matter?

Ngetich, K. F., Diels, J., Shisanya, C. A., Mugwe, J. N., Mucheru-Muna, M., & Mugendi, D. N. (2014). Effects of selected soil and water conservation techniques on runoff, sediment yield, and maize productivity under sub-humid and semiarid conditions in Kenya. *Catena*, 121, 288-296.

Nichols, M. H., Shaw, J. R., & Brandau, W. K. (2021). Unintended consequences of rangeland conservation structures. *International Soil and Water Conservation Research*, *9*(1), 158-165

Njuki, J., Kaaria, S., Chamunorwa, A., & Chiuri, W. (2011). Linking smallholder farmers to markets, gender and intra-household dynamics: does the choice of commodity matter? *The European Journal of Development Research*, *23(*3), 426-443.

Nkonya, E., Schroeder, T., & Norman, D. (1997). Factors affecting adoption of improved maize seed and fertiliser in Northern Tanzania. *Journal of Agricultural Economics*, *48*(1), 1–12.

Nyamekye, C., Thiel, M., Schönbrodt-Stitt, S., Zoungrana, B. J. B., & Amekudzi, L. K. (2018). Soil and water conservation in Burkina Faso, West Africa. *Sustainability*, *10*(9), 1–24.

Obiero, K. O., Waidbacher, H., Nyawanda, B. O., Munguti, J. M., Manyala, J. O., & Kaunda-Arara, B. (2019). Predicting uptake of aquaculture technologies among smallholder fish farmers in Kenya. *Aquaculture International*, 27, 1689-1707.

Obisesan, A. A., Amos, T. T., & Akinlade, R. J. (2016). Causal Effect of Credit and Technology Adoption on Farm Output and Income: The Case of Cassava Farmers in Southwest Nigeria. 5th International Conference of the African Association of Agricultural Economists, (No. 310-2016-5370).

Ogada, M. J., Mwabu, G., & Muchai, D. (2014). Farm technology adoption in Kenya: a simultaneous estimation of inorganic fertilizer and improved maize variety adoption decisions. *Agricultural and food economics*, *2*(1), 1-18.

Okeyo, S. O., Ndirangu, S. N., Hisaboke, H. N., Njiru, L. K., & Omenda, J. A. (2020). Analysis of the determinants of farmer participation in sorghum farming among small-scale farmers in Siaya County, Kenya. *Scientific African*, 10, e00559.

Onyalo, P. O. (2019). Women and agriculture in rural Kenya: role in agricultural production. *International Journal of Humanities and Social Science, 4*(4), 1-10.

Palacios-Lopez, A., Christiansen, L., & Kilic, T. (2017). How much of the labor in African agriculture is provided by women? *Food Policy*, 67, 52–63.

Partey, S. T., Zougmoré, R. B., Ouedraogo, M., & Campbell, B. M. (2018). Developing climate-smart agriculture to face climate variability in West Africa: challenges and lessons learnt. *Journal of Cleaner Production*, 187, 285–295.

Peter, K., & Itabari, J. K. (2014). In-situ soil moisture conservation: Utilisation and management of rainwater for crop production. *Adapting African Agriculture to Climate Change*,127-142.

Peterman, A., Behrman, J. A., & Quisumbing, A. R. (2014). A review of empirical evidence on gender differences in nonland agricultural inputs, technology, and services in developing countries. In *Gender in agriculture*, 145–186.

Pircher, T., Almekinders, C. J., & Kamanga, B. C. (2013). Participatory trials and farmers' social realities: understanding the adoption of legume technologies in a Malawian farmer community. *International Journal of Agricultural Sustainability, 11*(3), 252-263.

Quisumbing, A. R., Meinzen-Dick, R., Raney, T. L., Croppenstedt, A., Behrman, J. A., & Peterman, A. (2014). Gender in agriculture: Closing the knowledge gap on gender in agriculture. *Gender in agriculture*, 3-27.

Rabbi, F., Ahamad, R., Ali, S., Chandio, A. A., Ahmad, W., Ilyas, A., & Din, I. U. (2019). Determinants of commercialization and its impact on the welfare of smallholder rice farmers by using Heckman's two-stage approach. *Journal of the Saudi Society of Agricultural Sciences, 18*(2), 224–233.

Recha, C. W., Makokha, G. L., Traore, P. S., Shisanya, C., Lodoun, T., & Sako, A. (2012). Determination of seasonal rainfall variability, onset and cessation in semiarid Tharaka district, Kenya. *Theoretical and Applied Climatology, 108*(3–4), 479–494.

Rogers, E. M., Singhal, A., & Quinlan, M. M. (2014). Diffusion of innovations (pp. 432-448). Routledge.

Rojas, R. V., Achouri, M., Maroulis, J., & Caon, L. (2016). Healthy soils: a prerequisite for sustainable food security. Environmental Earth Sciences, 75(3), 180.

Rola-Rubzen, M. F., Paris, T., Hawkins, J., & Sapkota, B. (2020). Improving Gender Participation in Agricultural Technology Adoption in Asia: From Rhetoric to Practical Action. *Applied Economic Perspectives and Policy, 42*(1), 113–125.

Roose, E., Kabore, V., & Guenat, C. (1999). Zai practice: A west african traditional rehabilitation system for semiarid degraded lands, a case study in Burkina Faso. *Arid Soil Research and Rehabilitation, 13*(4), 343–355.

Sawadogo, H., Hien, F., Sohoro, A., & Kambou, F. (2001). Pits for trees: How farmers in semiarid Burkina Faso increase and diversify plant biomass. *Farmer Innovation in Africa: A Source of Inspiration for Agricultural Development.'*

Sell, M., & Minot, N. (2018). What factors explain women's empowerment? Decision-making among small-scale farmers in Uganda. *Women's Studies International Forum*, 71, 46-55.

Shahid, S. A., & Al-Shankiti, A. (2013). Sustainable food production in marginal lands—Case of GDLA member countries. *International soil and water conservation research, 1*(1), 24-38.

Serraj, R., Siddique, K.H.M., 2012. Conservation agriculture in dry areas. Field Crops Res. 132, 1–6

Sinyolo, S. (2020). Technology adoption and household food security among rural households in South Africa: The role of improved maize varieties. *Technology in Society*, 60, 101214.

Slingerland, M. A., & Stork, V. E. (2000). Determinants of the practice of zai and mulching in north Burkina Faso. *Journal of Sustainable Agriculture, 16*(2), 53–76.

Smil, V. (2011). Nitrogen cycle and world food production. *World Agriculture, 2*(1), 9-13.

Smucker, T. A., & Wisner, B. (2008). Changing household responses to drought in Tharaka, Kenya: vulnerability, persistence and challenge. *Disasters, 32*(2), 190–215.

Sultana, A. (2012). Patriarchy and Women's Subordination: A Theoretical Analysis. *Arts Faculty Journal*, 1–18.

Teklewold, H., Kassie, M., & Shiferaw, B. (2013). Adoption of multiple sustainable agricultural practices in rural Ethiopia. *Journal of agricultural economics, 64*(3), 597-623.

Teshome, A., de Graaff, J., & Kassie, M. (2016). Household-level determinants of soil and water conservation adoption phases: Evidence from North-Western Ethiopian highlands. *Environmental Management, 57*(3), 620–636.

Thinda, K. T., Ogundeji, A. A., Belle, J. A., & Ojo, T. O. (2020). Understanding the adoption of climate change adaptation strategies among smallholder farmers: Evidence from land reform beneficiaries in South Africa. *Land Use Policy*, 99, 104858.

Timans, R., Wouters, P., & Heilbron, J. (2019). Mixed methods research: what it is and what it could be. *Theory and Society, 48*(2), 193-216.

Tobin, J. (1958). Estimation of relationships for limited dependent variables. *Econometrica* 26, 24–36.

Olumeh, D. E., Adam, R., Otieno, D. J., & Oluoch-Kosura, W. An Insight into the Intra-Household Gender, Wealth-Status, Educational and Credit Access Dimensions.

Usman, Z., Olagunju, K. O., & Ogunpaimo, O. R. (2021). Determinants of adoption of multiple sustainable agricultural practices among smallholder farmers in Nigeria. *International Soil and Water Conservation Research, 9*(2), 241-248.

Vanlauwe, B., & Giller, K. E. (2006). Popular myths around soil fertility management in sub-Saharan Africa. *Agriculture, ecosystems & environment, 116*(1-2), 34-46.

Vanlauwe, B., Wendt, J., Giller, K. E., Corbeels, M., Gerard, B., & Nolte, C. (2014). A fourth principle is required to define conservation agriculture in sub-Saharan Africa: the appropriate use of fertilizer to enhance crop productivity. *Field Crops Research*, 155, 10-13.

Wale, E., & Yalew, A. (2007). Farmers' variety attribute preferences: implications for breeding priority setting and agricultural extension policy in Ethiopia. *African Development Review*, *19*(2), 379-396.

Wekesa, B. M., Ayuya, O. I., & Lagat, J. K. (2018). Effect of climate - smart agricultural practices on household food security in smallholder production systems: micro - level evidence from Kenya. *Agriculture & Food Security*, 1–14.

White, R. P., Tunstall, D. B., & Henninger, N. (2002). *An ecosystem approach to drylands: building support for new development policies* (pp. 1-14). Washington, DC: World Resources Institute.

Wodon, Q., & Blackden, C. M. (Eds.). (2006). *Gender, time use, and poverty in sub-Saharan Africa*. The World Bank.

Wooldridge, J. M. (2010). *Econometric analysis of cross section and panel data*. MIT press.

Wordofa, M. G., Okoyo, E. N., & Erkalo, E. (2020). Factors influencing adoption of improved structural soil and water conservation measures in Eastern Ethiopia. *Environmental Systems Research*, *9*(1), 1-11.

Yigezu, Y. A., Mugera, A., El-Shater, T., Aw-Hassan, A., Piggin, C., Haddad, A., Loss, S. (2018). Enhancing adoption of agricultural technologies requiring high initial investment among smallholders. *Technological Forecasting and Social Change*, 134, 199–206.

Zeng, D., Alwang, J., Norton, G., Jaleta, M., Shiferaw, B., & Yirga, C. (2018). Land ownership and technology adoption revisited: Improved maize varieties in Ethiopia. *Land Use Policy*, 72, 270-279.

APPENDICES

Appendix 1 Questionnaire

Questionnaire No……………

You are among several farmers in this area who have been selected for this study. The study seeks to evaluate the influence of gender on use of selected soil fertility and soil water conservation strategies. The information provided will be treated with utmost confidentiality. Your assistance in answering the questions truthfully and accurately will be highly appreciated.

Date ………………….Enumerator's name………………………………….

Geographical location

Ward ………………………….

Farmer characteristics

1. Gender of the household head 1=Male 0 =Female

2. Gender of household decision maker *(Who makes key agricultural decisions at household level i.e. relate to household headship)* 1=Male 0 =Female

Follow-up on gender of the household decision maker

Major decision making activity at household level	***Decision maker (indicate the decision maker i.e. 1 or 0***	***Remarks***
What crops to grow		
What size of land to cultivate		
Which SWC technologies to use		
Allocation of agricultural credit		
Control of farm income		
Farm produce sales		
Labour allocation		

3. Age of the household head …………………. years

4. Years of education of household head ……...years

What is your education level? 1=Primary, 2= Secondary, 3=Tertiary 4=Non formal education

5. Farming experience of the household head (*years the farmer has been making key farming decisions independently*) …….

6. Household size

Number of males ………

Number of females………

7. Does the household head participate in off-farm employment? 1= Yes 2=No

If yes, what is the average monthly income from off-farm employment………. Ksh

8. Are you a member of farmer based group/ organisation? 1= Yes 2=No

If yes, how many groups/ organisations ………….

If yes, what benefits does he/she derive from group membership?

1=Information on credit 2=General advice on farming 3=Information on climate change 4=Help in credit access 5=Others (specify)……

Farm characteristics

9. Do you own land that you are currently farming on with a formal title deed? 1=Yes 2=No

What is the size of land owned?..............acres

10. What is the total size of land under cultivation? …………...acres

11. Have you sold farm produce in the last one cropping season? 1=Yes 2=No

12. Do you have access to timely labour? (*during planting, harvesting periods or when applying SWC measures*) 1=Yes 2=No

13. Do you have access to animal drawn farm equipment? *("access" includes both ownership and renting)* 1=Yes 2=No

14. Do you keep livestock? 1=Yes 2=No

If yes, which livestock and how many of each do you keep in your farm? Please tick on livestock owned and indicate the number

Type of livestock	***Number***
1=Cattle	
2=Sheep	
3=Goats	
4=Donkeys	
5=Chicken	
6=Pigs	
7=Any other specify ………………………….	

15. Have you received any agricultural extension services within the last one year? 1=Yes 2=No

16. Have you received training on soil fertility and soil water management within the last one year? 1=Yes 2=No

If yes, how many times were you trained in the last one cropping season…………….

17. Do you have access to agricultural credit? 1=Yes 0=No

If yes, indicate the amount received last year……………. Ksh

Is the credit used in improving soil fertility and soil water management? 1=Yes 0=No

18. What is the distance in walking minutes to the nearest input/output market?...........

19. Have you received any form of relief either in form of inputs, farming implements or cash? *1=Yes 0=No*

If yes, was the relief beneficial in addressing soil infertility and soil water stress? 1=Yes 0=No

Soil and water conservation

20. What is the terrain of the cultivated land? 1=Sloppy 0=Otherwise

21. How do you perceive soil fertility status of the cultivated farm? 1=Very fertile, 2= moderate 3=Poor

22. Have you experienced soil erosion in your farm? 1= Yes 0=No

If yes, how do you perceive the severity of the soil erosion in your farm currently? 1=Very severe 2= Moderate 3= Not severe

Zai technology

23. Are you aware of zai technology/pits as a soil and water conservation technique? *(try to interrogate the respondent with more questions on measurements, spacing and application modalities to clearly know if they are aware)* 1= Yes 0=No

24. Are you using or have used zai technology in the last one cropping season? *(Where applicable, make observations*)1= Yes 0=No

If yes, what is the size of land is under zai technology? (confirm the size of land by measuring) ....acres

If yes, when incorporating zai do you add manure? 1= Yes 0=No

If yes, when incorporating zai do you add mineral fertilizer? 1= Yes 0=No

Mineral fertiliser

25. Are you aware of mineral fertiliser as a soil fertility enhancing technique? *(try to interrogate the respondent with more questions on application rates and other modalities, types of fertiliser to clearly know if they are aware)* 1= Yes 0=No

26. Are you using or have used mineral fertiliser in the last one cropping season? *(Where applicable, make observations*)1= Yes 0=No

If yes, what is the size of land is under mineral fertiliser? (confirm the size of land by measuring) ....acres

If yes, when incorporating zai do you combine with animal manure? 1= Yes 0=No

If yes, how many kilograms of fertilizer did you apply in the area of land given above?......Kgs (Interrogate more on amount of fertiliser applied vs the area of land)

Crop residue retention/ Mulching

27. Are you aware of crop residue retention/ mulching as a soil and water conservation technique? *(try to interrogate the respondent with more questions on residue retention, application modalities to clearly know if they are aware also types of mulch)* 1= Yes 0=No

28. Have you applied mulch/crops residue in the last one cropping season? *(Where applicable, make observations*)1= Yes 0=No

If yes, what is the size of land under mulch/crops residue? (confirm the size of land by measuring) ....acres

If yes, when incorporating zai do you add mineral fertilizer? 1= Yes 0=No

Animal manure

29. Are you aware of animal manure use as a soil and water conservation technique? *(try to interrogate the respondent with more questions on manure application modalities to clearly know if they are aware)* 1= Yes 0=No

30. Have you applied animal manure in the last one cropping season? *(Where applicable, make observations*)1= Yes 0=No

If yes, what is the size of land under animal manure? (confirm the size of land by measuring) ....acres

Legume-integration

31. Are you aware of legume-integration as a soil and water conservation technique? *(try to interrogate the respondent with more questions types of legumes used and spacing)* 1= Yes 0=No

32. Have intercropped with legumes in the last one cropping season? *(Where applicable, make observations*)1= Yes 0=No

If yes, what is the size of land under legume-intercropping? (confirm the size of land by measuring) ....acres

If yes, what are the major types of legumes used for intercropping?

Preference for technology specific-attributes

33. In a ten-point scale where, 0 is the least score and 10 is the highest score, score each attribute with regard to the soil and water management technology preference *(Discuss the attributes with the farmer before they score, engage more, why the farmer gave a certain score for each attribute)*

Attributes	**Soil and water management technologies**				
	Zai pits	Manure use	Intercropping	Fertiliser use	Mulching
Ease of application					
Soil water conservation					
Soil fertility improvement					
Labour intensive					
Economic returns (yields)					
Information availability					
Cost of inputs					

Thank you

Appendix 2 Checklist for focus group discussion

Theme one: Awareness and use of soil and water conservation techniques applied by farmers in the area. *(Guide the discussion to capture the technologies farmers are using currently and if they are aware of them as soil and water conservation strategies).*

Theme two: Major challenges when implementing soil and water management technologies.

Theme Three: Who majorly works in the farm, especially when applying the soil and water management technologies *(Discuss in line with gender, men women and youth)*.

Theme four: which are the most preferred soil and water management technologies attributes and why? *Discuss the technologies (zai, manure, mulching, intercropping and fertiliser use) and any other technology frequently mentioned. Reference the attributes below;*

1) *How easy the technology is to apply?*
2) *Ability of the technology to conserve soil and water*
3) *Ability of the technology to improve soil fertility*
4) *Nature of the technology with regard to labor needs*
5) *Ability of the technology to improve yields (economic returns)*
6) *Information availability and training on the technology*
7) *Cost implications when implementing the technology (inputs and not labor related inputs)*

Thank you

Appendix 3 Field updates

A Focus Group Discussion session

Enumerator interviewing a farmer

Farmer implementing legume-intercrop

Farmers constructing zai pits