FACTORS AFFECTING SMALLHOLDER FARMERS' ADOPTION OF INTEGRATED SOIL FERTILITY AND WATER MANAGEMENT PRACTICES IN MACHAKOS COUNTY

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DECLARATION

Student’s Declaration

I understand that plagiarism is an offence and therefore declare that this thesis report is my original work and has not been presented to any other institution for any other award.

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DEDICATION

This work is dedicated to my husband Paul Mutuku Kimeu who has been encouraging and supporting me though out the study period. To my children Maureen, Kevin, Gloria and Oprah who look upon me and to whom i hope to inspire to study religiously knowing that the sky is not the limit but the playing ground.

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ABBREVIATIONS AND ACRONYMS

AEZ	Agro-Ecological Zone
AMRI	Agricultural Mechanization Research Institute
APSIM	Agricultural Production Systems sIMulator
ASALs	Arid and Semi-Arid Lands
CAOs	County Agricultural Officers
CCAFs	Climate Change Agriculture and Food Security
CIAT	International Centre for Tropical Agriculture
FAO	Food Agricultural Organization
FRDA	Focal Research Development Areas
GPS	Geo-referencing Position System
ICARDA	International Center for Agricultural Research in the Dry Areas
ICT	Information and Communications Technology
ISSS	International Soil Science Society
KALRO	Kenya Agriculture and Livestock Research Organization
KARI	Kenya Agricultural Research Institute
KCB	Katumani Composite B
KNBS	Kenya National Bureau of Statistics
OECD	Organization for Economic Co-operation and Development.
SSA	Sub- Sahara Africa
SWC	Soil and Water Conservation
SWCPs	Soil Water Conservation Practices
UoN	University of Nairobi.

DEFINITION OF TERMS

Integrated soil fertility and water management practices is a set of soil fertility management practices that includes the use of inorganic fertilizer, organic inputs, and improved germplasm combined with the knowledge on how to adapt these practices to local conditions with the main aim of maximizing agronomic use efficiency of the applied nutrients and improving crop productivity (Vanlauwe *et al*. 2010)

Adoption is defined as a degree to which a new technology is used in long-run equilibrium when farmers' have complete information about the technology and it's potential (Kaliba *et al.* 2000). It is usually the current level of use and intensity of use of a given technology (Bett, 2006).

Perception is the process by which people receive information or stimuli from the environment and transforms it into psychological awareness (Ndiema, 2010).

Household head is that person in the household who takes the overall social and economic decisions, assigns responsibilities, allocate resources and shoulders all the challenges and threats in the household. Likewise, a household is defined as a group of persons who live, cook, and have meals together (Atuhaire *et al.* 2014).

ABSTRACT

Natural resource degradation and water scarcity are a global concern that threatens sustainability of smallholder farmers' livelihoods in arid and semi-arid lands (ASALs). In ASALs, low adoption of Integrated Soil Fertility and Water Management (ISFWM) technologies has contributed to food and nutrition insecurity. A study was carried out to assess factors influencing smallholder farmers' adoption decision of ISFWM technologies in Mwala and Yatta Sub-Counties. A questionnaire was administered to 248 household heads in the study region. Relationships between different variables were determined by the Tobit model and logistic regression models. Results revealed that age, gender, group membership, access to agricultural extension services and inaccessible credit influenced ISFWM adoption significantly ($p \leq 0.05$). Cost of inputs, access to radio information, cost of labor, access to appropriate farm machines, input-output markets and farmers' perception on seasons' reliability affected adoption of ISFWM practices highly significantly ($p \leq 0.01$). Results on logistic model indicated that age between 46-55years was important since it affected the use of tied ridges, organic fertilizers and improved seeds highly significant ($P<0.01$) as well as secondary education which influenced use of both fertilizers highly significantly. Farmers' perception on expected yield of maize and the results predicted by APSIM model clearly showed that farmers' adopting open ridges expected higher maize yields compared to what the APSIM model had predicted which gave an insight why most farmers' were adopting open ridges rather than tied ridges and or zai pits. The Cost-Benefit Analysis revealed that zai pit had the highest CBR among the ISFWM structures practiced in LM AEZ 4 and 5 reporting CBR of 6.98 and 5.63 in LM AEZ 4 and 5 respectively followed by tied ridges which indicated a CBR of 5.29 in LM AEZ 4 and 5.14 in LM AEZ 5 respectively. Majority of the respondents (93.9%) in the project areas were adopting a combination of tied ridges, organic fertilizer and improved seed compared to only 6.1% in the non-project area. There was also significantly ($p \leq 0.01$) higher adoption (76.5%) of a combination of tied ridges, both fertilizer and improved seed in the project area in contrast to 23.5% in non-project area, as well as those adopting a combination of zai pit, both fertilizer and improved seed which indicated 80% compared to only 20% in non-project area. Policy makers should focus on availability of affordable credit services and farm machines; ease access to: information, labor and input-output market infrastructure for enhanced farm productivity. When this happens, farm productivity will be boosted with consequent improved food and nutrition security for enhanced livelihoods of the smallholder farmers' in ASALs.

Keywords.

Low adoption, food and nutrition security, Tobit model, Logistic regression, ISFWM technologies, LM AEZ 4 and 5, ASALs.

CHAPTER ONE

1.0 Introduction

1.1 Background to the study

The world is facing multiple challenges in the 21st century which include poverty, food insecurity, scarcity of water, and most importantly, new and complex challenges emerging due to global warming and climate change (Leonard *et al*. 2010). There are emerging negative impacts of climate change and variability, such as trends towards reduced rainfall that is less reliable and unpredictable with greater spatial and temporal variability, more frequent extreme weather events, especially drought, but also flooding (Leonard *et al*. 2010). Demeke (2003) observed that, throughout dry land areas, depletion of natural resources is among the major problems facing human beings. The impact of these challenges would be minimized if adoption of integrated soil fertility and water management (ISFWM) know-how is enhanced by the smallholder farmers' in arid and semi-arid lands (ASALs) (Demeke, 2003).

In dry land areas of the world, inappropriate agricultural practices account for 28 percent of the degraded soils resulting to low land productivity (Demeke, 2003) and about one quarter of them are found in Africa and Asia. Various authors (Sanginga *et* a*l.* 2009; ISFM Africa., 2012; Vanlauwe *et al*. 2010; Odendo *et al*. 2009) defined ISFWM as a set of soil fertility management practices that includes the use of fertilizer, organic inputs, and improved germplasm combined with the knowledge on how to adapt these practices to local conditions with the main aim of maximizing agronomic use efficiency of the applied nutrients and improving crop productivity.

The major components of integrated soil fertility and nutrient management system are inorganic fertilizers, farmyard manure, compost, green manure, crop residues, recyclable wastes, bio fertilizers and soil moisture conservation measures. The later, include structures like; tied ridges, open ridges, zai pits and contour terraces (Farouque and Takeya, 2007) which collect and concentrate runoff water in the rooting zone. These components contribute nutrients, possess great diversity in terms of chemical and physical properties, nutrient release efficiencies, positional availability, and crop specificity and farmers' acceptability (Farouque and Takeya, 2007) and therefore important in enhancing soil fertility.

Smallholder farmers' tend to adopt and adapt new practices and technologies only if the switch offers additional gains in terms of either higher net returns or lower risks, or both (Shiferaw *et al.* 2009). Studies by (Mati 2005; Toborn 2011; Ajayi *et al.* 2007; Shiferaw *et al.* 2009; Gichangi, 2007; Nabhan *et al.* 1999; Irungu 2011) reported that increased prices of farm inputs like fertilizers, improved seed and farm machinery particularly for making soil conservation structures (tied ridges, open ridges and zai pits) coupled with labor and storage costs, poor roads and market infrastructure contribute significantly to low adoption of ISFWM practices by smallholder farmers'.

Waithaka *et al.* (2007) cited that lack of appropriate knowledge base to combine rainwater harvesting structure with suitable agronomic measures contributed also to low adoption of the ISFWM technologies.

According to Prokopy *et al.* (2008), farmer adoption rates can be improved significantly by focusing on determinants of agricultural best management practices such as capital, access to credit, labor availability, land tenure systems, appropriate farm machinery, access to information and accessibility to agricultural extension services.

Food security situation in the arid and semi-arid parts of Kenya, has continued to deteriorate over the years, despite the concerted efforts by many institutions and organizations to bring the situation down to acceptable levels (FAO, 2007). This has been mainly attributed to a long term decline in agricultural production attributed to among others, low adoption of ISFWM practices and the impact of prolonged drought and the inability to institute effective mitigation measures resulting to slow growth in industrial sector (FAO, 2007). Equally, slow adoption of ISFWM technologies by smallholder farmers' has occasioned in to widespread soil nutrient mining which undermines the ability of many agrarian households to sustainably produce adequate food for household subsistence needs and surplus for income generation. This has also led to, escalating rate of poverty among most rural households (Odendo *et al.* 2009) in the ASALs.

The history of Kenya's efforts to improve integrated soil fertility management shows clearly the positive and the negative aspects experienced that have precipitated to the present situation. The beneficial features comprised of registration of rights for Africans to land in individual freehold title (Whitehead and Tsikata 2003), intensifying and developing African agriculture, providing access to credit, and removing restrictions on growing crops for export (Bradshaw, 1990) stimulating land productivity and creation of wealth (Luke, 2014).

Kenya's modern agricultural foundation was laid in the early twentieth century with the arrival of the white settlers (Bett, 2006). Kenya's land tenure policy, suggested an influential Swynnerton Plan for Kenyan agriculture (Swynnerton 1954), which set in motion of colonial land tenure reform with the benefits of providing formal titling for improving agricultural productivity (Whitehead and Tsikata 2003). During this plan, a strategy to address the looming agricultural crisis in Kenya was drawn up. The plan laid down the foundation for farmer education, the extension system, the agricultural policy and Kenya's land tenure system including soil and water management practices (Bett, 2006). However, the potential of these economic policies undermined the widespread political instability (Whitehead and Tsikata 2003). Furthermore, findings by Platteau, (2000) indicates that land registration had promoted inequality and enhanced insecurity which opened up new possibilities of conflict within the local and the white settlers. Kimaru *et al.* (2006), observed that the colonial authorities in Kenya used coercive approaches to introduce new land-use and soil conservation methods such as terracing and forced destocking to manage natural resource use. The later, may have contributed to negative attitude to soil fertility and water conservation measures among smallholder farmers'. Though this effort was useful, it was abandoned after independence resulting to soil resource degradation.

This study was envisioned to identify the factors that affect smallholder farmers' adoption of integrated soil fertility and water management practices in Lower

Midland Agro Ecological Zone (LM AEZ) 4 and 5 of Yatta and Mwala Sub-Counties in Machakos County.

1.2 Statement of the Problem

Low adoption of ISFWM technologies is a fundamental challenge to food and nutrition security and economic growth in Africa (Bationo *et al.* 2007). Further, Bationo *et al.* (2007) noted that inappropriate ISFWM practices in Africa continent has contributed greatly to low incomes, poor nutrition, vulnerability to risks, threats and lack of empowerment particularly women. In addition, due to low adoption of isfwm technologies, African soils exhibits variation of constraints namely; physical soil loss from erosion, nutrient deficiency, low organic matter, acidity, crusting, moisture stress, aluminum and iron toxicity (Place *et al.* 2003). Some of these constraints occur naturally in tropical soils, but degradation processes related to poor land management issues such as inappropriate integrated soil fertility and water management practices exacerbate them (Place *et al.* 2003).

According to Hazell and Wood (2008), Africa farmers' have yet to experience the kind of technological revolution enjoyed elsewhere as they still uses few modern inputs in agricultural production which is as a result of low adoption of isfwm technologies. For example, its use of inorganic fertilizer (12kg ha^{-1}), share of irrigated crop land (less than 4%) and use of tractors (1 tractor per 620 hectares) rank the lowest of any region by a considerable margin (Hazell and Wood 2008). As a result, yields of all major crops in Africa have grown little over the past 40 years and cereal yields have stagnated for the past 20 years (Hazell and Wood, 2008).

Most economies in Sub-Saharan Africa (SSA) are agriculture-based and about two-thirds of Africans depend on agriculture for their livelihoods. However, recent estimates show that SSA faces what the World Bank study referred to as "an escalating soil fertility crisis" (Nambiro and Okoth, 2012) brought by inappropriate isfwm practices by farmers'.

Majority of farmers' in ASALs are smallholders, many earning less than US$1 per day and having an average farm size of 0.5 to 2 ha (Drechsel *et al.* 2012).This situation coupled with low adoption of isfwm practices escalates poverty in these regions. Similarly, (Drechsel *et al.* 2012; Bationo *et al.* 2007) argued that smallholder farmers' are limited by cash flow hence unable to purchase the necessary nutrients required by the soil for maximum production.

Waithaka *et al.* (2007) stated that, Africa has not changed much in use of fertilizer and its application is low (Staal, *et al*. 2003) because between 1960s and 1990s the change has been an increase of inorganic fertilizer from 5 kg per hectare to 8 kg per hectare. In comparison, China fertilizer use in the 1990s rose from 10 kg per hectare to 110 kg and in India to 240 kg which leads to the question why? Besides, losses of nutrients are also high, for example the estimated losses due to erosion, leaching, and crop harvests are sometimes staggering at over 60-100kg N, P and K per hectare each year in Western and eastern Africa (Miriti *et al.* 2007).

Information by Miriti *et al.* (2007) indicates that soil fertility in the semi-arid lands of eastern Kenya is low particularly where continuous cultivation without nutrient replenishment is practiced. Though integration of water harvesting and nutrient management is important in increasing and sustaining crop production, and also maximization of the return from inputs such as fertilizers, there is limited knowledge on their interaction and crop response in the drylands of Kenya (Miriti *et al.* 2007). Furthermore, Irungu, (2011) reported that low farm productivity in Kenya is caused by low adoption of improved technologies such as seeds and fertilizers due to high poverty levels amongst smallholder farmers'.

High level of poverty lies at the heart of soil fertility degradation problem with better-off households, having more options available and therefore more likely to adopt and manage their soils better. If a farmer has limited agricultural credit access, he or she may not afford to hire labor to do most farm operations such as making zai pits, proper terracing and tied ridges, buy improved seeds, timely planting and weeding that impacts significant negative effect on adoption of ISFWM technologies (Bationo *et al.* 2007).

In Kenya, the ASALs occupy more than 80 % of the country, and because of their vastness, they have an immense scientific, economic and social value (Omoyo *et al.* 2015, Nguluu *et al.* 2014). The ASALs of Kenya area also home to about 10 million people and approximately 70 % of the national livestock herd are more vulnerable to climate variability and change (Omoyo *et al.* 2015). Organic fertilizer is the most widely used nutrient input in these regions to improve soil fertility for crop production (Freeman and Coe, 2002). However, farmers' have indicated that inadequate quantities of organic fertilizers in relation to farm requirements compounded by high labor demands during its application presents as the major constraints they experience for its use (Omiti *et al.* 1999).

Data on fertilizer use in Machakos district, though scanty suggests that use of the input was low (Freeman and Omiti 2003). Further, the work of Freeman and Omiti (2007) suggested that high prices and high levels of risk associated with low and highly variable rainfall pattern, insufficient input distribution systems, unavailability of inputs in rural retail shops and relative return of the inaccessible inputs prohibit fertilizer use among the subsistence farmers'.

Climate change presents an additional burden for smallholder farmers' in ASALs which translates into production risks associated with crop yields due to high probability of extreme weather events, uncertainty of the timing of field operations and investments in new technologies (Fosu-Mensah *et al.* 2012). Moreover, the way soils are managed can improve or degrade the natural quality of soils (Gruhn *et al.* 2000). Reports by (Gruhn *et al.* 2000; Kathuli *et al.* 2014) suggested that mismanagement of the soils by smallholder farmers' in ASALs of Kenya due to low adoption of ISFWM practices has led to degradation of millions of acres of land through erosion, compaction, salinization and acidification.

1.3 Objectives of the study

1.3.1 General objective

The overall objective of the study was to assess the factors that lead to low adoption of ISFWM technologies and assess the cost effectiveness of the technologies in Mwala and Yatta Sub-Counties, Machakos County.

1.3.1 Specific objectives

1.3.2.1 Assess factors that influence smallholder farmers' adoption of ISFWM Technologies in Mwala and Yatta Sub-Counties.

1.3.2.2 Compare simulations using APSIM model predictions to understand farmers' perception of expected yields of maize when applying different ISFWM technologies in Mwala and Yatta Sub-Counties.

1.3.2.3 Identify cost-effective soil fertility and water management technologies in zone 4 and 5 in Yatta and Mwala Sub-Counties.

1.3.2.4 Compare smallholder farmers' adoption levels of ISFWM technologies in the project and non-project sites in the study regions.

1.4 Research Questions

1.4.1 What are the factors that influence smallholder farmers' adoption of ISFWM technologies in Yatta and Mwala Sub-Counties?

1.4.2 Are simulations using APSIM predictions able to enhance understanding of farmers' perceptions on yield of maize in Mwala and Yatta sub-counties?

1.4.3 Which ISFWM technology is cost effective in LM AEZ 4 and 5 in Mwala and Yatta sub-counties?

1.4.4 Is there any difference in adoption levels of ISFWM technologies regarding smallholder farmers' between the project and non-project sites in Yatta and Mwala sub-counties?

1.5 Justification of the Study

In Africa, a call for urgent found solutions to enhance adoption of ISFWM technologies is critically required as many parts of Sub-Saharan Africa are characterized by soil nutrient depletion (Heisey and Mwangi, 1996; De Jager *et al.* 1998). This will also include identifying the reasons why farmers' are not adopting the improved practices even though they are quite aware of the numerous benefits.

Research work on soils fertility and moisture management practices in Sub- Sahara Africa (SSA) has generated numerous outputs but very few have been translated into adoption and this is the greatest challenge Africa needs to address in order to achieve the highly sought food and nutrition security for its people (Bationo *et al.* 2011). Sub-Saharan Africa's problems not only illustrate the multifaceted nature of food insecurity, but also suggest that different dimensions require different approaches to successfully improve food security and nutrition such as appropriate ISFWM technologies (FAO, IFAD and WFP, 2015).

Despite many factors that influence technology adoption Feder *et al.* (1985), Kaliba *et al.* (2000), argued that much research on soil management has focused on technical aspects of soil management without consideration of determinants and attributes of the adoption process, which are important in guiding technical research. Moreover, adoption studies on soil fertility management have mainly focused on adoption of a single technology (Franzel, 1999; Kiptot *et al.* 2007).

Various authors (Bird, 2009; Mathers *et al.* 2009; Walonick, 2011) reported questionnaire methodologies as fundamental tools used for acquiring research information but none cited integrating survey questionnaire methodologies with crop growth models in order to understand the reasons behind farmer's decision making. Thus models such as the Agricultural Production Systems sIMulator (APSIM) have been used in this study to predict crop response to various ISFWM technologies which are linked to farmer decision making.

Improving natural resource management result in increasing productivity and income for the current generation as it is about preserving the quality of resources to safeguard the livelihood of future generation (Barrett *et al.* 2002). Furthermore, Nyikahadzoi *et al.* (2012) found that low uptake of improved technologies and inappropriate soil fertility management practices compromise environmental sustainability and food security among smallholder farmers' and therefore it is important to identify ISFWM factors, determinants and attributes of adoption in arid and semi-arid lands of Kenya for enhanced land productivity.

Besides, an important driver of agricultural growth for any country is higher returns to farm production; to increase those returns, producers in large numbers must adopt agricultural practices that increase productivity and use resources such as land and water more efficiently, effectively, and in an environmentally sustainable manner (World Bank Group, FAO and IFAD, 2015).

There is therefore a need to have holistic approach in unlocking the authentic constraints the smallholder farmers' face and experience regarding adoption and negative perceptions of ISFWM practices thus providing a more realistic target for action (Odendo *et al.* 2009). In this regard, it would be worthwhile to have a better understanding of the factors that will condition adoption and possibly encourage adoption of isfwm practices. Thus allowing formulation of well-tailored interventions that would result in rationalization of the scarce physical, financial and human resources that the nation most requires for use in other sectors of the economy (Chomba, 2004).

Therefore, food security and nutrition situation is expected to continue deteriorating and could worsen in future if integrated soil fertility technology measures are not taken up quickly in lower Eastern Kenya (Njeru *et al.* 2013) particularly in Mwala and Yatta sub-counties. In addition, Njeru *et al.* (2013) noted that more research is needed to understand the gaps that exist between scientific research findings and farmers' perceptions towards these technologies.

1.6 Limitation of the study

The study was limited by adequate resources and time to reach the whole population. However, this limitation was solved by scientifically using a representative samples for the study which reduced the time that could have been taken to interview the whole population. Time was also efficiently utilized by pre-arrangement on date and time of interview by the researcher and the household heads.

1.7 Scope of the study

Even though research work done in introducing integrated soil fertility and water management (ISFWM) practices by the KARI/McGill project covered three Counties of lower eastern Kenya, only household heads existing in LM AEZ 4 and 5 in Yatta and Mwala Sub-Counties of Machakos County were purposively, stratified according to agro-ecological zones and randomly selected for the interview.

The main focal point was based on factors that affect adoption of ISFWM practices in this region. Therefore, this study concentrated on factors that were assumed to contribute to low adoption of ISFWM practices by the smallholder farmers' in ASALs of lower eastern Kenya. These factors include: Social demographic characteristics, economic characteristics and farm machinery related characteristics.

Moreover, due to time limitation and resource constraints, the study targeted only the project beneficiaries and non-beneficiaries in Yatta and Mwala Sub-Counties of Machakos County.

CHAPTER TWO

2.0 Literature review

2.1 Adoption of Integrated Soil Fertility and Water Management (ISFWM) by the Smallholder farmers'

2.1.1 Smallholder farmers' determinants and attributes that influence adoption of ISFWM technologies

Adoption has been defined as a degree to which a new technology is used in long-run equilibrium when farmers' have complete information about the technology and it's potential (Kaliba *et al.* 2000). Thus, adoption at the farm level indicates farmers' decisions to use a new technology in the production process (Kaliba *et al.* 2000)

Studies conducted by Binod (2010) on adoption of improved maize varieties in developing countries, particularly Africa and South Asia, have pointed out a number of socio-economic characteristics, agro-ecological variables, and farmers' perception as important determinants of improved maize varieties in different countries. In addition, adoption literature shows that the adoption of agricultural technologies is affected by demographic, institutional, and technical factors, farmers' perception about technology attributes and their attitude towards risk (Binod, 2010). Thus labor demanding technologies may coincide with the low season of labor availability and in turn affect acceptance. On the other hand, studies on farmers' perceptions confirm that delayed response to adoption of soil conservation practices could be attributed to the demand and complex nature of such innovations, with some requiring more labor for instance making tied ridges, zai pits, planting, manure application, transporting, and their integration (William *et al.* 2012).

Report by Hughes and Venema (2005) suggested that soil, water and nutrient management options for optimizing crop productivity are more complex than some other technical options such as the introduction of a new variety. Farmers' must also optimize their use of available nutrient resources in order to maximize returns in the form of biological yield or cash under a given set of environmental and socio-economic conditions. This involves minimizing losses from applied nutrients, and enhancing positive interactions between the various activities on the farm and between the farm and its immediate surroundings and this can only be possible if adoption of ISFWM within the smallholder farming system is augmented.

Different scientists (Binod., 2010; Prokopy *et al.* 2008; Steven, 2010; Foti, 2008) have identified education level, age, capital, income, farm size, security of land tenure, soil characteristics, access to information, agricultural credit availability, yield and profitability, market access, positive environmental attitudes, environmental awareness, and utilization of social networks as factors that influences a new technology. Bett (2006) noted different variables such as age and education affect adoption of agricultural technologies either positively or negatively. He found that higher education influences adoption decision positively because it is associated with ability to synthesis more information on technologies that are on offer and this leads to improvement of the general management of the farm. On the other hand, more education can lead to a household head having more available occupation options thereby sparing less time to attend to this farm activities affecting adoption of agricultural related technologies negatively (Bett, 2006).

2 .2.2 Farmers' perceptions on soil fertility

Perception is the process by which people receive information or stimuli from the environment and transforms it into psychological awareness (Ndiema, 2010). According to Ndiema (2010), an individual perception will differ markedly from another in the same situation because of individual's previous experiences.

Smallholder farmers' have often perceived chemical fertilizers as substitutes to additions of soil organic matter rather than as compliments, a situation that is not surprising in case its use is constrained by lack of financial resources (William *et al*. 2012). However, according to William *et al.* (2012), organic fertilizers are not substitutes because they are capable of producing benefits associated with organic inputs, such as increasing the water holding capacity of soils or buffering low pH soils. Equally, Corbeels *et al.* (2000) observed that farmers' in Tigray Ethiopia described productive and fertile land as '*reguid*', which literally means fat and thus well prepared land with a good seedbed is known as '*limui*', which says nothing about its fertility or productivity concluding that, farmers' perceptions on soil fertility are not limited to the soil's nutrient status. Corbeels *et al.* (2000) further noted, that farmers' interpretation of soil fertility reflects the definition of soil productivity used by the International Soil Science Society (ISSS). The society, describes soil productivity as the capacity of a soil in its normal environment to produce a specified plant or sequence of plants under a particular system of soil management (Corbeels *et al.* 2000). William *et al.* (2012) reported that the farmers' perception of the soil fertility problem is a key determinant of the acceptance of improved fallows in Tanzania and that if farmers' perceptions are that soil fertility is not a problem, labor and capital resources will not be channeled towards this cause.

Ajayi (2007) reported that 93% of the farmers' interviewed in South Africa highly appreciate mineral fertilizers. This was evident from the farmers' perception that, "it produces bumper harvest" within a relatively short period and the input was effective and required lower labor inputs to work with. The key complaints of farmers' regarding mineral fertilizers is that they "spoil the soil," they need to be applied repeatedly in each farming season and that they are expensive and must be procured on cash or credit basis neither of which is readily available to farmers'.

In another study by Marenya *et al.* (2008) reported that low levels of education, poor access to and quality of agricultural extension services may lead to farmers' misperception of soil conditions and yield responses from fertilizer inputs. In particular, if farmers' under estimate one or both, they may fail to replenish soil nutrients because they erroneously view such investments as unnecessary, unprofitable or both.

2.3 Conceptual model

2.3.1 Conceptual model and adoption drivers of soil conservation practices

The effects of soil degradation and water shortages on crop productivity have led researchers to introduce some innovative practices such as mulching, banding, zai pits, open ridges, tied ridges, contour ridging, ripping, minimum tillage and others to check the downward spiral in agricultural production (Shiferaw *et al.* 2009).

Technology adoption can be modeled within frameworks that explain individual choice behavior (Oluoch-Kosura *et al.* 2001). Demeke (2003) developed a conceptual model for the adoption of soil conservation practices incorporating the diffusion of innovative ideas and the accompanying innovation-decision processes that occur in deciding whether to adopt or reject a particular practice. Studies by Oluoch-Kosura *et al.* (2001) reported that the decision to adopt an innovation is a behavioral response arising from a set of alternatives and constraints facing the decision technology adoption phenomena necessitating a different analytical approach from those used in consumer theory and hence discrete choice theory is a more appropriate basis for analysis.

Authors Drechsel *et al.* (2012); Ndiema, (2010) listed and discussed the following adoption drivers:

1) Returns to land, capital and labor: The major objective of farmer is to maximize returns on investment particularly for those production factors, which are in short supply but are required by the new technology.

2) Capital and credit availability- Farmer may be unable to raise sufficient funds to invest in the technology because of lack of capital, limited access to credit, or temporary cash flow problems.

3) Labor peaks and opportunity costs- Although the lack of fertile land can be the prime constraint to technological adoption, labor is still considered a major constraint especially to “low external input” technologies.

4) Land tenure- Permanent ownerships of land leads farmers’ to engage large capital investment in their farms compared to land tenure leases increasing ISFWM adoption practices

5) Perceptions and values- Farmer’s individual perception of the degree of a given problem may influence his or her decision on possible solutions. The same applies to farmers’ preferences for certain technology based on real experience or perceived characteristics.

6) Risk and stability- Farm enterprises are among those systems where disturbances are frequent and therefore yield fluctuations may occur due to erratic rainfall, floods,

insect pest attacks and diseases to the extent the farmer succeeds in minimizing such risks and uncertainties, he or she succeeds in maintaining returns.

7) Access to information and extension services-Poor performance of extension services or poor research-extension linkages are often blamed for limited spread of technologies.

8) Perceived attributes of an innovation -To understand farmers' perceptions of a technology, a number of attributes of such technology should be analyzed and these are: Comparative advantage, not only higher yields but also better soils, taste, compatibility with previous and current farming methods, complexity (how simple or difficult is the technology?), triability (can the technology be tested?), visibility (is the impact obvious and convincing?), trouble-free (are there any cultural, gender, technical difficulties?).

The length of time farmers' wait before adopting a new technology is a complicated process that may be influenced by interactive effects of many factors, some of which vary with time, whilst others may not vary over time (Odendo *et al.* 2011). Moreover, effects of most variables are often contradictory across technologies and study areas. Thus farmers' are discouraged to engage in land management practices due to input and output price variations, poor accessibility to output and input market, and poor flow of information e.g. technologies, markets and cropping practices brought about by poor infrastructure, farmers' face constrained resources in land, labor, management skills and capital hence activities and practices that ameliorate the pressure on these resources are more appealing to farmers' (Chomba, 2004).

The speed of adoption of an innovation is important in various aspects (Odendo *et al.* 2011). In addition, Odendo *et al.* (2011) observed that innovations that are adopted rapidly are more profitable than those with low rates of adoption. This is because, the benefits occur faster and the ceiling of adoption is achieved earlier other factors remaining constant. Steven (2010) noted that variables that were favored mostly were practices that were easier to implement and more effective for resource protection and food production. Years in residence (tenure security) and income emerged as primary explanatory variables for adoption of soil water conservation practices (SWCPs), while soil quality and formal education were perceived as secondary.

Farmers' adoption decisions of new agricultural technologies in semi-arid of eastern Kenya were used to identify factors that influence adoption of modified fanya juu (Bett, 2006). He observed, that the results from the estimated intensity of adoption model (Tobit) confirmed that variation in the proportion of land with technology was significantly influenced by age and level of education of the household head, access to markets, technology attributes, credit, off-farm income and risks.

2.3.2 Conceptual model and role of knowledge, attitude and perceptions in adoption of ISFWM technologies

Meijer, *et al.* (2014), listed and discussed the following linkages and interaction between extrinsic and intrinsic variables that influences decision-making process of adoption of any agricultural innovations including ISFWM technologies. (Figure 1). There are a large number of extrinsic variables which help shape the knowledge, attitudes and perceptions. The extrinsic variables can be grouped into three categories:

a) Characteristics of a smallholder farmer, which include personal characteristics (gender, age, marital status, etc.), socio-economic characteristics (income, assets, education, etc.), personality characteristics (self-confidence, independence, etc.), position in social networks (network size, connectedness, frequency of interaction, etc.), status characteristics (control over political power or economic resources) and familiarity with the technology.
b) Characteristics of an external environment that affect the development of knowledge, attitudes and perceptions as well as the geographical settings (ecology, topology, soil conditions, climate, demography, proximity to markets, roads and forests, etc.), societal culture (language, tribal background, religion, ideologies, norms, values, etc.) and political conditions (land tenure and access rights, national policies, the structure of government, bureaucracies, the political character of a state and the existence of political freedoms and laws).
c) Characteristics of agricultural innovation- characteristics of the new technology that also shape the knowledge, attitudes and perceptions. In the case of agricultural

innovations, it is the benefits and costs of the new practice, such as the contribution it can make to household income, food security, soil fertility improvement, health and nutrition, firewood and building materials and the costs such as purchasing inputs, equipment, managing pests and diseases, etc., which influence knowledge, perceptions and attitudes.

The intrinsic variables includes:

d) Influence of the intervening variable (Knowledge, attitudes and perceptions) in

(e) The decision-making process of adoption of agricultural innovations (Figure 1)

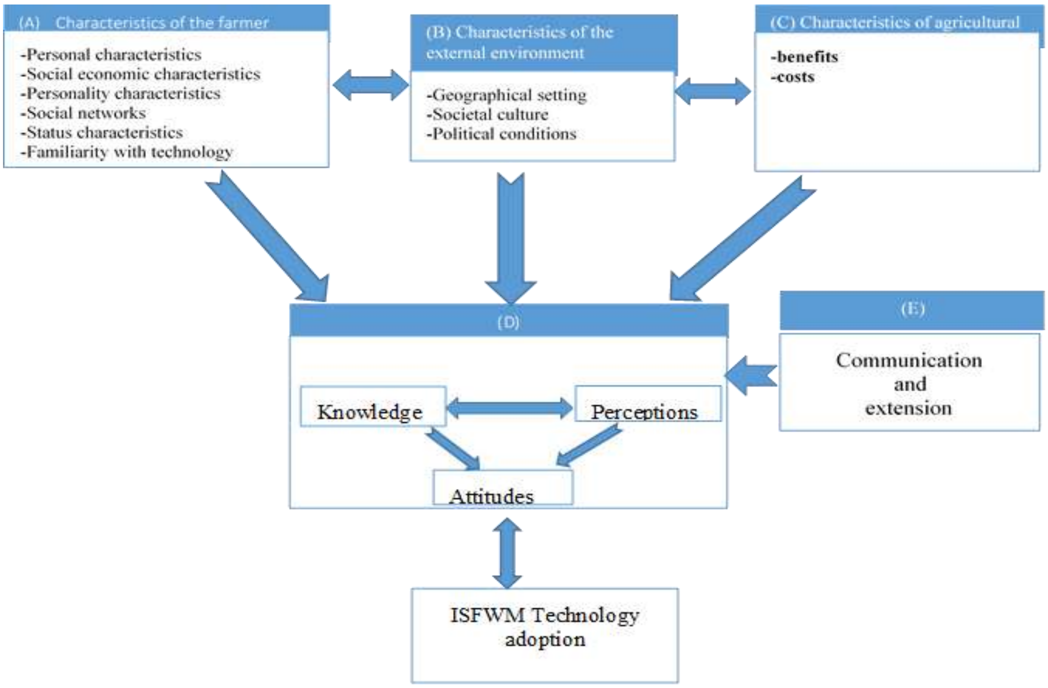

Figure 1.Conceptual frame work model and the role of knowledge, attitude and perceptions in adoption of an agricultural innovation. Adapted from (Meijer *et al*. 2014).

2.4 Combination levels of ISFWM technologies as they influence adoption

Research has revealed that the actual and potential levels of use of organic fertilizer is an important factor in determining the minimum requirements for take-off for organic agriculture in Nigeria (Olayide *at el*. 2011). The observation was that it was rated low

(37 percent) despite its potentials (Olayide *at el*. 2011). Furthermore, survey done on conservation agriculture in Zimbabwe confirmed that only 20% smallholder farmers' had adopted a combination of three aspects of the technologies namely minimum tillage, surface soil cover and use of crop rotation at the time of the study (Chiputwa *et al*. 2011). Studies done by Gichagi *et al.* (2007) in Machakos district showed that about 60% of the farmers' did not use inorganic fertilizers and among the users, 50% apply less than the recommended rate of the input. He further indicated that manure supplies are certainly low and of poor quality and might not alone prevent a decline in crop yields. Moreover, Gichagi *et al.* (2007) observed that, **r**egardless of research findings indicating that inorganic fertilizers can be feasible and profitable strategies in managing soil fertility, its adoption of fertilizer has been low. Similarly, Kathuli *et al.* (2010) reported that farmers' expressed their willingness to adopt sub-soiling and ripping technologies for rainwater harvesting, but indicated the need for the technology to be modified for enhanced adoption.

Studies by (Gathaara, et al. 2010; Odhiambo, 2015; Ogada, et al. 2014) reported an average of 20.2% on adoption of different soil fertility and water management practices in Machakos County.

2.5 The Empirical Model

2.5.1 Specification of analytical models and variables'

2.5.1.1 Tobit analytical Model

A farmer's decision to apply a technology such as soil fertility management can be explained by a set of factors that influence the welfare criterion of expected efficacy. These factors are related to the characteristics of the technology, its environment and the potential adopter. Smallholder farmers' are therefore assumed to make ISFWM adoption practices on basis of utility maximization (Freeman and Omiti 2003). Thus farmers' efficiency maximization framework has been used in a number of studies to model farmers' adoption decisions using Tobit model (Jogo *et al.* 2013).The model (by Tobin, 1958) measures not only the probability that the smallholder farmer will adopt ISFWM practice but also the intensity of use of the technology once adopted (Akinwumi and Zinnah 1993). Moreover, Tobit procedure is a special case used for more general censored regression model (Mudiwa 2011), it is also efficient and consistent.

Following conceptual framework described by Freeman and Omit (2003), the study assumed that farmer's adoption decision is based on an underlying utility function. Since the farmer has a choice to adopt the recommended ISFWM practices or not to adopt, let the farmer's choice be represented by Y_i*, where Y_i*=1 if the farmer chooses to adopt the ASALs recommended ISFWM packages (which includes tied ridges and or zai pit + Combined organic and inorganic fertilizers + improved seed) and Y_i*=0 if otherwise. The latter may include use of less combination of recommended ISFWM practices in ASALs.

The specifications of ISFWM adoption decision is therefore based on a Tobit model defined as

$Y_i^*=\beta x_i + \varepsilon_i$

$Y_i = Y_i^*$ if $Yi^* > c$

$Y_i = 0$ if $Yi^* \leq c$

Where Yi^* is a latent variable indexing isfwm technology adoption, Y is an observable but censored variable measuring both the adoption and intensity of use of ISFWM practices, c is an unobservable threshold, β is a vector of unknown parameters or unknown coefficients, X is a vector of explanatory variables (such as Age, gender, education, Credit access, access to agricultural extension, seed, both organic and inorganic fertilizers) and ε_i are residuals that are independently distributed with i zero mean and constant variance.

2.5.1.2 Logistic Regression Model

Estimated coefficient of the logit model define the slope or the rate of change of a function of the dependent variable per unit change in the explanation variable (Bett, 2006). A positive sign for a coefficient indicates that the log of the odds ratio of adoption of ISFWM technologies increases as the value of the variable rises and a negative sign indicates that the ratio decreases as the value of the variable drops (Bett, 2006).

The logistic model is specified as follows:

$P_i = 1/1+\exp[-(\alpha+\beta_i X1_i + \beta_2 X_{2i} + \text{-----------} + \beta_n Xn_{i)}]$

Where

P_i is the probability that an individual will make a decision to adopt a particular technology.

α and β_n are parameters to be estimated

X_{ni} is the n^{th} explanatory variable to the i^{th} observation.

2.6 Agricultural Production System Simulator (APSIM) Model

The Agricultural Production Systems Simulator (APSIM) model is a mature and stable modeling framework used widely in Australia and elsewhere in the domain of farming systems research and extension (Holzworth *et al.* 2006; Zhibo *et al.* 2014).

Work done by Keating and McCown (2001) quoted that models of production processes in crop and animal sciences provide means of evaluating possible causes for changes in yield over time within a given location. According to Keating and McCown (2001) cited that APSIM is a modeling framework that allows individual modules of key components of the farming system (defined by model developer and selected by model user) to be 'plugged in'. They reported that APSIM was designed at the outset as a farming systems simulator that sought to combine climate risk analysis (which requires sensitivity of yield to weather extremes) with prediction of the long-term consequences of farming practice on the soil resource (e.g. soil organic matter dynamics, erosion, acidification etc.). The model has been used in the semi-arid areas of eastern Kenya to predict soil fertility parameters and has been shown to be effective in mimicking experiments (Keating *et al.* 1992; Nguluu, 1994).

Several authors, (Amarasingha *et al.* 2014; Fosu-Mensah *et al.* 2012; Boyd, 2015; Fosu-Mensah *et al*. 2012) cited that crop models such as APSIM predict the response of crops to weather and soil management by simulating the growth and development of plant organs such as leaves, roots, stems and grains. Thus, a crop growth simulation model not only predicts the final state of total biomass or harvestable yield, but also contains quantitative information about major processes involved in the growth and development of a plant.

The model provides not only the short time-step essential for simulating effects of management on nutrient availability and crop growth but also incorporates longer-term effects of changes in soil organic matter content on N mineralization and hence on crop growth. Fosu-Mensah *et al.* (2012) reported that the model can be used to quantify potential yield gaps between prevailing management options and potential yields of different crops. In addition, it provides a means of quantifying possible dynamics in crop yield responses over a given time within a given location (Fosu-Mensah *et al.* 2012).

In addition, the production models serve as a research tool to valuate optimum management of cultural practices, fertilizer use water use and also evaluate impact of climate change on agricultural production, economies of climate change impact.

The major APSIM pay-off comes from the ability this gives scientists to link research-derived understanding with decision-makers' needs to address difficult system management issues (Hammer *et al.* 1993). Thus APSIM environment is an effective tool for analyzing whole-farm systems including smallholder farmer's perceptions of ISFWM technologies.

Holzworth *et al.* (2014) reported that an important application of APSIM on climate change research has been the study of crop performance under recent weather variability of past decades. This type of study enables evaluating key climate components affecting historical yields, the effectiveness of recent management adaptation and to explain current yield-gaps (Holzworth *et al.* 2014).

Farmer's individual perception of the degree of a given problem may influence his or her decision on possible solutions (Drechsel *et al.* 2012). Carberry *et al.* (2009) reported that farmers' in Zimbabwe apply manure preferably on land planted to maize and then sorghum usually in *ihlabathi* (sandy) soils rather than *ipane* (sodic-like) soils. The amount of manure applied varied a great deal from 3 to 8 scotch-carts (about 600 kg) ha^{-1} in every 2–5 years (Carberry *et al.* 2009).

The study found out an average of 12kg DAP ha $^{-1}$ {Di-Ammonium Phosphates; (18:46:0)} inorganic fertilizer was used during planting by the household heads in the study area in October-November 2011/12SR. In similar studies, Nambiro and Okoth (2012) reported that almost 80 % farmers' in Western Kenya used very low amounts (< 10 kg ha $^{-1}$) of Di-Ammonium Phosphates (18:46:0) and UREA (46:0:0) or CAN (26:0:0) in a given season. Similarly, Fosu-Mensah *et al.* (2012) reported that farmers' in Africa usually apply about 9 kg/ha fertilizer compared to 86 kg/ha in Latin America, 104 kg/ha in southern Asia, and 142 kg/ha in Southeast Asia.

2.7 Cost-Benefit Ratio Analysis

Cost–benefit analysis (CBA), sometimes called benefit–cost analysis (BCA), is a systematic approach to estimating the strengths and weaknesses of alternatives that satisfy transactions, activities or functional requirements for a business (Umesh, 2014). A cost–benefit analysis involves the identification of costs and benefits occurring over the economic life of a project (Woltersdorf *et al.* 2014). Cost benefit analysis (CBA) is used instead of cost-effectiveness analysis (CEA) because according to Dossetor, (2011), CEA considers only the costs as they are expressed in monetary terms whereas CBA goes one step further to quantify benefits of the outcomes. Furthermore, CBA is used to determine options that provide the best approach for the adoption and practice in terms of benefits in labor, time and cost savings and many more (Umesh, 2014).

CHAPTER THREE

3.0 Methodology

3.1 Materials and methods

3.1.1 Description of the Study Area

The survey was conducted in pilot research areas found in lower Eastern Kenya. The research study which was funded by the Canadian and Kenya governments was established to assess the effects of different ISFWM technologies on crop yield. It had activities in the ASALs of LM AEZ 4 and 5 of Yatta and Mwala, Machakos County, Kenya.

Yatta Sub-county lies between 700-800 m a.s.l and latitude 0° 03′ and 1°12′ South and longitude of 37°47′ and 38°57′ East (Jaetzold and Schmidt, 2006). The sub-county covers an area of 1059km^2, with a population of 125,755; 60,794 males and 64,961 females and 24,630 households (Jaetzold and Schmidt 2006) and most of whom were not in the study area. However, the study targeted for only 331 households that were located in the study zone.

Mwala sub-county lies in geographical coordinates of 00^o 38'N 33^o 29' E/ 0.633^o N 33.483^o E, altitude between 1100-1550m a.s.l (KNBS 2010). The sub-county covers an area of 481.5 km^2, a population of 89,211; 42,992 males and 46,219 females and 16,685 households (Jaetzold and Schmidt, 2006) most of whom were outside the study area. The area targeted by the study had 306 households.

The two sub-counties falls under lower midland agro-climatic zone 4 and 5, which are classified as ASALs (Jaetzold and Schmidt, 1983). The rainfall distribution ranges from 500 to 800 mm annually (Nguluu *et al.* 2014; Ibraimo and Munguambe, 2007) which is erratic, unreliable and occurs as short duration with high intensity storms coupled with partial or total crop failure in over 50% of the times (Walker 2008). The rainfall reliability is 66% with less than 100-450mm during the growing period of the first rainy season and that of second rainy season ranges between 80-530mm (Jaetzold and Schmidt, 2006). Soils are fragile and prone to decline in fertility, attributable to erosion hazards due to poor natural and human-modified vegetation cover and low land value per unit area. Moreover, the soils are generally sandy-loam, shallow, and deficient in major plant nutrients such as nitrogen and phosphorus, and susceptible to hard pan formation due to their inherent low organic matter (Kathuli *et al*. 2014).

3.1.2 The research design

The design from which the household heads were chosen from was based on the extension model formally referred to as the ‘Primary and Secondary Participatory Agricultural Technology Evaluations’ (PPATEs/SPATEs) or, in lay terms, the ‘farmer-led adoption approach’ (Leigh *et al*. 2014). The model constitutes both technology and technique; it contains what to adopt to build resilient farming systems, and how to scale up that adoption. Thus farmer-led adoption approach catalyzed both horizontal and vertical scaling-up of adoption of resilience-building technologies and practices (Leigh *et al*. 2014) such as use of soil and moisture conservation structures’ (e.g. tied ridges in comparison with open ridges), improved versus local seeds and appropriate use of fertilizers.

Selection of household heads was also done from non-project areas otherwise referred to as non-PPATEs/SPATEs areas where the farmer led adoption approach did not register its present during the entire project period (March 2011-August 2014)

The research implementation areas are shown in Tables 3.1 and 3.2 and figures 2, 3 and 4

Table 3.1Project implementation FRDAs and PPATEs in Mwala and Yatta Sub-Counties

Sub-county	FRDA	AEZ	PPATE	No. randomly selected
Yatta	Katangi	5	Meko Ma Aka	5
			Kamumbu SHG	5
			Mengukya SHG	6
	Ndalani	4	Mavia Atatu	11
			Ken Works	10
			Wendo wa Mutui	10
	Kinyaata	5	N3K	5
			Ika wi Yike	5
			Makutano local poultry	5
Mwala	Kavumbu	4	Kavumbu Seed growers	5
			Kavumbu Paradise SHG	5
			Kavumbu Net work	6
	Miu	4	Miu Fruit growers	5
			Itithini fruit growers SHG	5
			Wendono wa Aka Ngamba	5
	Kyawango	5	Wendano wa Kwa Mwonga	10
			Kithito women group	11
			Wendo wa Mbusyani	10
	Total			124

Table 3. 2 Non FRDA/PPATE Households members

Sub-county	LM AEZ	Location	Sub-Location	No. of villages	No. randomly selected
Yatta	4	Ndalani	Kwa-Ndolo	6	31
	5	Katangi	Kyua	6	31
Mwala	4	Mango	Wetaa	6	31
	5	Wamunyu	Kaitha	6	31
Total					124

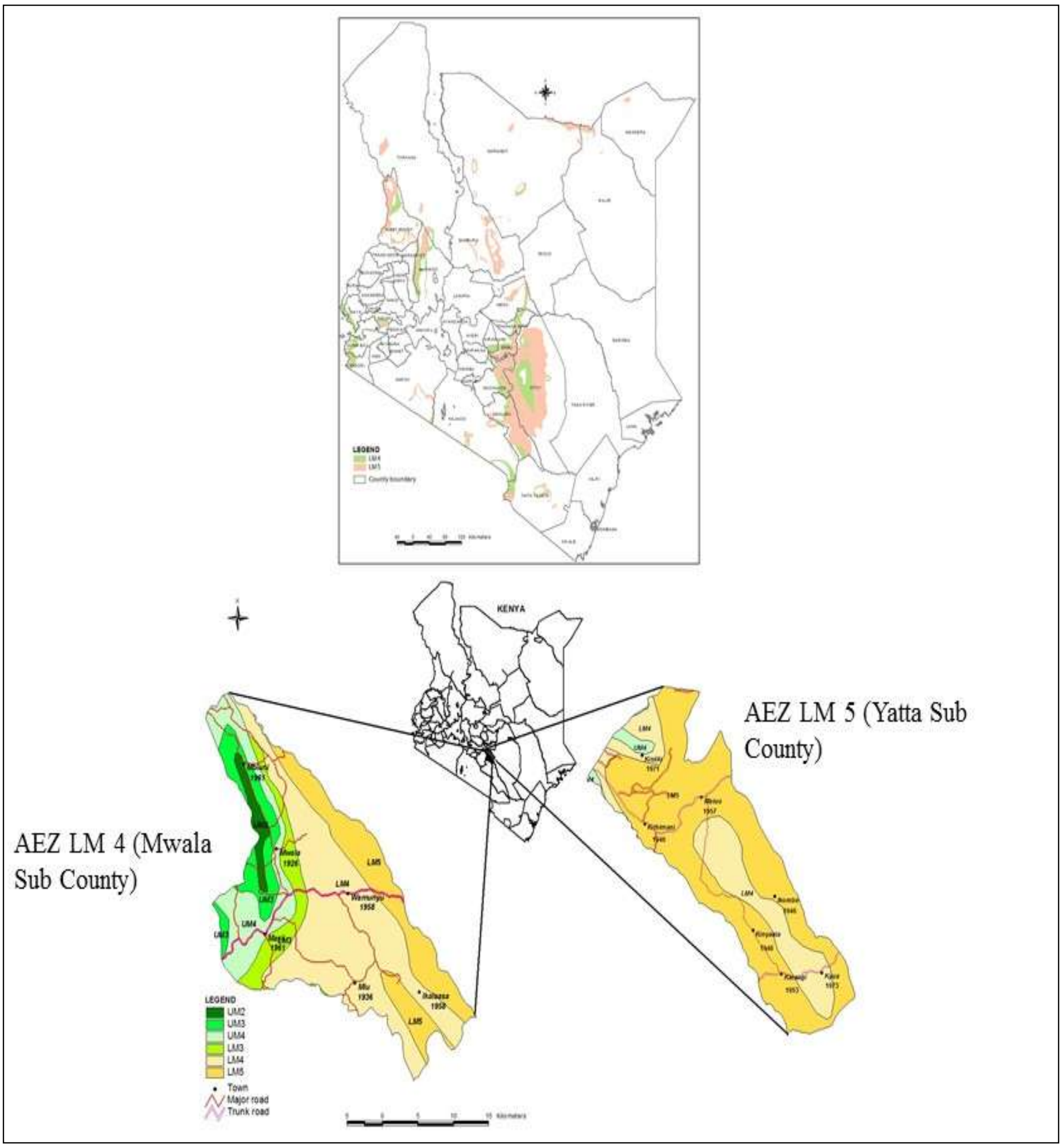

Figure 2. Map of Kenya showing the position of Yatta and Mwala sub-counties and their LM AEZ 4 and 5. Adapted from (KALRO-Kabete 2012)

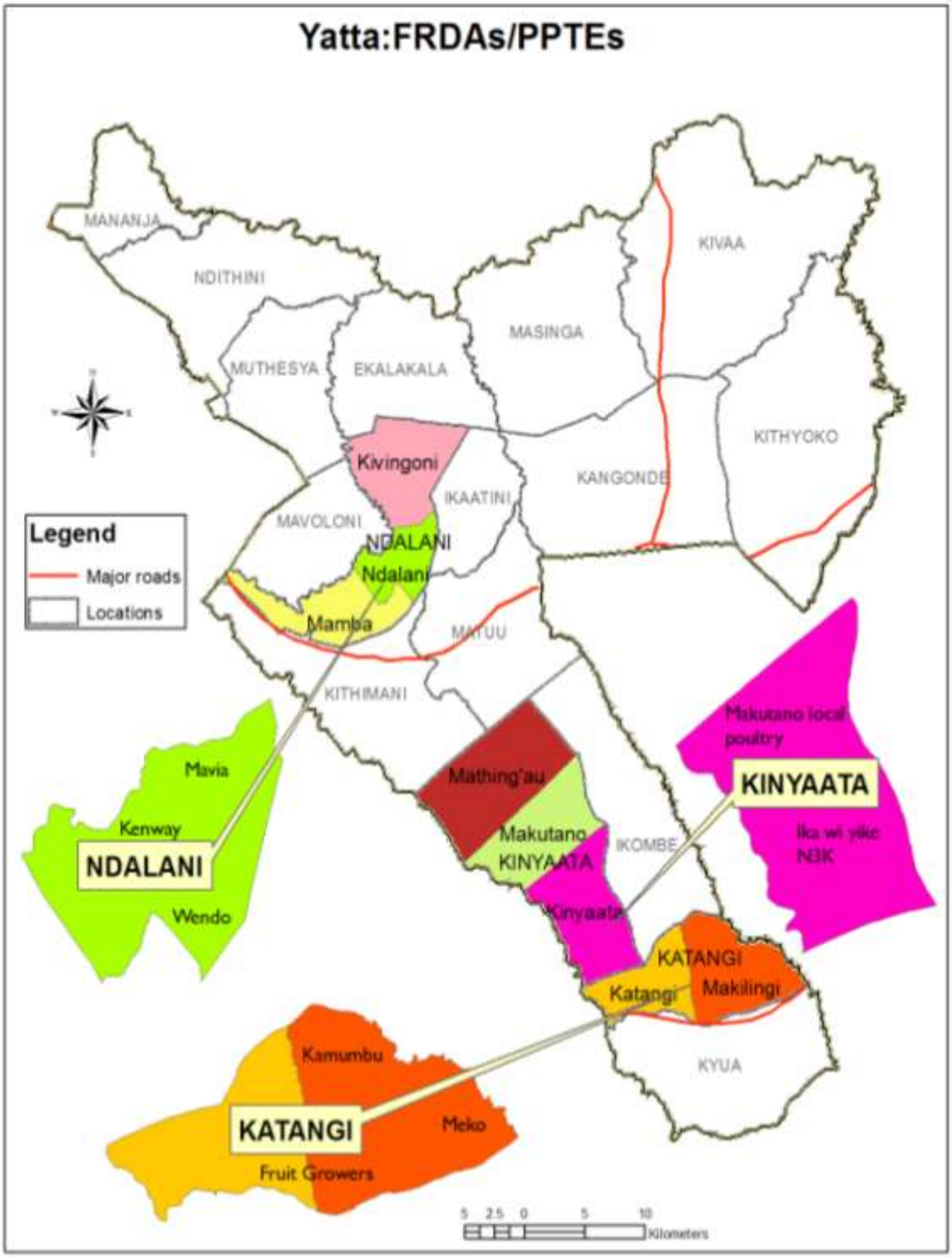

Figure 3. Yatta sub-county showing FRDAs and PPATEs. Adapted from (KALRO-Kabete 2012)

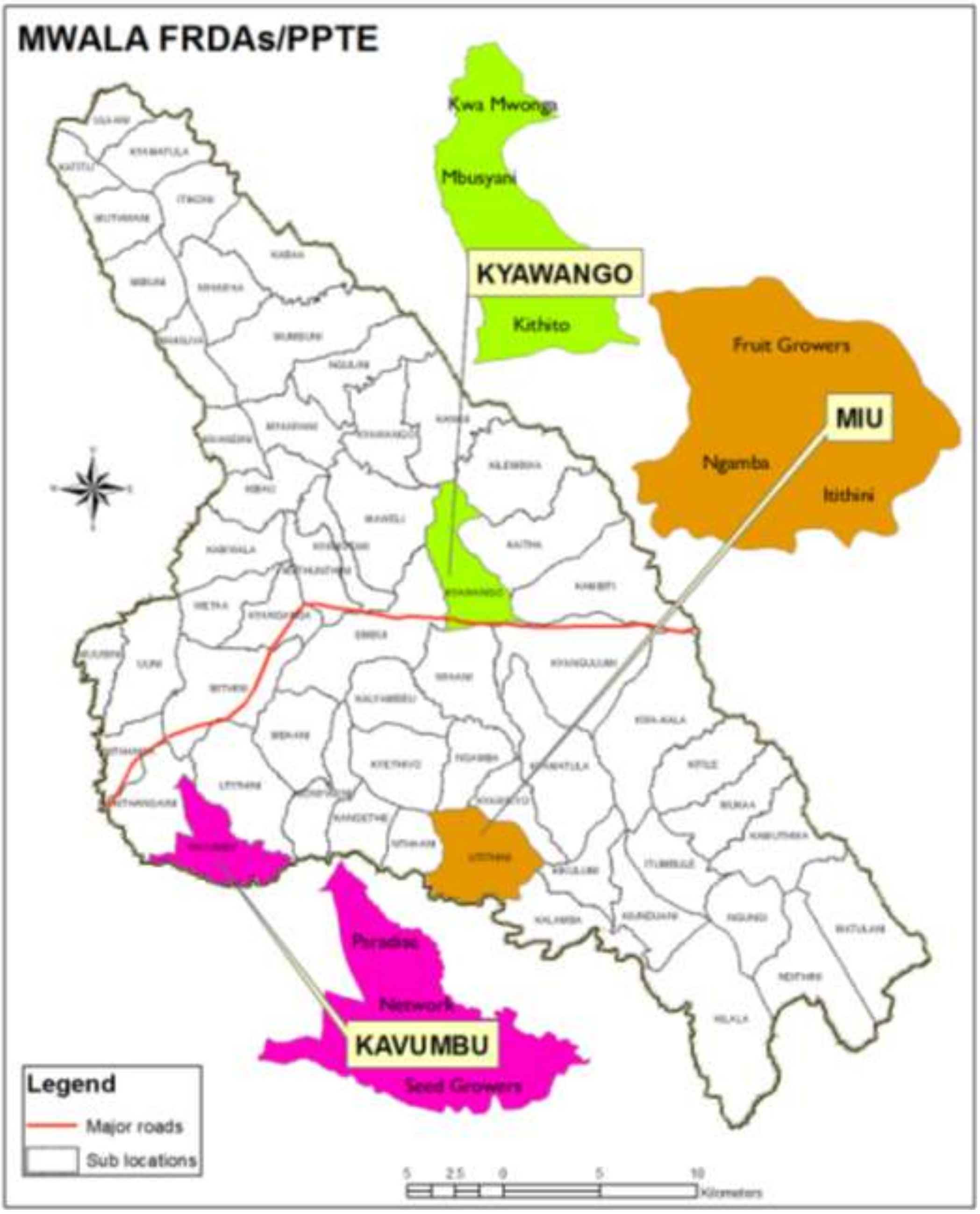

Figure 4.Mwala FRDAs/PPATEs. Adapted from (KALRO-Kabete 2012)

3.1.3.0 Base Sample-size Calculation for household heads in Mwala and Yatta sub-counties

Household demographic characteristics lead to understanding of the farming household heads as these influence farming decisions, choice and adoption of agricultural technologies (Njarui, *et al.* 2012; Atuhaire *et al.* 2014).

Household head is that person in the household who takes the overall social and economic decisions, assigns responsibilities, allocate resources and shoulders all the challenges and threats in the household in addition, a household is defined as a group of persons who live, cook, and have meals together (Atuhaire *et al.* 2014).

3.1.3.1 Household heads sample size determination for the ISFWM technologies survey

The sample size for the study was determined using the formula described by Magnani (1997) as shown

$$\mathbf{n} = \frac{\mathbf{t^2 \times p(1-p)}}{\mathbf{m^2}}$$

Description:

n = required sample size

t = confidence level at 95% (standard value of 1.96)

***p* =** Estimated % of soil fertility and water management practices in the study area= 20.2% (Gathaara, et al. 2010, Odhiambo, 2015, Ogada, et al. 2014)

m = margin of error at 5% (standard value of 0.05)

E.g. Sample size $= \frac{1.96^2 * 0.202(1-0.202)}{0.05^2} = \frac{3.8416*0.202}{0.0025} = 247.7$

Based on the above formula described by Magnani (1997) the sample size was expected to have a total of 247.7 respondents. This was slightly adjusted to 248 for ease of sampling and avoid non-integer samples in the different zones and areas.

3.1.4 Sampling of household heads

A multi-stage sampling process involving a combination of purposeful, random and substitution sampling was applied in order to draw a representative sample of household (OECD, Statistics, 2005; Geta, *et al.*, 2013). The first step involved purposive selection of the two sub-counties (Mwala and Yatta) based on AEZ and areas with highest concentration of ISFWM activities as well as in areas falling under where the project activities were not done.

A purposive identification of non-project areas was also used to identify sites that fall far from the project sites with buffer zones in between to ensure no influence by any project activities. Random selection of the respondents was done from the list of entire population of household heads provided by the local sub-chiefs and the local sub-county agricultural officers in each study area.

A random sample of 124 households was taken in each sub-county, for a total of 248 households. In case of any missing household heads substitution selection was involved of the next household in the list. Global Position System (GPS) tool was used to identify precisely the position of homesteads of all households in question.

Data was collected for October-November 2012 short rains (SR) season and March-April 2013 long rains (LR) season using both qualitative and quantitative data collection techniques. Administration of the 248 questionnaires started in Mid-March 2014 and concluded after three weeks. The questionnaire captured data on the socio-demographic characteristics, economic characteristics and machine related characteristics of the household heads in the study area.

3.2 Data Sources, Tools and Methods of Collection

3.2.1 Data sampling

Sampling of 248 household heads was done from the two sub-counties from a list of entire population of the households provided by the area assistant chief. However, the study targeted for random selection of 331 households heads in Yatta and 306 household heads in Mwala. Information was obtained from 124 household heads who had participated in project activities and 124 household heads who had not been exposed to any project activities. In each group, 62 participating household heads in each sub-county were randomly selected for interview, 31 household heads from LM AEZ 4 and same number from LM AEZ 5. The same sampling was done from four locations where non-participating households were identified from a sub-location in each zone who were located far from project activities and assumed not to have been influenced by project activities. Geo-referencing Position System (GPS) tool was used in order to identify the position of the households.

3.2.2 Sources of data

Pretesting of the questionnaire was done in a totally different location from where the survey was conducted. This was done before the actual survey to define the effectiveness of the survey questionnaire.

This also aided in determining the strengths and weaknesses of the survey concerning question format, wording and order. Data was then obtained from secondary sources for sites description and primary data collected using questionnaires. Data collected was for October-November 2012 short season and March-April 2013 long season and the study used both qualitative and quantitative data collection techniques using the following tools.

3.2.3 Questionnaires

Questionnaires were administered to 248 household heads that were selected for the study. The items on the questionnaire were developed on the basis of the objectives of the study. The instruments were then administered to household heads to collect the required data in face-to-face interview and their responses recorded accordingly. The questionnaire captured data on the socio-demographic characteristics of the household heads, what type of ISFWM technologies practiced, constrains that slow down ISFWM adoption, socio-economic and farm machine related characteristics.

The survey questionnaire was designed to solicit information on smallholder farmers' perception on what quantities in kilograms of maize yield per hectare they expect to harvest after applying different quantities of either organic, inorganic or combination of fertilizers in their farms with responses to both inorganic and organic fertilizer use recorded as a continuous variables. Agricultural Production Systems sIMulator (APSIM) was then used to generate simulation predictions on maize yield per hectare using 53 years data; as a result mean yield of maize per hectare was obtained.

3.3 Observations

Data was collected by well-trained enumerators so that a detailed understanding of the values and beliefs held by the members of the population could be understood. Information of inputs used such as the type of maize seed farmers' plant (Improved and Local), what quantities of inorganic and organic fertilizers applied during 2012SR and 2013LR seasons, what ISFWM structures practiced, use of a single, or combinations of the technologies.

The quantities of what smallholder farmers' expected on yield of maize in kilograms per hectare was also recorded down. Farmers' perception on the most reliable season (the October-November short rains versus March-April long rains), the smallholder farmers' expectation on yield of maize (increased/reduced/no yield difference) when they use different amounts of organic and inorganic fertilizers. In addition, ISFWM adoption constraint such as fertilizer and labor costs, lack of proper farm machinery, social economic factors such as age, education level, land tenure farmers' adoption drivers on why they use certain inputs such as ease access of fertilizers and less labor requirement were also recorded.

Available climate data (Rainfall, humidity, temperatures) from 1957 to 2009 for Katumani was used for simulation in order to predict the yield of maize. APSIM software was then configured to simulate the maize yield response to organic and inorganic fertilizers using ISFWM structures explicitly Open Ridges (OR), Tied Ridges (TR) and Zai pit (ZP) over 53 years. The recommended rate of inorganic fertilizer for ASALs is 40kgN ha^{-1} (Onyango *et al.* 2012, Marenya *et al.* 2008) and that of organic fertilizer is 4,000kg ha^{-1} (Bekeko *et al.* 2013). Miriti *et al.* (2007) reported that in a continuous cropping system, results have shown that the optimum maize yields were obtained from the application of 40 kg N ha^{-1}. Thus Miriti *et al.* (2007) suggested that any more addition of fertilizer rates higher than 40 kg N ha^{-1} does not result in increased crop yields. Based on these findings, the study used organic fertilizers at the rate of (0tons ha^{-1}, 600kg ha^{-1} and 4,000$Kgha^{-1}$) and inorganic fertilizers at a rate of (0$kgha^{-1}$ 12$kgNha^{-1}$ and 40$KgNha^{-1)}$ in APSIM to predict the maize yield results. The results were then compared with the farmers' perceived maize yields in kg per hectare.

During the household head interview, a total financial plan approach was undertaken to estimate costs and returns accruing to each households. The financial plan summarized the income, cost and profit. Gross income which is the difference between total revenue and total variable cost was analyzed.

The total cost component was expressed as: Total Cost (TC) =Total Fixed Costs (TFC) +Total variable Costs (TVC) whereas the Gross Revenue (GR) was generated using the Total revenue (TR)-Total Variable Costs (TVC) in a hectare of land.

Total revenue was the income received from sale of the farm produce and the TVC was the costs incurred during the farm operations per hectare such as labor costs, chemical used for storage of the farm produce, seed costs and costs of fertilizers in the two seasons (i.e. October-November 2011SR and March-April 2013 LR.

The Cost-Benefit Ratio (CBR) was then derived from Total Revenue divided by Total Costs.

Data on adoption of ISFWM technologies was also documented on farmers' different technology practices such as different use of the ISFWM structures, (Open ridges, Tied ridges and Zai pits), use of improved and local maize seed, and use of inorganic and organic fertilizers and to what quantities.

3.4 Dependent, independent, Endogenous and instrumental variables

Dependent, Independent, Endogenous and Instrumental variables were considered during the study. The dependent variable used in the model was ISFWM adoption, the independent variables comprised of the land tenure systems, education, labor, gender, age, group membership, crop income, yield of crops grown, farm size, inaccessible credit, agricultural information access, and accessibility of inputs, and output market access. Degree of adoption in this case was a continuous dependent variable. The degree of adoption referred to as the different levels of ISFWM technologies practiced by the smallholder farmers' in both sub-counties. The off-farm income was used in the Tobit model as endogenous variable and the lower Mid-land Agro-Ecological Zones (LM AEZ) was used as the instrumental variable.

Table 3.3 Summary of independent (explanatory), endogenous and instrumental variables

	Variable Code	Operational definition of the variable
Household Age	Age	Categorical variable
Household gender	Gender	A dummy variable with value 1 if the household is female and 0 otherwise.
Education level	Educlevel	Categorical variable
Membership in social groups	Grpmemship	A dummy variable with value 1 if belonging to any social group and 0 otherwise.
Land tenure	Landtenr	A dummy variable with a value of I if household head has secured land title deed and 0 otherwise
Seedcost	ImprvdSdcost	A dummy variable with a value of I if seed cost is the major constraint and 0 otherwise
Inorganic fertilizer cost	InorgFertcost	A dummy variable with a value of I if fertilizer cost was the major constraint and 0 otherwise
Labor	Labor	A dummy variable with a value of 1 if cost of labor was a major constraint and 0 if otherwise
Crop income	Crpincome	Continuous variable in Kes.
Agricultural extension access	AgrExtAccess	A dummy variable with a value of 1=yes if access to agricultural extension was a problem and 0=No if otherwise
Agricultural credit access	AgrCredinaccess	Dummy variable with a value of 1 if access to agricultural credit was a problem and o otherwise
Farmers' perception on yield	Perceptydincres	A continuous variable if farmers' perceives use of inputs 1= Increased yield, 2=Reduce yield 3=No
Farmers' perception on Oct-	PercptOctNov SRReliable	Dummy variable with a value of 1 if farmer perceives Oct/Nov SR was most reliable and 0
Accessibility of inputs	Inputaccess	Equals to 1 if inputs were easily accessible of inputs and 0 otherwise.
Output Market Access	OutptmktAccess	Dummy variable with a value of 1 if output-market access was a problem and o otherwise

Based on Adolwa *et al.* (2012) definition of ISFWM, for any household in the study area to have adopted ISFWM technologies, the farmer must have acknowledged to have practiced any of the following adoption levels.

Table 3.1: Different combinations levels of ISFWM technologies practiced in Mwala and Yatta Sub-Counties

	TR+org+local seed	ZP+org+local seed
OR+org+improved seed	TR+org+improved seed	ZP+org+improved seed
OR+inorg + local seed	TR+inorg+ local seed	ZP+inrg+local seed
OR+inorg+ improved seed	TR+inorg+ improved seed	ZP+inorg+improved seed
OR+combined fert + local	TR+combined fert+local seed	ZP+combined fert + local seed
OR+combined fert +improved seed	TR+combined fert+improved seed**	ZP+combined fert+improved seed**

Key. OR-Open ridges, org-Organic fertilizer, Inorg-Inorganic fertilizer, fert-fertilizer, combined fert-combination of both organic and inorganic fertilizers, Tr-Tied ridges and ZP-zai pit,
*least recommended, **highly recommended for arid and semi-arid lands

3.5.0 Data Analysis

Collected survey data was analyzed by use of IBM SPSS analytical software version 22 using descriptive statistics, comparison of means using paired sample t-test multinomial logistic regression and excel Microsoft software. Relationships between different variables was determined by the Tobit (Econometric) model, as presented by Freeman and Omit (2003) conceptual framework as well as use of logistic regression model, Farmers' perception on expected yield of maize using different ISFWM practices was analyzed using IBM SPSS analytical software version 22 and compared with the APSIM model prediction results.

This comparison captures how closely APSIM may approximate farmers' perception on yield of maize after using different Soil fertility and Water Management technologies. This information can therefore be used to guide the farmers' at arriving on a better likelihood decisions underlying their perceptions on expected yields of maize (Marenya *et al.* 2008).The open ridges (OF), tied ridges (TR) and the zai Pits (ZP) structure cost efficacy was examined using Cost Benefit Ratio (CBR) analysis. Comparison on ISFWM technology adoption levels between PPATEs and Non-PPATEs was achieved via IBM SPSS version 22 using descriptive statistics.

CHAPTER FOUR

4.0 RESULTS

4.1.0 Social demographic characteristics of the household heads

Social demographic information in this study comprised of gender, group membership, age, and education levels of the household heads in both sub-counties (Table 4.1). Regarding gender, the distribution of the sample size in both sub-counties revealed a mean of 29% females and 71% males.

About a mean of 68 % of the farming household heads interviewed belonged to a certain social group with only 31.9 % reported not to affiliate to any social group. Farmers' were asked to indicate the categories of their age with majority of the household heads stating an age bracket of between 46-55 years as reported by 49.2% of the household heads in Mwala and 51.6% in Yatta (Table 4.1).

Majority (51.6 % and 64.9%) of the household heads in Mwala and Yatta respectively had attained primary school level of education with a mean of 58.3% followed by secondary level of education (mean of 29%). Only 5.9% of the farmers' had attained post-secondary level of education in both sub-counties.

Table 4. 1 Demographic characteristics of households in Mwala and Yatta Sub-Counties

	Mwala n=124	Yatta n=124	Mean
Gender of household heads (%)			
Female	29.8	28.2	29(.482)
Male	70.2	71.8	71(.458)
Group membership (%)			
Belonging to social group	57.8	78.4	68.1 (.495)
None group membership	42.2	21.6	31.9 (.441)
Age bracket of household head			
26-35	5.6	5.6	5.6 (.488)
36-45	37.9	28.2	33.1 (.472)
46-55	49.2	51.6	50.4 (.473)
>55	7.3	14.5	10.9 (.463)
Education levels of household			
Informal education	6.2	8.1	7.15 (.437)
Primary	51.6	64.9	58.3 (.464)
Secondary	35.9	21.6	28.8 (.485)
Post-secondary	6.3	5.4	5.9 (.547)

Note. Figures in parenthesis indicate standard deviation of the means

4.1.1 Factors influencing smallholder farmers' adoption of ISFWM technologies in Yatta and Mwala sub-counties

It was hypothesized that adoption of the ISFWM technologies by household heads was influenced by social demographic characteristics such as age, gender, education, group membership and others which included; land size, land tenure systems, access to inputs, access to radio, cost of labor, availability of appropriate farm machinery, access to information and services, inaccessible credit services and output markets, farmers' perception on seasons' reliability and perception on improved seeds.

These factors were regressed using Tobit model to determine their significance in influencing adoption of ISFWM technologies (Table 4.2). Social demographic characteristics such as age, gender, group membership were significant ($P \leq 0.05$) while education was highly significant ($P \leq 0.01$) in influencing the general adoption of ISFWM technologies by the household heads. Similarly, access to extension and inaccessible credit services were also significant ($P \leq 0.05$). Access: to inputs, radio, labor, out-put market, farm machinery and perception on seasons reliability affected adoption of ISFWM technologies highly significant ($P \leq 0.01$) in both sub-counties.

Table 4.2 Tobit regression analysis of factors affecting smallholder farmers' adoption of ISFWM technologies in Mwala and Yatta Sub-Counties

ISFWM adoption variables	Coef.	Std.	P value
Age	-0.676	0.303	0.027*
Gender	0.685	0.303	0.025*
Education	-0.033	0.013	0.010**
Group membership	0.207	0.085	0.016*
Land size	-0.001	0.002	0.452
Land tenure systems	-0.207	0.112	0.068
Access to inputs	-1.307	0.180	0.000**
Access to radio	0.066	0.012	0.000**
Labor	0.645	0.221	0.004**
Availability of farm machinery	0.025	0.158	0.001**
Access to extension services	0.675	0.303	0.027*
Inaccessible credit services	-0.028	0.012	0.017*
Access to out-put markets	-2.550	0.091	0.006**
Perception on season reliability	-0.258	0.089	0.004**
Perception on improved seeds	0.160	0.094	0.090
Constant	3.844	0.263	0.000

Note.* Significant at 5% and ** Significant at 1% levels

4.1.2 Influence of social demographic factors on adoption of specific ISFWM technologies

Regarding specific ISFWM technologies, adoption varied among the household heads. Table 4.3 indicates that majority (64.1%) of the household heads had adopted use of open ridges compared to 31.5% and only 4.4% who were reported to have adopted use of tied ridges and zai pit, respectively.

Majority (50.8%) of the household heads were found to apply organic fertilizer in their farms compared to merely 5.2% who had adopted use of inorganic fertilizers. Those who applied both fertilizers were reported to be 44%.

Moreover, 87.5% of the household heads were reported to have adopted the use of improved seeds compared to only 12.5% who were started to have adopted the use of local seeds.

Table 4. 3 Adoption of different ISFWM technologies as reported by household heads in Mwala and Yatta sub-counties

Type of technology	Specific Technology	n=248
Structures	Open Ridges	64.1 (159)
	Zai pits	4.4 (11)
	Tied Ridges	31.5 (78)
Fertilizers	Inorganic fertilizer	5.2 (13)
	Organic fertilizer	50.8 (126)
	Both fertilizer	44 (109)
Seeds	Local seed	12.5 (31)
	Improved seed	87.5 (217)
	Sample size	248

Note. Figures in parenthesis indicate frequencies of the household heads

4.1.2.1 Influence of gender on adoption of different ISFWM technologies

Table 4.4 shows adoption of different levels of ISFWM practices as influenced by gender of the household heads in the study area. The following combinations of technologies were reported to be practiced in both sub-counties: open ridges, organic fertilizer and improved seeds; open ridges, combined fertilizers and improved seed;

tied ridges, organic fertilizer and improved seed; and tied ridges, combined fertilizers and improved seeds.

Adoption of the above technologies were generally found to be higher among male household heads compared to the female counterpart and gave a highly significant ($p \leq 0.01$) effects. Only a combination of zai pit, organic fertilizer, and improved seed influenced ISFWM adoption of technologies significantly at 5% level.

Table 4. 4 Effect of gender on adoption of different ISFWM technologies

ISFWM technologies	Male n=176 %	Female n=72 %	t-value	P
Or+Org+Local seed	6.25 (11)	4.2 (3)		ns
Or+Org+Improved seed	29 (51)	27.8 (20)	10.614	.000**
Or+Inorg + Local seed	0.6 (1)	1.4 (1)		ns
Or+Inorg+ Improved seed	1.7 (3)	4.2 (3)		ns
Or+combined fert + Local seed	2.3 (4)	1.4 (1)		ns
Or+Combined fert+Improved seed	25 (44)	23.6 (17)	6.708	.001**
Tr+Org+Local seed	1.7 (3)	5.6 (4)		
Tr+Org+Improved seed	13.1 (23)	12.5 (9)	9.000	.001**
Tr+Inorg+ Improved seed	1.7 (3)	1.4 (1)		
Tr+Combined fert+Improved seed	14.8(26)	1.4 (1)	6.708	.001**
zp+Org+Improved seed	1.1 (2)	11.1 (8)	8.000	.015
zp+Inorg+ Improved seed	0.6 (1)	1.4.(1)		ns
zp+combined Fert + Local seed	0.6 (1)	1.4 (1)		ns
zp+Combined fert+Improved seed	1.7 (3)	2.8 (2)		ns

Note. Figures in parenthesis indicates frequencies, * significant at 5%, **significant at 1%, ns =not significant. Key: Or=Open ridges, Org=organic fertilizer, Inorg=Inorganic fertilizer, Fert=fertilizer, TR=Tied ridges, Zp=Zai pits

4.1.2.2 Effect of social farmer group on adoption of ISFWM technologies

Results in table 4.5 indicates significantly ($p \leq 0.01$) higher (10.9) percentage of non-group members who practiced a combination of open ridge, organic fertilizer and local seed compared to the household heads who were affiliated to certain social groups (2.6%). In addition, household heads who were reported to align themselves to social groups were found to practice significantly ($p \leq 0.01$) higher percentage of tied ridges as soil conservation structure, organic fertilizer and improved seed; a combination of tied ridges, combined fertilizers and improved seed as well as a combination of zai pit structure, combined fertilizers and improved seed.

Table 4. 5 Influence of farmer groups on adoption of ISFWM technologies

ISFWM Technologies	Group Member	Non group member n=92		
	%	%	t-test	P value
Or+Org+Local seed	2.6 (4)	10.9 (10)	13.682	0.000**
Or+Org+Improved seed	23.1 (36)	37 (34)	8.000	0.015*
Or+Inorg + Local seed	0.6 (1)	1.1 (1)		ns
Or+Inorg+ improved seed	1.9 (3)	3.3 (3)		ns
Or+combined fert + Local	1.9 (3)	3.3 (3)		ns
Or+Combined fert+Improved	19.9 (31)	32.6 (30)		ns
Tr+Org+Local seed	3.2 (5)	2.2 (2)		ns
Tr+Org+Improved seed	21.2 (33)	(0)0	6.708	0.001**
Tr+Inorg+ improved seed	1.9 (3)	(0)0	2.28	0.04*
Tr+Combined fert+ Local	(0)0	(0)0		Ns
Tr+Combined fert+Improved	18.6 (29)	5.4 (5)	6.708	0.001**
Zp+Org+Improved seed	0.6 (1)	2.2 (2)		Ns
Zp+Inorg+Improved seed	0.6 (1)	1.1 (1)		Ns
Zp+Combined fert + Local	0.6 (1)	1.1 (1)		Ns
Zp+Combined fert +Improved	3.2 (5)	0 (0)	3.873	0.008**

Note. Figures in parenthesis indicates frequencies, * significant at 5%, **significant at 1%, ns =not significant Key: Or=Open ridges, Org=organic fertilizer, Inorg=Inorganic fertilizer, Fert=fertilizer, TR=Tied ridges, Zp=Zai pits.

4.1.3.0 Oct/November 2012 short rains versus March/April 2013 long rains isfwm practices reported in Mwala and Yatta sub-counties

Table 4.6 shows different isfwm practices reported by household heads in both sub-counties.

Majority (92.3%) of household heads perceived that October/November short rain is usually more reliable compared to the March/April long rains (7.7%). This was evident by most (90.7%) and (70.6%) of the household heads who stated that they applied organic and inorganic fertilizers respectively during the short rains.

Similarly majority (84.7%) of household heads in the study area were reported to have planted improved seeds in the short rains compared to only (62.1%) in long rains. Furthermore, most (19.4%) of the household heads indicated that they planted the recycled seeds in long rains compared to merely 5.2% in the short rains.

Table 4. 6 October/November 2012SR versus March/April 2013 LR isfwm practices

Variable	Oct/November SR		Mar/April LR		Both seasons	
	Freq.	%	Freq.	%	Freq.	%
Season more reliable n=248	229	92.3	19	7.7	-	-
Season organic fert. Applied n=248	204	90.7	2	0.9	42	8.4
Season inorganic fert. Applied n=248	175	70.6	1	0.4	72	29
Improved	210	84.7	52	62.1	-	-
Local	25	10.1	18	7.3	-	-
Recycled	13	5.2	48	19.4	-	-

4.1.4 Logistic regression results showing influence of age and education classifications' of the household head on adoption of ISFWM technologies

Table 4.7 shows logistic regression coefficients (β), odds ratios and significance statistics for adoption of different ISFWM technologies as predicted by household heads age and education. As far as age is concerned, adoption of tied ridges, inorganic fertilizers and improved seeds significantly varied among household heads. Thus household heads who were aged between 46 to 55 years showed highly significant ($p \leq 0.01$) though negative effect on adoption decision of the above three ISFWM technologies.

Furthermore, the model showed that the household heads who were between the category of 46-55 year of age had the highest though negative influence on adoption of tied ridges (coefficient= -3.232, odds ratio=25.32), this suggests that *ceteris paribus*, for every one unit increase of the farmer's age, the odds ratio (i.e. the probability) in favor of adopting tied ridges would reduce by a factor of 25.32. Similarly, by estimating the logit model the results obtained a coefficient of -3.158 (odds ratio =23.533), a highly significant but a negative effect on inorganic adoption decision of the age category 45 to 55 years. Thus *ceteris paribus*, if a unit increase in of the age of a household is realized by one unit, the probability of inorganic fertilizer adoption drops by 23.533 units.

Adoption decision of household age on improved seeds showed a highly significant ($p \leq 0.01$) but also a negative effect with a coefficient of -3.038 and odds ratio of 20.867 suggesting that as age advances by one unit, the likelihood of the household heads to adopt improved seeds compared to local seeds reduces by 20.867. However, the lowest influence though positive was adoption decision of the household heads who had attained secondary level of education that indicated significantly more likely to adopt both fertilizers than organic fertilizer alone ($p \leq 0.01$, odds ratio=0.002). Thus holding all things constant, if a unit increase in education of a household head who had acquired secondary education was achieved by one unit, the log of odds ratio in favor of adopting both fertilizer goes up by 0.002 units.

Table 4. 7 Effect of age and education distribution of the household head on adoption of ISFWM technologies

Technology	Factor	Classification	β	Std.	P	Odds ratio
Tied Ridges	**Age**	26-35	0.472	0.834	0.572	0.624
		36-45	0.418	0.630	0.507	0.658
		46-55	-3.232	1.081	0.003	25.32**
	Education	No education	0.441	0.622	0.478	0.643
		Primary	-0.768	0.838	0.360	2.156
		Secondary	0.092	0.017	0.896	0.912
Zai pits	**Age**	36-45	-1.401	1.003	0.163	4.058
		46-55	-1.192	0.919	0.195	3.292
	Education	Primary	-1.030	1.740	0.187	2.812
Inorganic	**Age**	36-45	-1.100	1.510	0.218	3.017
		46-55	-3.158	0.954	0.001	23.533**
Both fertilizer	**Age**	26-35	-0.918	1.340	0.247	2.504
		36-45	-0.156	0.085	0.77	1.169
		46-55	0.321	0.382	0.537	0.725
	Education	No education	-1.500	2.790	0.095	4.492
		Primary	-1.240	2.540	0.111	3.465
		Secondary	16.027	0.729	0.000	0.002**
Improve seed	**Age**	26-35	0.210	0.028	0.868	0.811
		36-45	0.665	0.907	0.341	0.514
		46-55	-3.038	0.944	0.001	20.867**

Note. The reference categories are: Open ridges, Organic fertilizers and local seed, ** significant at 1% level

4.2 Comparison of simulated and farmers' expected yields of maize in Yatta and Mwala Sub-Counties

Figure 5 shows trend results on farmers' perceived expectations on yield of maize and that of APSIM generated after using different combination of ISFWM technologies in Mwala and Yatta sub-counties.

Generally, farmers' using open ridges expected higher maize yields compared to what the APSIM model predicted when they applied inorganic fertilizer in the range of 0KgN-40kgN ha $^{-1}$, organic fertilizer in the range of 0.6tons-4tons ha^{-1} as well as a combination of inorganic and organic fertilizers at the rate of 12KgN $^{-1}$ ha with 0.6tons^{-1} ha respectively. Farmers' perceived expectations on yield of maize per hectare and predictions of the model indicated equal results when a combination of 40kgN $^{-1}$ ha inorganic and 4tons $^{-1}$ ha organic fertilizers was applied. However, when both inorganic and organic fertilizers and their combinations were applied using tied ridges and zai pits as soil conservation measures, farmers' expectations on yield of maize were reported to be lower than what the APSIM model had predicted.

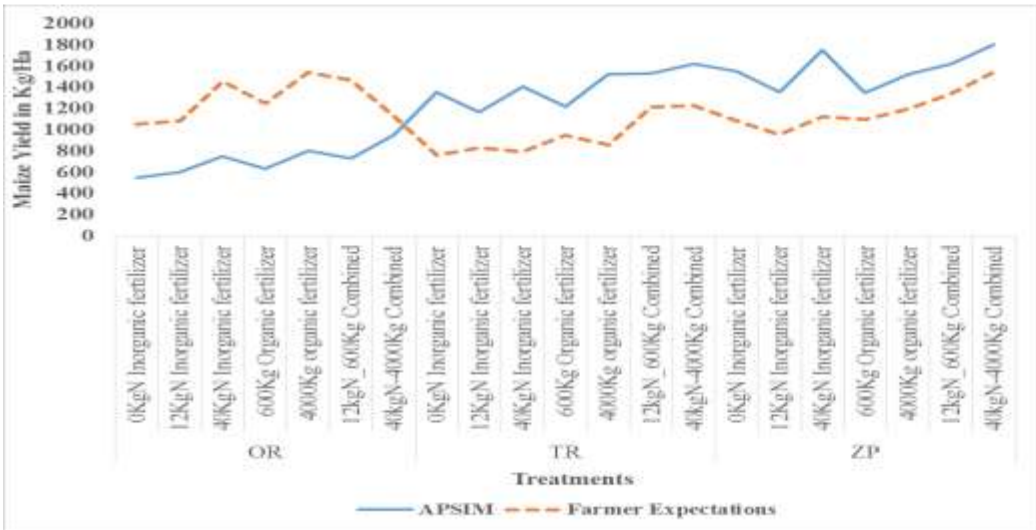

Figure 5. Comparison between APSIM simulated and farmers' expectation results on maize yields under different ISFWM technologies

4.3 Cost-effective ISFWM technologies for zone 4 and 5 in Yatta and Mwala Sub-Counties

Table 4.8 specifies the cost benefit ratio of using different ISFWM structures explicitly Open Ridges (OR), Tied Ridges (TR) and Zai pit (ZP) practiced in LM AEZ 4 and 5. In every one Kenya shilling the farmer spent as a cost for making open ridges, tied ridges and zai pit, he is able to get a benefit of Ksh.3.81, 5.29 and 6.98 respectively in LM AEZ 4 and Ksh. 3.26, 5.14 and 5.63 respectively in LM AEZ 5.

Table 4. 8 Cost-benefit ratio of ISFWM technologies in Yatta and Mwala sub-counties

Item	LM AEZ 4			LM AEZ 5		
	OR (n=50)	TR(n= 39	ZP (n=35)	OR (n=54)	TR (n-40)	ZP (n=11)
Labor	3,327	3,485	4,243	3,463	3,590	4,334
Storage chemical	3,564	3,696	2,123	2,225	2,141	2,370
Seed	5,514	4,898	5,221	5,684	6,971	4,812
Fertilizer	4,653	4,474	3,802	4,624	5,259	4,720
Yield	1,412	1,592	1,924	1,288	1,730	1,681
Total Revenue	65,964	82,59	91,255	52,975	93,711	92,718
Total costs (TC)	17,313	15,61	13,070	16,236	18,230	16,480
Gross Revenue	48,650	66,97	78,185	36,739	75,481	76,238
Cost-benefit ratio	3.81	5.29	6.98	3.26	5.14	5.63

Note. The result of cost–benefit analyses depended on the choice and quality of data input and often, as in study, only limited data (e.g. Costs and sales of yields of only 1 year from 2011SR and 2012 LR)
Key. OR –Open ridges, TR-Tied ridges, ZP- Zai Pit

4.4 Comparison of adoption levels of ISFWM technologies in the project and non-project sites in Mwala and Yatta Sub-Counties

There were significant differences in the household heads who were reported to have adopted different levels of technology combinations between project and non-project areas (Table 4.9). Majority of the respondents (93.9%) in the project areas adopted a combination of tied ridges, organic fertilizer and improved seed compared to merely 6.1% in the non-project area.

There was significant ($p \leq 0.01$) higher adoption (76.5%) of tied ridges, combined fertilizers and improved seed in the project area in contrast to 23.5% in non-project area.

Adoption was also highly significant ($p \leq 0.01$) for household heads who majority (80%) had reported adopting a combination of zai pit, combined fertilizer and improved seed improved in the project area as compared to non-project areas household heads who stated only 20%. However, a combination of open ridges, organic fertilizer and local seed was adopted by a significantly ($p \leq 0.05$) higher percentage (78.6) in non-project area compared to project area with only 21.4%.

Table 4. 9 Adoption levels among project and non-project areas

Levels of ISFWM technologies	Project area %	Non-Project area %	t-ratio	p value
Or+Org+Local seed	21.4 (3)	78.6 (11)	9.833	0.027*
Or+Org+Improved seed	30 (21)	70 (49)	24.773	.000**
Or+Inorg + Local seed	50 (1)	50 (1)		ns
Or+Inorg+ improved seed	33.3 (2)	66.7 (4)		ns
Or+combined fert + Local	33.3 (2)	66.7 (4)		ns
Or+Combined fert+Improved seed	39.3 (24)	60.7 (37)	25.474	.000**
Tr+Org+Local seed	71.4 (5)	28.6 (2)		ns
Tr+Org+Improved seed	93.9 (31)	6.1 (2)	3.187	0.004**
Tr+Inorg+ improved seed	100 (3)	0 (0)	0.458	0.017*
Tr+Combined fert+ Local	100 (1)	0 (0)		ns
Tr+Combined fert+Improved seed	76.5 (26)	23.5 (8)	6.671	0.001**
Zp+Org+Improved seed	33.3 (1)	66.7 (2)		ns
Zp+Inorg+Improved seed	0 (0)	100 (1)		ns
Zp+Combined fert+ Local seed	33.3 (1)	66.7 (2)		ns
Zp+Combined fert +Improved seed	80 (4)	20 (1)	6.978	0.006**

Key. Or=Open ridges, Org=organic fertilizer, Inorg=Inorganic fertilizer, fert=fertilizer, Tr=Tied ridges, Zp=Zai pits, Figures in parenthesis indicates frequencies, * significant at 5% level, ** significant at 1% level

CHAPTER FIVE.

5.0 Discussion

5.1 Factors that influence adoption of ISFWM technologies

5.1.0 Social demographic characteristic findings

Demographic information in this study comprised of gender, membership to any social group, age, and education level of the household heads in both Sub-Counties as reported in Table 4.1

5.1.1 Gender influence on adoption of ISFWM technologies

Gender was one of factors found to contribute to adoption of ISFWM technologies. The distribution of gender registered a mean of about 29% females and 71% males with 70.2% males, 29.8% females in Mwala and 71.8% males, 28.2% females in Yatta. These findings indicates that gender household heads in the study region were dominated by males and this is in line with earlier findings (Wambua, 2014; Mwangi *et al.* 2015; Atuhaire *et al.* 2014; Njarui *et al.* 2012). Furthermore, Wambua (2014) reported male participation in dairy farming of 70%, 73.3% and 66.7% against females who recorded 30%, 26.7% and 33.3% in three locations in Wamunyu, Kilembwa and Nunga respectively Machakos county, Kenya. Gender was captured as social role in the study and was observed to be significant at ($P \leq 0.05$) with a positive coefficient (0.6845) in relation to adoption of ISFWM technologies. This was obvious as household heads in the study areas were found to be dominated by males.

Male farmers' are resource endowed by virtue of their cultural setting and more apt to adopt any new technology (Baffoe-Asare *et al.* 2013). Earlier findings have reported gender difference to be one of the factors influencing adoption of any new technology thus due to many social-cultural values and norms males have freedom to mobility and consequently have greater access to information (Okuthe *at el*. 2013, Kiptot and Franzel 2011). In addition, Kiptot and Franzel (2011) observed that Men receive more extension visits than women and participate in more field days and other extension activities off the farm.

On the other hand, females are usually occupied with domestic activities and are not resource (financial and human) endowed and therefore if not fully involved may impact negatively on both adoption decision and the extent of use of certain ISFWM practices (Martey *et al.* 2014; Kassie *et al.* 2009; Ogada *et al.* 2014).

5.1.2 Age influence of household head on adoption of ISFWM technologies

Age was found to influence the general adoption of ISFWM technologies with majority of the household heads reported to be aged between 46-55 years in Mwala (49.2%) and Yatta (51.6%) with a mean of 50.4%. The findings were consistent with earlier studies Mbungu, (2014) cited that majority (42.2%) of the respondents were ranging between 41 and 50 years with most of the employees being in the age bracket of 31-50. In similar studies, Mugwe *et al*. (2012) reported a mean age of 49 years across the respondents ranging from 25 to 90 years.

The logistic model results obtained on tied ridges showed that, the effect of household heads aged between 46-55 year's had a highly significant ($P \leq 0.01$) but a negative influence on adoption decision. This suggests that *ceteris paribus*, a unit increase in age by one unit of the household head will reduce the probability of adoption of the tied ridges, inorganic fertilizers and improved seed technologies by 25.232, 23.538 and 20.867 respectively. The study also revealed that the mean percentage of the youth and the elderly (age between 26-35 years and >55years respectively) registered in both sub-counties were 5.6% youth and 10.9% >55 years. These results suggests that the youth and the elderly do not engage themselves fully in the farming activities. The possible explanation for this might be that most of the young household heads are motivated towards other occupations rather than farming activities (Osmani and Hossain, 2015; Bett, 2006). While the older farmers' have shorter planning horizons and hence are more reluctant to invest in soil conservation technologies which take a long time before farmers' realize the benefits (Chiputwa *at el.,* 2011; Bett, 2006; Tizale, 2007). However, it is also true that the older farmers' were likely to have more farming experience and would therefore be likely to be more receptive to adopt ISFWM technologies. Thus if the youth and the elderly farmers' do not engage themselves in these practices, then sustainable agricultural productivity may be constrained (Wambua, 2014).

5.1.3 Influence of education of the household head on adoption of ISFWM technologies

The study found that most (51.6% and 64.9%) of household heads in Mwala and Yatta, respectively had attained primary level of education with a mean of 58.3% followed by secondary education (mean of 29%). Tobit and logistic regression models results indicated that education had a significant effect on adoption of ISFWM technologies.

Findings from Tobit regression model results gave a highly significant ($p \leq 0.01$) though negative (-0.033) influence on education. This indicates that as the level of education increases by one unit, the probability of the household heads adopting isfwm practices decreases by 0.033. However, after classification of education of the household heads in the study area, results from logit model revealed not only negative but also a positive effect on adoption of both fertilizers with household heads who were not educated, attained primary level of education, and secondary level of education showing a coefficient of (-1.500), odds ratio=4.492, (-1.24), odds ratio 3.465 and (16.027), odds ratio=0.002 respectively. These results suggest that as the level of education advances by one unit, the probability of adopting both fertilizers for household heads who were not had no education and those who had acquired primary level of education though not significant, dropped with a decreasing rate of 4,492 and 3.465 times respectively. Whereas the likelihood of household heads who had accomplished secondary education was highly significant ($p \leq 0.01$) and positive indicating that *ceteris paribus*, one unit increase in education will increase the probability of adoption of both fertilizers by 0.002 units.

These results are consistent with earlier findings by Arapovic and Karkin (2015) who reported that market integration for strawberry though not negative, dropped from 0.6215 pre-ICT to 0.3638 post-ICT, signifying that there has been some increase in the level of market integration.

Besides, findings from Zhou *et al.* (2010) reported that education gives farmers' better access to information about the fertilizers and more knowledge of how much fertilizer to use and thus education is expected to favorably affect fertilizer decisions. Exposure to education may enhance the awareness of a new technology and hence increase the capacity of the farmers' to apply a given technology.

Demeke (2003) reported that education had a significant effect on farmers' choice to adopt maize production technologies in Uganda. Similarly, Jeanette *et al.* (2005) noted that there is a direct relationship between formal education and uptake of natural resource management practices that enhances adoption. Moreover, smallholder farmers' who participated in training courses and field days were reported to have increased resource management practices compared to those who did not (Jeanette *et al.* 2005). Equally, previous studies (Ndiema, 2010; Farouque and Takeya 2007) reported that literacy plays an important role of enabling farmers' to get access to written material, thereby facilitating awareness of any new information.

5.1.4 Household head participation in social groups and adoption of ISFWM technologies

The study established that association of the household heads to any organization affected ISFWM technology adoption positively and significantly. The positive coefficient (0.207) signifies that an increase in one household head to a group increases adoption of ISFWM technologies by 0.207 units.

The study also found out association of the household heads to any organization affected highly significantly ($p \leq 0.01$) adoption of the following combination of technologies: use of open ridges, organic fertilizer and the local seeds; use of tied ridges, organic fertilizers and improved seeds; use of tied ridges, combination of both fertilizers and improved seeds and use of zai pits with combination of both fertilizers.

The results concur with previous studies by Odendo *et al.* (2009) who reported that group membership enables its members to be exposed to information on improved technologies such as organic and inorganic fertilizers separately and in combination. Besides, IFAD (2003) reported that, smallholder farmers' participation to any organization enhanced their bargaining power enabling them to interact on equal terms with other, larger and stronger stakeholders particularly in market intermediaries. Also, Manyeki *et al.* (2013) reported that high adoption of natural pasture improvement (NaPI) technologies was reported from a household head who was affiliated to farmer group association which was attributed with constant interaction among members aiding them to become more aware of improved farming technologies. It is also possible that a farmer may participate in a developmental project for other technical supports thus impacting negatively on isfwm technology adoption and use intensity (Martey *et al.* 2014).

Mwangi *et al.* (2015) reported that being a member of a group significantly increased access to output market by 9.7% in the aggregated sample while at disaggregation level, it significantly increased access to output market by 8.3%, 7.2% and 10.8% among male, youth and adult-headed households.

5.1.2 Access to agricultural input on adoption of ISFWM technologies

Access to agricultural inputs revealed a negative (-1.307) and highly significant ($p \leq 0.01$) relationship with the probability of ISFWM technology adoption. This denotes that as agricultural inputs such as inorganic fertilizers and improved seeds becomes more inaccessible, the farmer become reluctant to buy them giving him the option of using the only available organic fertilizers and local seeds.

Nambiro and Okoth, (2012) reported a significant but a positive influence of use of improved maize seed and use of inorganic fertilizer in Western Kenya. Looking at the input prices, a major determinant of adoption of conservation practices is the price that farmers' have to pay to have the technology in place (Shiferaw *et al.* 2009). The prevailing prices of improved seed and mineral fertilizers affects profitability of any crop grown in semi-arid lands e.g. seed price of the staple (maize) cost of capital (interest rate), cost and level of subsidy on fertilizer were reported to be the key determinants of financial attractiveness and the potential adoptability of the different soil fertility options (Ajayi *et al.* 2007; Humphreys *et al.* 2008). In Zimbabwe, Gumbo, 2010 reported that farmers' reduced their use of inorganic fertilizer as a consequence of their higher prices

5.1.3 Access to agricultural information and services on adoption of ISFWM technologies

5.1.3.1 Access to agricultural extension information

Access to agricultural extension information on adoption of ISFWM technologies of the household heads showed a positive (0.675) and significant at $P \leq 0.05$. In line with this, Kassie *et al. (*2009) in a study in semi-arid regions of Ethiopia reported a highly significant ($p \leq .01$) and positive coefficient on adoption of compost, stubble tillage and both combined with agricultural extension input. This implies that the more the households are exposed to agricultural extension information, the more they are likely to adopt new technologies. In addition, access to information on new technologies is crucial to creating awareness and attitudes towards technology adoption (Kassie *et al.* 2009).

Furthermore, Adolwa (2012) reported that agricultural organizations such as extension services, institutions of higher learning and research, farmer unions or cooperatives, input dealers or stockiest, mass media, ICTs as well as the community-based have been described as modern sources and channels of information that influences adoption.

5.1.3.2 Access to agricultural credit.

The findings of study indicated that inaccessible agricultural credit influenced adoption of ISFWM technologies negatively (-0.0281) and significant at $P \leq 0.05$. The negative coefficient signified that the smallholder farmers' in the study region were reluctant to access credit. Thus the more the agricultural credit becomes more difficulty to access, the more the smallholder farmers' become hesitant to go for loans. The possible explanation to this was probably due to lack of land ownership that would serve as collateral for loans (Mutoko *et al*. 2015) and high interest rate offered by various financial institutions in Kenya. Demeke (2003), disclosed that there was a systematic association between participation in credit and adoption of conservation structures. Therefore, lack of access to cash or credit may hamper smallholder farmers' from adopting new technologies that require initial investments and therefore its access is assumed to be positively associated with adoption Chiputwa *et al.* (2011). Similarly, by Demeke, (2003) indicated that poor rural households in developing countries lack access to credit which in turn impacts a significant negative influence to technology adoption. Access to credit by farmers' enhances their purchasing power and this in turn may increase purchases of improved seeds Nyamai, (2010) with consequent adoption.

5.1.3.3 Access to radio information

Radio access was found to influence ISFWM technologies positively (0.066) and highly significantly ($p \leq 0.01$). The positive coefficient suggests that as more smallholders farmers' access radio information, the more they are exposed to new information and knowledge giving them higher probabilities of identifying the best alternatives they deem fit to use on their farms without even considering their long term impacts. The results concur with previous findings by Lwoga *et al.* (2011) who reported that 96.3% of the farmers' used radios to access information and knowledge in farming systems. Lwoga *et al.* (2011) noted that radio was an appropriate channel for acquiring information for large numbers of famers in rural areas probably due to its oral nature, low costs and independence of electricity.

5.1.3.4 Access to market information

Rural poor people in many parts of the world have often reported one reason why they cannot improve standards of living is that they face serious difficulties in accessing markets (IFAD, 2003). The study found out that market access was negative (-2.550) and highly significant at $p \leq 0.01$ level of probability. This suggests that a unit increase in non-market access mighty result to a decrease in adoption of ISFWM practices by 2.550 times. Past studies have revealed that market access (time taken to the market) having a negative effect on productivity, which indicates that aggregate productivity increases with 'decreasing time to markets'. This also suggests that improved market access increases agricultural productivity (Kamara, 2004).

Likewise, Nambiro and Okoth (2012) found that distance to input and output markets having a negative sign (shows market access is important) although it did not significantly influence the use of inorganic fertilizer in maize production. In addition, the rural poor are also frequently constrained by lack of understanding of the markets, their limited business and negotiating skills (IFAD, 2003).

Further, ease market access for any agricultural products often facilitate commercialization of production and adoption of commercial inputs such as fertilizers, improved seeds and pesticides. Moreover, Odendo *et al.* (2010) reported that improved market access can be the driving force for sustainable intensification of agriculture.

5.1.4 Availability of Labor and adoption of ISFWM practices

Labor is an important variable in agricultural production process and is likely to influence adoption of other labor based technologies. The coefficient of labor was significant and negative indicating that at the mean, increased labor use has a decrease influence of adoption of ISFWM technologies (Mutoko *et al.* 2015). Odendo *et al.* (2010) cited that labor constraint revealed a significant impact on the adoption of tree fallows which are relatively labor-intensive. Similarly, labor is still considered a major constraint especially to “low external input” technologies (Drechsel *et al.* 2012). Gichangi *et al. (*2007) stated that in ASALs of Kenya farmers’ were worried of labor requirement for applying the organic fertilizer in the furrows. Likewise, Farouque and Takeya (2007) reported that preparation of organic manure was labor intensive and was ranked first in their study as a major constraint.

5.1.5 Appropriate Farm Machinery

Inappropriate farming machinery especially implements used in making the soil conservation structures was established to be one of the major constraint as far as ISFWM technology adoption was concerned. This was evident by having a highly significant ($p \leq 0.01$) and positive (0.645) coefficient. The positive coefficient means that as the appropriate farm machinery becomes more accessible, so is the farmer willingness to adopt that particular ISFWM technology. This is in line with earlier findings by Gichangi *et al.* (2007) who reported that farmers’ in arid and semi-arid lands of Kenya admitted that they were impressed by water harvesting techniques especially using tied ridges but noted that there is need for a suitable implement that could be invented to allow making of the tied ridges easier. Mati (2005) reported that, the use of modern agricultural inputs (fertilizers, improved seeds and agro-chemicals) is limited in Kenyan ASALs probably due to lack of improved farm implements during their application.

Mati, (2005) argued that when suitable machinery technology is not accessible, then labor constraint becomes more prevalence with consequent low adoption of the said ISFWM technology. Similarly, Dorward *et al.* (2008) reported that the immediate technical challenge for cassava where it is widely grown in West Africa was related to reducing labor requirements for harvesting and processing. Thus farmers' expressed interest in adopting the high yielding varieties coupled with acceptable processing characteristic if suitable harvesting and processing machines for labor saving were made easily accessible.

5.1.6 Farmer's Perception on Season Reliability

Farmers' perception on the short rain season was negatively (-0.258) and highly significant ($P \leq 0.01$) in relation to adoption of ISFWM technologies. The negative coefficient implies an inverse relationship that as farmers' perception on season's reliability becomes more uncertain, adoption of ISFWM technologies decreases by 0.2581 and vice versa. This is evidenced by the results of the current study which showed that most smallholder farmers' use more ISFWM technologies such as organic fertilizers (90.7%), inorganic fertilizers (70.6%) and improved seed (84.7%) in the 2012SR compared to only 0.9% organic fertilizers, 0.4% inorganic fertilizers, and 62.1% in 2013LR season. These findings are consistent with earlier reports by Recha *et al.* (2013) who found that on average, 18% of the farm were left fallow during the SR season while 34% land were left fallow during the LR season, reflecting the general perception that November-October short rain seasons are more reliable compared to March-April long rain season. Similarly, farmers' in lower Eastern Kenya perceives October-December as the most reliable rain season as they tend to increase the acreages and planting of late maturing crop varieties and agro-forestry species (Recha *et al.* 2013).

5.2 Assessment of the smallholder farmers' perception on expected yields of maize ccompared with APSIM yield prediction results in Yatta and Mwala sub-counties

Figure 4 in chapter four indicates APSIM simulated yield of maize presenting lower results in farms of household heads adopting open ridges compared to those adopting tied ridges or zai pits. The same figure revealed that farmers' expectations on yields of maize were slightly higher than those predicted by the model when they used open ridges and then decreased in farms of household heads who were using tied ridges and or zai pits.

The results provides an insight probably why farmers' were using open ridges instead of tied ridges and or zai pits. This trend was seen in yields of maize from both the APSIM simulated and the farmers' expectations. The study also observed that for those farmers' adopting open ridges, the farmer expected and model simulation results on maize yields where the same when they applied a combination of 40kgN inorganic fertilizers and 4tons of organic fertilizers. This implies that farmers' are quite aware that when they use the recommended rates of fertilizers, they would obtain high yields. But in reality, this do not happen probably due to inaccessible inputs in terms of costs, quantities, lack of appropriate machines and timeliness. However, for those farmers' who used tied ridges and zai pits the trend of the model simulated yield of maize showed slightly higher yields which were increasing steadily with increase in fertilizer application rates. The results conforms with earlier findings by Masika (2014) who recommended especially in short rains an application rate of inorganic fertilizer for dry land areas of 40KgN ha^{-1} . Thus famers may compare the growth and development of maize grown in different technologies using their local knowledge and experience to have an informed decision on the way they perceived yield of maize grown in each technology (Ogalleh *et al.* 2012).

5.3 Cost-effective soil fertility and water management structures for zone 4 and 5 in Yatta and Mwala Sub-Counties

Results revealed that zai pit practiced in both LM AEZ 4 and 5 as the most cost effective ISFWM structure with cost-benefit ratio of 6.98 and 5.63 in LM AEZ 4 and 5 respectively followed by tied ridges with 5.29 in LM AEZ 4 and 5.14 in LM AEZ 5. These results are consistent with earlier findings by Akinola and Owombo (2012) reported benefit-cost ratios of 4.79 and 3.13 for adopters and non-adopters, respectively.

Open ridges gave the least CBR in LM AEZ 5 of 3.26 and 3.81 in LM AEZ 4. Previous studies, Ibraimo and Munguambe (2007) observed more than double increase in the yield of maize planting in Zai pits compared with those planted in conventionally tilled lands. Similar studies conducted by Kilasara *et al.* (2015) revealed that tied ridging, open ridging and sub-soiling improved soil water contact in the root zones during cropping period compared to traditional tillage system by 25%, 15% and 30% respectively resulting to increased yield.

5.4 Adoption of ISFWM technologies in project and non-project areas

The study indicated that 93.9% and 6.1% of the household heads in project and non-project areas reported to have adopted a combination of tied ridges, organic fertilizer and improved seed which was highly significant ($p \leq 0.01$). In addition, 76.5% and 23.5% of the household heads in the project and non-project areas respectively were specified to have adopted a combination of tied ridges, applied both fertilizers and planted improved seed, a highly significant ($p \leq 0.01$) practice among the project and non-project household heads. This suggests that the household heads in the project areas had adopted this combination which was one of the practice the project team had advocated as one of the good agronomic measures for increased yields in dry land areas.

The study also reported significant differences in ISFWM technology adoption of 21.4% and 78.6% of household heads in project and non-project areas who had adopted a combination of open ridges, organic fertilizer and local seed. A significant ($p \leq 0.05$) practice which was least recommended by the project team for ASALs.

Furthermore, the findings reported that 100% the household heads in the project side had adopted a combination of tied ridges, inorganic fertilizers and improved seed. This was important as none had adopted this kind of combination in the non-project area. The results are in line with previous findings, Chiputwa *et al.* (2011) reported that farmers' go through a transitional phase in adopting new technologies that they are introduced to, tend to disassemble technology packages and adopt what they perceive as the most relevant components followed by additional components with time.

Similarly, Bett, (2006) reported that when a technology is first adopted, smallholder farmers' will undergo a phase of trying the technology to a small extend or in small quantities. Besides, Mazvimavi and Twomlow (2009) cited that farmers' tend to disassemble technology packages and adopt the most relevant parts initially, followed by additional components over time.

CHAPTER SIX

6.0 Conclusion and recommendations

6.1 Conclusion

The essence of the study was to examine factors that influence ISFWM technologies in ASALs of Yatta and Mwala sub-counties in Machakos County, Kenya. Thus gender, group membership, radio access, labor, availability of appropriate farm machinery and access to agricultural extension indicated a strong positive coefficient vis-à-vis adoption of ISFWM technologies. Household head: age, education, access to inputs, inaccessible credit services, out-put markets and farmers' perceptions on seasons gave a negative coefficient regarding adoption of ISFWM technologies by the smallholder farmers' in these regions.

Logistic regression results indicated that the age between 46-55 years was important as it affected adoption of tied ridges, inorganic fertilizers and improved seeds significantly and varied among household heads. Thus household heads who were aged between 46 to 55 years showed highly significant ($p \leq 0.01$) though negative effect on adoption decision of the above three ISFWM technologies.

APSIM simulated yield of maize presented lower results in farms of household heads adopting open ridges compared to those adopting tied ridges and or zai pits when they applied inorganic fertilizer in the range of 0-40kg ha $^{-1,}$, organic fertilizer in the range of 0.6tons -4tons ha $^{-1}$ and a combination of inorganic and organic at the rate of 12KgN $^{-1}$ ha with 0.6tons $^{-1}$ ha of organic fertilizers respectively. At the same time, farmers' expectations on yields of maize indicated slightly higher than those predicted by the model when they used open ridges and then decreased in farms of household heads who were using tied ridges and or zai pits. This gives an insight probably why farmers' are not adopting tied ridges, zai pits or both. However, the results equaled when the farmers' applied a combination of 40kgN inorganic fertilizers and 4tons of organic fertilizers. This implies that farmers' are quite aware that when they use the recommended rates of fertilizers, they would obtain high yields. But in reality, this do not happen probably due to inaccessibility of inputs by the farmers' in terms of costs, quantities, lack of appropriate machines and timeliness. However, for those farmers' who used tied ridges and zai pits the trend of the model simulated yield of maize showed slightly higher yields which were increasing steadily with increase in fertilizer application rates.

The Cost-Benefit Analysis revealed that among the ISFWM structures practiced in LM AEZ 4 and 5, Zai pit indicated the highest CBR of 6.98 and 5.63 in LM AEZ 4 and 5 respectively followed by tied ridges which showed CBR of 5.29 in LM AEZ 4 and 5.14 in LM AEZ 5.

Majority (93.9%) of the household heads in the project areas had adopted a combination of tied ridges + organic fertilizer + improved seed compared to only 6.1% in the non-project area, one of appropriate ISFWM practice though not the most ideal supported by the project team. Moreover, the study established that 76.5% and 23.5% of the household heads in the project and non-project areas respectively had adopted a combination of tied ridges, applied both fertilizers and planted improved seed, an ISFWM practice highly recommended for ASALs. However, the study revealed that merely 21.4% and of household heads in project sites and majority (78.6%) of the household heads in the non-project area had adopted a combination of open ridges, organic fertilizer and local seed which is an inappropriate practice for ASALs. Therefore the study revealed that the KARI/McGill project had a positive impact on dissemination of ISFWM technologies in the period that they project was present.

6.2. Recommendations

The study recommends that the policy makers to focus:

- Mainly on accessible output markets, credit facilities, labor and ease access to information.

- Ease access to complimentary inputs such as seeds, inorganic fertilizers which can pose if inaccessible by limiting productivity of improved practices.
- Timely access to agricultural subsidies to such as seeds, fertilizers and chemicals.
- The specific needs of women can be addressed more effectively when they own, participate in decision making and in implementation of the projects at household levels therefore these required urgent measures to be upheld.
- The key to minimize labor drudgery during planting, weeding, harvesting and postharvest processes of the farm products is to ensure ease access of small hand oxen drawn or engine driven machine for making the zai pits, tied ridges, open ridges and postharvest processes.
- Enhancement of agricultural research, extension services and other related agents are required in these areas as ISFWM technology adoption reported to be low in practice.
- Infrastructure is necessary to ensure that enhanced agricultural marketing structures are put in place to augment smallholder farmer productivity and profitability.

When this happens, farm productivity will be boosted with consequent improved food and nutrition security for enhanced livelihoods of the smallholder farmers' in ASALs of Kenya.

6.3 Future studies

- Use of APSIM model to show appropriateness and probabilities of success of ASALs technologies in predicting adoption of various agricultural value chain studies (crops and livestock production)
- In depth prediction studies on impacts of Climatic Change and Adaptations on common hazards in Kenya (Extreme weather conditions such as drought, floods etc.)
- It will be useful to have more synthesis studies which cut across different fields of agricultural research and bring together findings of adoption processes for a wider range of sustainable agricultural technologies.

The gap the study understanding seems to be:

1. Life-spans of the various rain water harvesting structures e.g., tied ridges would be put in place each season i.e. How long "tied" ridges or indeed, zai should pits last? To answer this question, research would need to take into account of factors such as terrain, soil type, season etc. These would in turn impact cost benefit relationships and estimates.
2. For structures which last for more than one season, risk and time preference factors have to be brought into the policy debate.
3. Probabilities of profit levels associated with use of tied ridges and zai pits on different dry land crops.

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LIST OF APPENDICES

APPENDIX I. Questionnaire template

KARI-McGill PROJECT

NATURAL RESOURCE MANAGEMENT

Household questionnaire on adoption of Integrated Soil Fertility and Water Management (ISFWM) technologies in Mwala and Yatta Sub-Counties, of Machakos County.

SECTION 1: Household member 1= PPATE member 2=Non-PPATE member

Name of interviewer……………………………………………………………

Date of interview---------------------------Start time………………………………

S/no. of questionnaire: -----------------------

1.0 Household identification for Primary Participatory Agricultural Technology Evaluations (PPATEs) and non- PPATE members

1.1 Agro-Ecological Zone (AEZ): 1=LM AEZ 4 2= LM AEZ 5

1.2 GPS Coordinates Longitude: (1=North 2=South) (--------------------) Latitude: East (-------------)

1.3 Altitude m -----------

1.4 District:-----------------------------------

1.5 Division:---------------------------------

1.6 Location:--------------------------------

1.7 Sub-location-----------------------------

1.8 Village-----------------------------------

1.9 Head of Household (HHH) Name--

1.10 Name of the respondent ---

1.11 Relationship of the respondent to HH head (Use code A)--------------------------

1.12 Respondent telephone number-------------------------------------

1.13 Are you a member of any farmer group 1=Yes 2=No

1.14 If yes, what is the name of the group ----------------------------

1.15 Farmer group membership number: Females……….Males------------.

1.16 Distance from the Primary Participatory Agricultural Technology Evaluation (PPATE) demonstration site----------------- (KM).

SECTION 2: Household social economic characteristics

2.1 Household type (select only one)

[-------] Male headed and managed

[-------] Male headed female managed (wife makes most HH agricultural decisions)

[-------] Female headed and managed

[-------] Child headed 1=below age of 18 2= Orphan below age of 18

2.2 Demographic characteristics of HH members (including students, but do not include employed children not residing or depending on the HH)

Household members: A group of people who cook, eat together, and share granary together NB family members who work away or are not depended on the HH for at least 6 months are excluded.

Table 2.21 social economic characteristics

	Full name of HHH(Start with HH Head)	Age in years according to your ID	AGE in years 1=18-25 2=26-35 3=36-45 4= 46-55 5=>55	Sex of the person (1=Male 2= Female)	Relationship currently of HHH (CODE A)	Highest education completed (CODE B)	Primary occupation (CODE C)
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
11							
12							

SECTION 3: Farm characteristics

3.1 How many parcels of land are owned by the household…………….

Provide name of the land as given by the farmer	Land 1 (where homestead is	Land 2:	Land 3:	Land 4:
3.3 Land size (acres)				
3.4 How far from the homestead (km)?				
3.5 Who owns the piece of land? 1= HHH 2= spouse 3=HHH and Spouse 4= rented 5=communal 6=Relative non household member				
3.6 What is the type of land tenure for this parcel of land? (see Code D below)				
3.7 Who among the HH members currently uses that parcel of land? (Code E below)				
3.8 Are you allowed to put in ISFWM structures? 1=yes 2=No				
3.9 What ISFWM structures were used in the last the last 12 months? (Code: F below)				
4.0 Land use allocated to the different uses in the last 12 months? (specify area in acres)				
1. Homestead (houses, livestock sheds etc.)	`			
2. Subsistence crop production. (HH consumption)				
3. Commercial crop production. (for marketing)				
4. Improved pastures /forages production				
5. Natural pastures				
6. Wood lot				
7. Fisheries				
8. Unusable land (Swampy, rocky, hilly etc.)				

SECTION 4: Natural resource management (NRM)

4.1 ISFWM technologies practices by the smallholder farmers', their costs and constraints encountered during November 2012/13 SR and 2013 LR

ISFWM input used	Did you know about it? 1=Yes 2=No	If yes, did you practice it 1= During planting 2=During weeding 3=Both during Planting & weeding	Mention at most three land parcels used (Name from Table 3.1 above)	Crops grown (Code: I)	Did you practice it in 1=2012/13 SR 2=2013 LR 3=Both seasons	Which season did you mostly practice it? 1=2012 SR 2= 2013 LR 3=Both	Is it within a terrace guarded by a cut-off drain? 1=Yes 2=No	Mention three major constraints encountered for input use in 2012/13SR (Use Code V: below) Rank [1=1st major2=nd major 3=3rd major 4=Any other constraint (specify)] (Code: V)	Mention three major constraints encountered for input use in 2013LR (Use Code K: below) Rank [1=1st major2=nd major 3=3rd major 4=Any other constraint (specify)] (Code: V)
TR									
OR									
ZP									
TR + OR									
All above									

4.3 Smallholder farmers' perception on use of ISFWM technologies during October/Nov 2012/13 SR and March/April 2013 LR

4.3.0 Information on ISFWM technologies practiced and smallholder farmers' perceptions

4.3.1 Perceptions of smallholder farmers' on the effects of ISFWM technologies on yield of maize, crop 2 (……………………….), crop 3 (………………………..) and or the intercropped crop varieties during Oct/Nov 2012 SR and March/April 2013 LR.

4.3.1.1 Which season is more reliable? 1= Oct/Nov Short Rains (SR) 2= Mar/April Long Rains (LR) 3=Both seasons

4.3.1.2 Do you expect any yield difference when you practice 1=Tied ridges 2=Open ridges 3=Zai pits 4= Both (Tied +Open ridges) ((Yes/No)) on maize? Please circle/Tick as appropriate

4.3.1.3 What do you expect when you practice the ISFWM mentioned in Q.4.3.1.2 with Maize crop variety ……………….. (Code I) 1=increased yield 2=Reduced in yield 3=No yield difference

4.3.1.4 Do you expect any yield difference when you practice 1=Tied ridges 2=Open ridges 3=Zai pits 4= Both (Tied +Open ridges) (Yes/No) on crop 2? Please circle/Tick as appropriate

4.3.1.5 What do you expect when you practice the ISFWM mentioned in Q.4.3.1.4 with crop 2 variety ……………………… (Code I) (1=increased yield 2=Reduced in yield 3=No yield difference

4.3.1.6 Do you expect any yield difference when you practice 1=Tied ridges 2=Open ridges 3=Zai pits 4= Both (Tied +Open ridges) (Yes/No) on crop 3? Please circle/Tick as appropriate

4.3.1.7 What do you expect when you practiced the ISFWM mentioned in Q.4.3.1.6 with crop 3 variety……….. (Code I) 1=increased yield 2=Reduced in yield 3=No yield difference

4.4.0 Information on ISFWM technologies practiced and smallholder farmers' adoption drivers

4.4.1 What drives you to use the technology mentioned in

- ✓ Q4.3.1.2 1=Less labor requirement 2=Ease access of farm implements 3=Increased yield 4= others (specify) use Code: W ………………………………
- ✓ Q 4.3.1.4 1=Less labor requirement 2=Ease access of farm implements 3=Increased yield 4= others (specify) use Code: W………………………………
- ✓ Q4.3.1.6 1=Less labor requirement 2=Ease access of farm implements 3=Increased yield 4= others (specify) use Code: W ………………………………

4.4.2 Who made most of production decisions regarding this crop ………………….(Code: E)

4.4. 3. What makes you decide to plant the Maize crop variety selected in Q4.3.1.3.0=Early maturing 1=pests and disease resistant 2=Market forces 3=Adds soil fertility 4= Drought tolerant 5= others (Specify)………………………………….

4.4.4 What makes you decide to plant the crop 2 variety selected in Q4.3.1.5 0=Early maturing 1=pests and disease resistant 2=Market forces 3=Adds soil fertility 4= Drought tolerant 5= others (Specify)………………………………….

4.4.5 What makes you decide to plant the crop3 variety selected in Q4.3.1.7. 0=Early maturing 1=Pests and disease resistant 2=Market forces 3=Adds soil fertility 4= Drought tolerant 5= others (Specify)………………………………….

4.4.0 Information on inorganic and organic fertilizers and smallholder farmers' perceptions

4.4.1 Perceptions of smallholder farmers' on the effects of inorganic and organic (Manure) fertilizer technologies on yield of maize, crop 2 and crop 3 and or the intercropped crop varieties during Oct/Nov 2012 SR and March/April 2013 LR:

4.4.1 Which season do you apply Inorganic fertilizer 1= Oct/November SR 2=March/April LR 3= Both seasons. Please circle/Tick appropriately.

4.4.2 Which season do you apply Organic fertilizer 1= Oct/November SR 2=March/April LR 3= Both seasons. Please circle/Tick appropriately.

4.4.3 Do you expect any yield difference when you apply 1=Inorganic fertilizer 2= Organic fertilizer 3= Both fertilizers. Please circle/Tick appropriately. (Yes/No) in maize crop variety mentioned in Q 4.3.1.3. Please circle/Tick appropriately.

4.4.4 If yes to Q 4.4.3. What do you to expect to obtain in terms of yield of maize crop variety mentioned in Q 4.3.1.3
1=increased yield 2=Reduced in yield 3=No yield difference. Please circle/Tick appropriately.

4.4.5 Do you expect any yield difference when you apply 1=Inorganic fertilizer 2= Organic fertilizer 3= Both fertilizers. Please circle/Tick appropriately. (Yes/No) in crop2 variety mentioned in Q4.3.1.5 Please circle/Tick appropriately.

4.4.6 If yes to Q 4.4.5, what do you to expect to obtain in terms of yield of crop 2 variety mentioned in Q 4.3.1.5
1=increased yield 2=Reduced in yield 3=No yield difference. Please circle/Tick appropriately.

4.4.7 Do you expect any yield difference when you apply 1=Inorganic fertilizer 2= Organic fertilizer 3= Both fertilizers. Please circle/Tick appropriately. (Yes/No) in crop3 variety mentioned in Q4.3.1.7 Please circle/Tick appropriately.

4.4.8 Perceptions of smallholder farmers' on effects of application of inorganic and manure fertilizers on yield during Oct/Nov 2012 SR and 2013 LR

Season	If yes to one or more than one of above question, please provide the following details														
	Maize					Crop 2					Crop 3				
	When you use this amount of fertilizer(KG) (Put zero if no fertilizer used)	What do you expect to harvest (Kg)	When you use this amount of manure	What do you expect to harvest (kg)	When you use Combination of fertilizer+ manure did you expect to harvest 1=More yield 2=less yield 3=No change in yield	When you use this amount of fertilizer(KG) (Put zero if no fertilizer used)	What do you expect to harvest (Kg)	When you use this amount of manure	What do you expect to harvest (kg)	When you use Combination of fertilizer+ manure did you expect to harvest 1=More yield 2=less yield 3=No change in yield	When you use this amount of fertilizer(KG) (Put zero if no fertilizer used)	What do you expect to harvest (Kg)	When you use this amount of manure	What do you expect to harvest (kg)	When you use Combination of fertilizer+ manure did you expect to harvest 1=More yield 2=less yield 3=No change in yield
Oct/Nov 2012/2013 (SR)															
March/April 2013 (LR)															

4.5.0 Information on inorganic and organic technologies practiced and smallholder farmers' adoption drivers

4.6.0 What drives you to use the inorganic fertilizer in maize crop variety mentioned in Q4.4.3. 1=Less labor requirement 2=Ease access of the fertilizers 3=Increased yield4= Low cost 5= others (specify)……………………………………

4.5.2 What drives you to use the organic fertilizer in crop2 variety mentioned in 4.4. 5 1=Less labor requirement 2=Ease access of the fertilizers 3=Increased yield4= Low cost 5= others (specify)……………………………………

4.5.3 What drives you to use the inorganic fertilizer in crop3 variety mentioned in Q4.4.7 1=Less labor requirement 2=Ease access of the fertilizers 3=Increased yield4= Low cost 5= others (specify)……………………………………

4.5.4 What drives you to use the organic fertilizer in maize crop variety mentioned in Q4.4.3 1=Less labor requirement 2=Ease access of the fertilizers 3=Increased yield4= Low cost 5= others (specify)……………………………………

4.5.5 What drives you to use the organic fertilizer in crop2 variety mentioned in 4.4. 5 1=Less labor requirement 2=Ease access of farm implements 3=Increased yield 4= others (specify)……………………………………

4.5.6 What drives you to use the organic fertilizer in crop3 variety mentioned in Q4.4.7 1=Less labor requirement 2=Ease access of the fertilizers 3=Increased yield4= Low cost 5= others (specify)……………………………………

4.6 Crop rotation practices, area planted, amount, and cost of seeds in Oct/Nov 2012/13SR and March/April 2013LR.

4.6.1 Farm layout: Please sketch the farm layout for one main land parcel that maize had been planted in the three seasons in Land 1

Oct/Nov 2012/13 SR	March/April 2013 LR

4.6.2 Information on crops grown, varieties and quantity of seeds used during 2012/13 SR and 2013 LR

Q1	Q2	Q3	Q4	Q5	Q6	Q7		Q8	Q9	Q10
Seed crop	Crop name (code I: below)	land parcel (Name mentioned in table 3.1 above)	Variety (Code I)	Variety planted 1=Improved 2=recycled 3= Local	Area planted in acres	Seeds planted		Cost of seed /kg Kes.	Did you plant 1=Pure stand 2= Intercrop	Which crop did you intercrop with Code: I
						Amt. (kgs)	Code J			
Season 2012/13SR										
Maize										
Maize										
Maize										
Crop										
Crop 2 :										
Crop 3:										
Crop 3:										
Season 2013 LR										
Maize										
Maize										
Maize										
Crop										
Crop 2 :										
Crop 3:										
Crop 3:										

4.6.3 Information on area planted, quantity, costs of inorganic& organic fertilizers a inputs used and output obtained and their constraints

Crops	Season 2012/2013SR							Season 2013LR						
	ISFWM input type (Code G)	In which land parcel mentioned in Table 3.1	Amount used (Code: J)	Price/unit (Kes)	Area planted (Acres)	Yield in Kgs.	Major three constraints (Code: V)	ISFWM input type	In which land parcel mentioned in Table 3.1	Amount used (Code: J)	Price/unit (Kes)	Area planted (Acres)	Yield in Kgs.	Major three constraints (Code: V)
Maize														
Crop1														
Crop2														

4.4.5 Livestock manure production and utilization

4.4.5.1 Have you used the livestock manure from your farm in the last 12 months?

4.4.5.2 If yes, provide details on manure produced from your farm in the last 12 months

Livestock types in order of priority (CODE: L)	Treatment of manure (CODE : M)	Quantity produced in the last one year		Quantity used in the farm (put zero if not used in the farm)	Quantity sold (Zero if not sold)	Units (CODE: J above)	Price per unit in KES	Who makes decision on the use of the money? (CODE: E above)
		Quantity	Unit (Code: J)					

5.0 Input-Output information: Cost of various farm operations during Oct/Nov 2012/2013 SR and March/April 2013LR

Detailed information on one of the two land parcels sketched in 4.1.3 above (1=land 1 parcel 2=land 2 parcel) Circle/ Tick one

5.1. 1 Labor costs during Primary land preparation (Maize, Crop 2 and crop 3)

5.1. 2 Do you use oxen drawn animals 1=Yes 2=No

5.1.3 If yes, provide the following details on primary land preparation, planting and weeding

\

Farm activity	Cost of primary land preparation																	
	If family labor, provide the following details									If Hired labor, provide the following details								
	Male (>35yrs)			Female (>35 yrs.)			Youth (18=35yrs)			Male (>35yrs)			Female (>35 yrs.)			Youth (18=35yrs)		
	No. of persons	No. of Days	Amt. paid (KES)	No. of persons	No. of Days	Amt. paid (KES)	No. of persons	No. of Days	Amt. paid (KES)	No. of persons	No. of Days	Amt. paid (KES)	No. of persons	No. of Days	Amt. paid (KES)	No. of persons	No. of Days	Amt. paid (KES)
Season 1 Oct/Nov 2012/13 SR																		
Maize																		
Crop 2:																		
Crop 3:																		
Season 2 March/April																		
Maize :																		
Crop 2:																		
Crop 3:																		

5.1.4 Labor costs during planting.

Land parcel ticked in 5.1 above

Farm activity	Cost of Planting																	
	If family labor, provide the following details									If Hired labor, provide the following details								
	Male (>35yrs)			Female (>35 yrs.)			Youth (18=35yrs)			Male (>35yrs)			Female (>35 yrs.)			Youth (18=35yrs)		
	No. of persons	No. of Days	Amt. paid (KES)	No. of persons	No. of Days	Amt. paid (KES)	No. of persons	No. of Days	Amt. paid (KES)	No. of persons	No. of Days	Amt. paid (KES)	No. of persons	No. of Days	Amt. paid (KES)	No. of persons	No. of Days	Amt. paid (KES)
Season 1 Oct/Nov 012/13 SR																		
Maize																		
Crop 2:																		
Crop 3:																		
Season 2 March/April LR																		
Maize :																		
Crop 2:																		
Crop 3:																		

5.1.5 Cost of labor for making the following structures during weeding maize field Land parcel ticked in 5.1 above

Farm activity	Cost of weeding maize																	
	If family labor, provide the following details									If Hired labor, provide the following details								
	Male (>35yrs)			Female (>35 yrs.)			Youth (18-35yrs.)			Male (>35yrs)			Female (>35 yrs.)			Youth (18=35yrs.)		
	No. of persons	No. of Days	Amt. paid (KES)	No. of persons	No. of Days	Amt. paid (KES)	No. of persons	No. of Days	Amt. paid (KES)	No. of persons	No. of Days	Amt. paid (KES)	No. of persons	No. of Days	Amt. paid (KES)	No. of persons	No. of Days	Amt. paid (KES)
Season 1 Oct/Nov 012/13 SR																		
TR																		
OR																		
ZP																		
TR+ OR																		
TR + ZP																		
OR + ZP																		
Season 2 March/April LR																		
TR																		
OR																		
ZP																		
TR+ OR																		
TR + ZP																		
OR + ZP																		

5.1.5 Cost of labor for making the following structures during weeding crop 2

Did you use oxen drawn? 1=Yes 2. No

Land parcel ticked in 5.1 above

Farm activity	Cost of weeding Crop 2																	
	If family labor, provide the following details									If Hired labor, provide the following details								
	Male (>35yrs)			Female (>35 yrs.)			Youth (18-35yrs)			Male (>35yrs)			Female (>35yrs)			Youth (18=35yrs)		
	No. of persons	No. of Days	Amt. paid (KES)	No. of persons	No. of Days	Amt. paid (KES)	No. of persons	No. of Days	Amt. paid (KES)	No. of persons	No. of Days	Amt. paid (KES)	No. of persons	No. of Days	Amt. paid (KES)	No. of persons	No. of Days	Amt. paid (KES)
Season 1 Oct/Nov 012/13 SR																		
TR																		
OR																		
ZP																		
TR+OR																		
TR+ZP																		
OR+ZP																		
Farm activity	Cost of weeding Crop 2																	
	Male (>35yrs)			Female (>35 yrs.)			Youth (18-35yrs.)			Male (>35yrs.)			Female (>35 yrs.)			Youth (18=35yrs)		
	No. of persons	No. of Days	Amt. paid	No. of persons	No. of Days	Amt. paid	No. of persons	No. of Days	Amt. paid	No. of persons	No. of Days	Amt. paid	No. of persons	No. of Days	Amt. paid	No. of persons	No. of Days	Amt. paid (KES)
Season 2 March/April LR																		
TR																		
OR																		
ZP																		
TR+OR																		
TR+ZP																		
OR+ZP																		

5.1. 6 Cost of labor for making the following structures during weeding of crop 3

(Land parcel ticked in 5.1 above)

Did you use oxen drawn? 1=Yes 2. No

Farm activity	Cost of weeding																	
	If family labor, provide the following									If Hired labor, provide the								
	Male			Female (>35			Youth (18-			Male			Female			Youth		
	No. of persons	No. of Days	Amt. paid	No. of persons	No. of Days	Amt. paid	No. of persons	No. of Days	Amt. paid	No. of persons	No. of Days	Amt. paid	No. of persons	No. of Days	Amt. paid	No. of persons	No. of Days	Amt. paid
Season 1 Oct/Nov 012/13 SR																		
TR																		
OR																		
ZP																		
TR + OR																		
TR+ ZP																		
OR+ ZP																		
Season 2 March/April LR																		
TR																		
OR																		
ZP																		
TR + OR																		
TR+ ZP																		
OR+ ZP																		

5.1.7 Cost of harvesting

Did you use 1=Family labor 2= Hired labor?

Farm activity	Cost of harvesting																	
	If family labor, provide the following details									If Hired labor, provide the following details								
	Male (>35yrs)			Female (>35 yrs.)			Youth (18=35yrs)			Male (>35yrs)			Female (>35 yrs.)			Youth (18=35yrs)		
	No. of persons	No. of Days	Amt. paid (KES)	No. of persons	No. of Days	Amt. paid (KES)	No. of persons	No. of Days	Amt. paid (KES)	No. of persons	No. of Days	Amt. paid (KES)	No. of persons	No. of Days	Amt. paid (KES)	No. of persons	No. of Days	Amt. paid (KES)
Season 1 Oct/Nov 2012/13 SR																		
Maize																		
Crop 2																		
Crop 3																		
Season 2 March/April LR																		
Maize																		
Crop 2																		
Crop 3																		

5.1.8 Cost of spraying and cost of postharvest storage

Farm activity	Name of Chemical used for spraying	Cost per/lt.	Family labor 1=Yes 2=No		Hired labor 1=yes 2=No		Name of Chemical used for storage	Cost in Kgs/lts.
			Male	Female	Male	Female		
Season 1 Oct/Nov 2012/13 SR								
Maize								
Crop 2								
Crop 3								
Season 2 March/April LR								
Maize								
Crop 2								
Crop 3								

6.0 Household income and expenditure profile

6.1 Income received from agricultural products

Income received from agricultural activities	Q 2. Did someone in your household receive income from that activity 1=yes 2=No	Q3. If yes, who generally receives that income (Code: E)	Q4. Amount received in the last 12 months (KES)	If question4 is difficulty to answer, probe further for monthly income		Q4. Amount received in the last 12 months (KES)
				Q5. Monthly income (KES)	Q6. For how many months/yr.	
Income from farm related activities in the last 12 Months						
Income from crop activities (Including agroforestry)						
Income from livestock etc. activities (including beekeeping, use of bulls/AI etc.)						
Income from woodlot activities (Farm forest)						
Income from fish activities (Pond and natural)						
Income from renting out/selling pastures and forages						
Any other farm income (Specify)						

6.2 Income from off-farm activities

	Q1. Off-farm income activity	Q 2. Did someone in your household receive income from that activity 1=yes	Q3. If yes, who generally receives that income (Code: E)	Q4. Amount received in the last 12 months (Kes.)	If question4 is difficulty to answer, probe further for monthly income	
					Q5. Monthly income (Kes.)	Q6. For how many months/yr.
01	Salaried employment					
02	Salaried employment					
03	Pension income					
04	Farm labor wages					
05	Non-farm labor					
06	Agri-business NET					
07	Non-farm labor					
08	Amount received					
09	Net income from					
10	Remittances (from					
11	Renting out land					
13	Renting out					
14	Sales of off-farm					
15	Sales of handcraft					
16	Renting out oxen for					
17	Others 1 (specify)					

7.0 Access to various agricultural related information

Did any member access any market information in the last 12 months? ....1=Yes 2= No Please Circle/Tick one

If yes, provide the following details

7.1 Access to knowledge

Q1. Technology/ Issue	Q2-14. In the last 12 months, where did you get information about the following practices (Put X in all the information that apply)				
1. Improved crop varieties	[--] Did not get any information [--] Government extension service [--] Farmer cooperative	[--] NGOs [--] Field days [--] Barazas	[--] Seed traders/ Agro vets [--] Neighbors/other farmers' [--] Research center	[--] School [--] News paper [--] Radios	[--] TV [--] cell phone [--] Others (specify)………………
2. Fruit trees	[--] Did not get any information [--] Government extension service [--] Farmer cooperative	[--] NGOs [--] Field days [--] Barazas	[--] Seed traders/ Agro vets [--] Neighbors /other farmers' [--] Research center	[--] School [--] News paper [--] Radios	[--] TV [--] cell phone [--] Others (specify) …………………..
3. Vegetables	[--] Did not get any information [--] Government extension service [--] Farmer cooperative	[--] NGOs [--] Field days [--] Barazas	[--] Seed traders/ Agro vets [--] Neighbors /other farmers' [--] Research center	[--] School [--] News paper [--] Radios	[--] TV [--] cell phone [--] Others (specify) …………………..
4. Pest and disease control	[--] Did not get any information [--] Government extension service [--] Farmer cooperative	[--] NGOs [--] Field days [--] Barazas	[--] Seed traders/ Agro vets [--] Neighbors /other farmers' [--] Research center	[--] School [--] News paper [--] Radios	[--] TV [--] cell phone [--] Others (specify) …………………..
5. Soil and water management	[--] Did not get any information [--] Government extension service [--] Farmer cooperative	[--] NGOs [--] Field days [--] Barazas	[--] Seed traders/ Agro vets [--] Neighbors /other farmers' [--] Research center	[--] School [--] News paper [--] Radios	[--] TV [--] cell phone [--] Others (specify) …………………..

6. Adaptation to climate change	[--] Did not get any information [--] Government extension service [--] Farmer cooperative	[--] NGOs [--] Field days [--] Barazas	[--] Seed traders/ Agro vets [--] Neighbors /other farmers' [--] Research center	[--] School [--] News paper [--] Radios	[--] TV [--] cell phone [--] Others (specify) …………………..
7. Crop storage	[--] Did not get any information [--] Government extension service [--] Farmer cooperative	[--] NGOs [--] Field days [--] Barazas	[--] Seed traders/ Agro vets [--] Neighbors /other farmers' [--] Research center	[--] School [--] News paper [--] Radios	[--] TV [--] cell phone [--] Others (specify) …………………..
8. Livestock production	[--] Did not get any information [--] Government extension service [--] Farmer cooperative	[--] NGOs [--] Field days [--] Barazas	[--] Seed traders/ Agro vets [--] Neighbors /other farmers' [--] Research center	[--] School [--] News paper [--] Radios	[--] TV [--] cell phone [--] Others (specify) …………………..
9. Nutrition and diet	[--] Did not get any information [--] Government extension service [--] Farmer cooperative	[--] NGOs [--] Field days [--] Barazas	[--] Seed traders/ Agro vets [--] Neighbors /other farmers' [--] Research center	[--] School [--] News paper [--] Radios	[--] TV [--] cell phone [--] Others (specify) …………………..
10. Agro-forestry	[--] Did not get any information [--] Government extension service [--] Farmer cooperative	[--] NGOs [--] Field days [--] Barazas	[--] Seed traders/ Agro vets [--] Neighbors /other farmers' [--] Research center	[--] School [--] News paper [--] Radios	[--] TV [--] cell phone [--] Others (specify) …………………..
11. Market information	[--] Did not get any information [--] Government extension service [--] Farmer cooperative	[--] NGOs [--] Field days [--] Barazas	[--] Seed traders/ Agro vets [--] Neighbors /other farmers' [--] Research center	[--] School [--] News paper [--] Radios	[--] TV [--] cell phone [--] Others (specify) …………………..

7.2 Access to credit and rural finance

7.2.1 General questions about credit

Did you or other household member (18 years and above) receive any cash and or input (formal or informal) credit for October 2012 and or April 2013 for crop or livestock production or household consumption? 1=Yes 2=No

If yes, provide the following details

Household member who access credit 1=Male >35 yrs. 2=Female >35 yrs. 3=Male 18-35yrs 4=Female 18-35yrs	Product/Services (Code: N below)	Main source of agricultural loan (Code : O below)	Amt. Borrowed (Kes.)	Amount paid in cash equivalent back	What was the interest rate for the loan (%)	What collateral used if any (Code: P)	Main purpose of the loan (Code: Q below)	HHH satisfaction with the credit services (Code: R below)

7.2.2 Information on input credit

Here we to learn about the credit you have received in the form of agricultural inputs (seed, fertilizers)

Seed credit – Directly received in the form of seeds.

Q1 Crop (Code: I)	Q2. Variety (Code: I)	Q3. Qty. (kgs.) (Code: J)	Q4. Units (Code: J)	Q5. Source of loan (Code: O)	Q6. Form of repayment (Code: T)	Q 7. What was the collateral if any (Code: P)	Q.8 Who received the credit (Code: E above)
October 2012SR							
1							
2							
3							
April 2013 LR							
1							
2							
3							

7.2.3 Information fertilizer use

	Q9 Fertilizer type (Code: G)	Q10. Qty. (kgs.)	Q11. Units (Code: J:)	Q12. Source (Code: T)	Q.13 Form of repayment (Code: S)	Q.14 What was the collateral if any (Code: P)	Q15. Who received the credit (Code: E)
October 2012SR							
1							
2							
3							

April 2013 LR							
1							
2							
3							

7.3 Access to agricultural related services and infrastructure (including market access)

a. provide the following information on services and infrastructure

Service/infrastructure	Access in the last 12months 1=Yes 2=No	Who mainly accessed? 1=<18 years 2=Male >35years	Distance to the nearest service/ infrastructure [km]	No. of contacts in the last 12 months	Main service provider (Code S: below)	Level off satisfaction (Code: R below)
Agricultural extension						
Agricultural research						
AI services						
Livestock dipping/spraying						
Climate early warning						
Agricultural credit						
Agricultural insurance						
Electricity						
Warehouse receiving system						
Input market						
Output market						
Health center dispensary						
Primary school						
All weather road						

Piped water						
Watering pints for livestock						
Agro forestry services (Tree						
Natural resources (Wells,						
Canals						
Slaughter houses						
Bore holes						
Dams						

8.0 Marketing and related constraints of maize, crop 2 and crop 3 during Oct/Nov 2012/113SR and March/April 2013LR

Type of crop	Q1 Type of produce 1=Grain 2= Leaves 3=livestock feed 4= certified seed	Q 2 answer per 1=variety 2= bulk	Q3. Qty. sold (Code J)	Q4. Where sold (Code: Y)	Q5. Units (Code J)	Q6. Farm gate price per unit (Kes)	Q7. Market price per unit (Kes)	Q8. Who does the selling (Code E)	Q9. Who owns the revenue	Q10. 3 major constraint to marketing (Code U above)
Oct/Nov 2012/13 SR			If any of the following crops were not planted put X and go to March/April 2013 LR							
Maize		Bulk								
		Variety 1								
		Variety 2								
		Variety 3								
Crop 2		Bulk								
		Variety 1								
		Variety 2								
		Variety 3								
Crop 3		Bulk								
		Variety 1								
		Variety 2								
		Variety 3								

Type of crop	Q1 Type of produce 1=Grain 2= Leaves 3=livestock feed 4= certified seed	Q 2 answer per 1=variety 2= bulk	Q3. Qty. sold (Code J)	Q4. Where sold (Code Y)	Q5. Units (Code J)	Q6. Farm gate price per unit (Kes)	Q7. Market price per unit (Kes)	Q8. Who does the selling (Code E)	Q9. Who owns the revenue	Q10. 3 major constraint to marketing (Code U above)
March/April 2013 LR										
Maize		Bulk								
		Variety 1								
		Variety 2								
		Variety 3								
Crop 2		Bulk								
		Variety 1								
		Variety 2								
		Variety 3								
Crop 3		Bulk								
		Variety 1								
		Variety 2								
		Variety 3								

9.0 Integrated Soil Fertility and Water management practices constraints

ISFWM technology type	Please mention three major constraints of the following ISFWM structures in relation to input used during different farm operations; constraint 1 being the major one (Code: V)								
	Tied ridges			Open ridges			Zai pits		
	Constraint 1	Constraint 2	Constraint 3	Constraint 1	Constraint 2	Constraint 3	Constraint 1	Constraint 2	Constraint 3
Maize seed									
Maize seed +Manure									
Maize seed +Manure+ DAP									
Maize seed+ manure +NPK									
Maize seed + manure + [1=CAN 2=Urea]									
Crop 2 seed									
Crop 2 seed+ manure									
Crop 2 seed + manure									
Crop 2 seed + manure +									
Crop 2 seed + manure+ [1=CAN 2=Urea]									
crop 3 seed									
Crop 3 seed + Manure									
Crop 3 seed+ manure + DAP									
Crop 3 seed+ manure + NPK									
Crop 3 seed + manure+ [1=CAN 2=Urea]									

End time:,,

APPENDIX II. Journal paper

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Factors Affecting Adoption of Soil and Water Management Practices in Machakos County, Kenya

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Abstract—**In Africa's dry land areas, inappropriate agricultural practices including adoption of ISFWM technologies account for 28 percent of the degraded soils resulting to low land productivity with consequent increased food and nutrition insecurity. The study was carried to establish the factors that affect smallholder farmer's adoption of ISFWM technologies. A multi-stage sampling was used. Two hundred and forty eight households were sampled in both sub-counties; Data collection was done by well-trained enumerators' and analyzed using SPSS software. Regression models (Tobit and logit), as well as descriptive statistics were used to analyze factors that affect smallholder famers' adoption of ISWFM technologies. The cost-effectiveness of the ISFWM structures was analyzed through Cost- Benefit Analysis. Tobit regression results revealed that The variables Age, gender, access to agricultural extension access and agricultural credit were found to influence adoption of ISFWM technologies significantly (P<0-05) whilst Education level, access to inputs, access to radio, Labor, appropriate equipment farm implements, output Market access and farmers' perception on reliability of October-November Short rain season were cited to affect adoption of ISFWM highly significantly ($P\leq0.01$). The Cost-Benefit Analysis revealed that among the ISFWM structures practiced in LM AEZ 4 and 5 was Zai pit with CBR of 6.98 and 5.63 in LM AEZ 4 and 5, respectively followed by tied ridges with 5.29 in LM AEZ 4 and 5.14 in LM AEZ 5.**

Index Terms—**soil, water, farmers, yatta, Mwala, Kenya**

I. Introduction

The world is facing multiple challenges in the 21st century which include poverty, food insecurity, scarcity of water, and most importantly, new and complex challenges emerging due to global warming and climate change [1]. In the dry land areas, inappropriate agricultural practices account for 28 percent of the degraded soils resulting to low land productivity [2]. Various authors [3], [4] defined ISFWM as the application of soil fertility practices and knowledge to adapt those to local conditions which maximize fertilizer and organic use efficiency and crop productivity.

Kenya's modern agricultural foundation was laid in the early twentieth Century with the arrival of the white settlers [5]. During the Swynnerton plan of 1954, there was a move to address the looming agricultural crisis in Kenya. The plan laid down the foundation for farmer education, the extension system, agricultural credit, the agricultural policy and Kenya's land tenure including also soil and water management practices. However, [6], cited that the colonial authorities in Kenya used coercive approaches to introduce new land-use and conservation methods such as terracing and forced destocking that may have contributed to negative attitude to soil fertility and water conservation measures among smallholder farmers.

Various authors [7], [8] defined such sustainable resource-conserving technologies as skills that enable a farmer to produce his or her desired output, while using the available resources such as land, water, labor, energy, inputs more efficiently and maintaining the productive capacity for the future.

Farmers tend to adopt and adapt new practices and technologies only if the switch offers additional gains in terms of either higher net returns or lower risks, or both [9]. This means that smallholder farmers are likely to adopt Natural Resource Management (NRM) interventions only when the additional benefits from such investments outweigh the added costs [9].

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TABLE I. TOBIT REGRESSION ANALYSIS OF FACTORS AFFECTING SMALLHOLDER FARMERS' ADOPTION OF ISFWM TECHNOLOGIES IN MWALA AND YATTA SUB-COUNTIES

ISFWM adoption variables	Coef.	Std. Err.	T	P>|t|
Age	-0.6752945	0.3026915	2.23	0.027*
Gender	0.6844905	0.3028938	2.26	0.025*
Education	-0.032818	0.0126182	2.6	0.010**
Group membership	0.2072526	0.0850131	2.44	0.016*
Land size	-0.0011474	0.0015236	0.75	0.452
Land tenure systems	-0.2065312	0.1124082	-1.84	0.068
Costs of inputs	-1.307192	0.1800221	7.26	0.000**
Access to radio	-0.0661206	0.0121874	5.43	0.000**
Cost of labor	0.6451344	0.2208105	2.92	0.004**
Availability of farm machinery	0.0249648	0.1579676	0.16	0.001**
Access to extension services	0.6752945	0.3026915	2.23	0.027*
Access to credit services	-0.0280713	0.0116234	2.42	0.017*
Access to output markets	-2.550073	0.091092	-2.8	0.006**
Perception on season reliability	-0.2581763	0.0890947	2.9	0.004**
Perception on improved seeds	0.1600545	0.0940362	1.7	0.090
Constant	3.844093	0.2627518	14.63	0.000

Tobit regression Number of obs 248 $F (18, 229) = 28.54$
Prob> $F = 0.0000$ Log pseudo likelihood = -178.67432
Pseudo $R^2 = 0.8333$
Key- Significant at 5% and ** Significant at 1%*

TABLE II. ADOPTION OF DIFFERENT ISFWM TECHNOLOGIES AS REPORTED BY HOUSEHOLD HEADS IN MWALA AND YATTA SUB-COUNTIES

Type of technology	Specific Technology	Frequency	Percentage
Structures	**Open Ridges**	159	64.1(.489)
	Zai pits	11	4.4 (.522)
	Tied Ridges	78	31.5 (.499)
Fertilizers	**Inorganic fertilizer**	13	5.2 (.000)
	Organic fertilizer	126	50.8(.000)
	Both fertilizer	109	44 (.262)
Seeds	**Local seed**	31	12.5 (.000)
	Improved seed	217	87.5 (.500)
	Sample size	248	100

iender difference was found to be one of the factors iencing adoption of a new technology thus due to y social-cultural values and norms because males have freedom to mobility and consequently have greater access to information [14]. [15] on his study on the dynamics of soil degradation and incentives for optimal management in the Central Highlands of Ethiopia noted that the chances of using inorganic fertilizers on an average plot would be higher by 22.2% for households having access to extension.

Adoption is a decision to make continued use of an innovation as the best course of action available and excludes occasional use of the idea, object or practice [6]. The explanation why the farmers were reluctant to access credit probably due to lack of land ownership for security purposes [2]. However the results were in line with the work of [2] who showed that there was a systematic association between participation in credit and adoption of conservation structures. The coefficient of Agricultural credit access for the household interviewed was found to be negative (-0.0281) regarding ISFWM technology adoption. This indicated that households who had previously accessed agricultural credit facility were more likely to adopt ISFWM agricultural credit access compared to those who had not [16]. Other studies on factors influencing the adoption of soil conservation practices in Northwestern Ethiopia by [6] indicated that poor rural households in developing countries lack access to credit which in turn impacts a significant negative influence to technology adoption. Similar trends were reported in Tanzania [17] who reported 96.3% of the farmers used radios to access information and knowledge in farming systems.

V. Conclusion

The study established that adoption of ISFWM technologies among smallholder farmers in the region varied within the project and non-project sites where results from the adoption were slightly of higher percentage within farmers in the project areas of Mwala and Yatta compared to non-project sites.

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