COMMUNICATION AND UPTAKE OF INTEGRATED SOIL FERTILITY MANAGEMENT AND SOIL WATER CONSERVATION TECHNOLOGIES BY FARMERS IN THARAKA-NITHI COUNTY, KENYA

MAUREEN WAIRIMU NJENGA

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DECLARATION

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

Signature**………………………………** Date **……………………**

Maureen Wairimu Njenga

Department of Agricultural Economics and Extension

A512/1234/2018

This thesis has been submitted for examination with our approval as University Supervisors.

Signature**………………………………** Date **……………………**

Dr. Hezron R. Mogaka

Department of Agricultural Economics and Extension

University of Embu

Signature**………………………………** Date **…………………….**

Prof. Jayne Njeri Mugwe

Department of Agricultural Science and Technology

Kenyatta University

Signature**………………………………** Date **…………………….**

Prof. George Nyabuga

Department of Journalism and Mass Communication

University of Nairobi

DEDICATION

This work is dedicated to my dad Julius Njenga, mom Veronica and siblings Jacinta, Daniel, and Lillian.

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ABBREVIATIONS AND ACRONYMS

AEZ	Agro Ecological Zones
AGRA	Alliance for a Green Revolution in Africa
ASALs	Arid and Semi-arid Lands
CA	Conservation Agriculture
FAO	Food and Agriculture Organization of the United Nations
ROK	Republic of Kenya
INM	Integrated Nutrient Management
INRM	Integrated Nutrient Resource Management
ISFM	Integrated Soil Fertility Management
LISA	Low Input Sustainable Agriculture
LM	Lower Midland
SDGs	Sustainable Development Goals
SPSS	Statistical Packages for Social Sciences
SSA	Sub-Saharan Africa
SWC	Soil Water Conservation

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DEFINITION OF TERMS

Animal manure	This is the solid and liquid waste from livestock and poultry
Communication factors	These are factors associated with communication of agricultural technologies that can either accelerate or decelerate uptake of the selected technologies.
Communication pathway	This is a means by which information flows from one individual or agent to another (Rogers, 2003). It is the route used by information providers to disseminate information to potential users and also receive feedback.
Communication	The process of passing agricultural information from source to a recipient with the intention of getting a feedback from the recipient and influence.
Effectiveness	Effectiveness is conceived as availability, accessibility, reliability and informativeness of communication pathways for disseminating ISFM and SWC information.
Information dissemination	This is the spread of information from the source to a wider targeted audience. This study defines information dissemination as the process of sharing information and knowledge from researchers and extension agents to a wider community of farmers to promote access to and use of innovations relevant in agricultural productivity enhancement.
Information packaging	The physical recording, arrangement and presentation of information in a given medium and in given format.
Information	It is data, which has been processed into a meaningful form.

Mulching	This is the use of organic materials such as crop residue to cover the soil to conserve soil water
Uptake	This is the process of taking up or using up the selected technologies

ABSTRACT

Integrated soil fertility management and soil water conservation practices are possible solutions to persistent soil quality decline and low availability of soil moisture which are affecting agricultural productivity in the dry lands of Tharaka-Nithi County. Nonetheless, the rate of uptake of these technologies and practices by smallholder farmers has stagnated over the years despite recommendations for their use. Lack of effective communication between the extension agents and research institutions and the smallholder farmers could be among the reasons for low uptake. This study therefore aimed to evaluate the influence of communication on uptake of integrated soil fertility management and soil water conservation technologies by farmers in Tharaka-Nithi County, Kenya. The study adopted a cross-sectional survey design and used an interview schedule for data collection from 400 randomly selected farming households. The study targeted smallholder farmers in Tharaka South sub-county. Data was analyzed using descriptive and inferential statistics, using Statistical Packages for Social Sciences. In assessing farmer's perceptions on effectiveness, a ten-point scoring scale was used to score farmer's perceptions on the effectiveness of the selected pathways. Descriptive statistics such as frequencies and means were used to summarize data. One-way analysis of variance (ANOVA) was then used to analyze data where Tukey's honest significant difference test was used for means separation. To assess the farmers' knowledge level, 24 questions were asked requiring an answer of either true or false. Respondents scored (1) for every correct answer and (0) for every wrong answer. Knowledge index was calculated then respondents were classified into three categories. With knowledge levels having more than two levels, multinomial logistic regression was used to analyze the data. Binary logistic regression was employed to assess the influence of information packaging and communication factors on the uptake of the selected technologies. Results showed that other farmers and radio were the most available, accessible, reliable and informative communication pathways thus could be effective in disseminating information in the dry lands of Tharaka-Nithi County. Group membership, training, access to credit and farm equipment were important variables that informed farmer's level of knowledge. In addition, Practical orientations, mode of message display, accessibility of extension agents after the introducing the technology and information repetition were among the factors that influenced the adoption of combined organic and inorganic fertilizers, mulching and Zai pits. Training was essential for mulch and Zai pit technologies, while farmer group membership was necessary for combined organic and inorganic and Zai pit technologies. Continued use of audio-visual materials was recommended, also, extension agents and other stakeholders should consider the use of demonstrations and a simple and clear message to increase adoption of integrated soil fertility management (ISFM) and soil water conservation (SWC) technologies by farmers. Policies and interventions should target technology-specific social economic and institutional determinants to improve knowledge levels of the selected ISFM and SWC technologies.

CHAPTER ONE

INTRODUCTION

1.1 Background

Diminishing soil fertility and climate change are major threats to long-term agricultural production globally and in Sub-Saharan Africa (SSA) (Vanlauwe & Giller, 2006; Thompson et al., 2010). This has resulted to low agricultural productivity, increasing food insecurities, and a rise in poverty levels, especially in the arid and semi-arid lands (ASALs) which largely depend on rain-fed agriculture (Yazar & Ali, 2016; Kanyenji et al., 2020). Declining agricultural productivity is primarily attributed to improper agricultural intensification characterized by continuous cultivation without adequate replacement of the lost nutrients through mining and run-off, non-use of organic amendments, and low fertilizer application rates (Wheeler & von Braun, 2013). High dry spell frequencies, which subject crops to soil moisture stress, especially at the crucial stages of crop development compounds the low agricultural productivity (Ali-Olubandwa et al., 2011; Ngetich et al., 2012; Jayne et al., 2014; Ngetich et al., 2014; Oduor et al., 2020). It has been projected that by 2050, yields from main crops such as sorghum, maize, and millet will reduce by 8 - 22% unless sustainable techniques are adapted and adopted to curb the impacts of climate variability and declining soil fertility (Schlenker & Lobell, 2010). With a growing population, shrinking farm sizes, rapidly degrading soils, and climate change, the use of technologies that can increase crop yields sustainably is therefore critical in averting the declining food security in SSA (Shiferaw et al., 2013; Mucheru-Muna et al., 2021).

Over the past decades, various integrated soil fertility management (ISFM) and soil water conservation (SWC) technologies have been recommended to mitigate declining soil fertility and water shortage in the arid zones (Kuotsu et al., 2014; Kiboi et al., 2017). Integrated soil fertility management technologies have the ability to improve the quality and productivity of soil leading to sustainable yield increase (Mugwe et al., 2009; Mucheru-Muna et al., 2010; Mucheru-Muna et al., 2014; Zhang et al., 2021). The use of SWC technologies such as Zai pits, mulching, and ridge furrowing conserves soil and enhances water use efficiency (Okeyo et al., 2014; Mo et al., 2016; Jiménez et al., 2017;

Kiboi et al., 2020). Despite evidence suggesting positive returns in yields, the adoption of these novel technologies by smallholder farmers has stagnated over the years (Kassie et al., 2013; Kamau et al., 2014). Low adoption has been associated with inadequate awareness, inadequate knowledge and understanding of the technologies among farmers and improper information dissemination (Macharia et al., 2014 Lambrecht et al., 2016; Seitova & Stamkulova, 2017). Poor communication of the technology performance, benefits, and advantages to farmers has created wide communication gaps between the change agents and the farmers (Adolwa et al., 2018; Spurk et al., 2020). Eventually, adoption of the technologies has remained low.

Communication and knowledge sharing is vital in the adoption and sustainability of agricultural technologies and innovations (Babu et al., 2012; Ashraf et al., 2015). Effective communication is considered indispensable, especially in demonstrating the importance of investing in ISFM and SWC technologies because they are not only knowledge-intensive but also challenging to differentiate from effects of the season-specific climatic factors such as rainfall (Vanlauwe et al., 2017; Spurk et al., 2020). The effectiveness of up scaling the use of ISFM and SWC hinges upon the usefulness of communication and the tools used in the dissemination of research findings.

The choice of dissemination pathway is vital because it has been reported that dissemination pathway positively relates to communication effectiveness (Kigatiira et al., 2018, Adolwa et al., 2018). Not all pathways of communication are useful in attaining the same purpose. For instance, mass media pathways such as radio and TVs are important in awareness creation while interpersonal pathways are effective in the knowledge and persuasion stage in the innovation-decision process because they improve the credibility of information (Adolwa et al., 2018). Besides, some communication pathways are interactive and communicative in nature allowing the bi-directional flow of information (Arbuckle et al., 2014). Conversely, others such as print media are disseminative in nature thus do not allow a two-way flow of information between sender and receiver (Adolwa et al., 2018). Different technologies have different attributes of knowledge and information requirements sets. These sets are likely to objectively determine the communication pathways to use if the adoption of the technology in question is to succeed (Murage et al., 2012).

Understanding communication factors that can accelerate or decelerate adoption is key for effective promotion of ISFM and SWC technologies (Marteyet et al., 2014; Wiredu et al., 2014). Several studies have argued that poor perception of information, knowledge, and choice of inappropriate pathways for disseminating information coupled with improper organization and dissemination of agricultural knowledge are the root cause of low technology adoption in SSA (Adolwa et al., 2017; Adolwa et al., 2018). Others have attributed low agricultural productivity to use of ineffective tools for disseminating research findings, poor information packaging, and the use of poor communication methodologies (Mapfumo et al., 2013; Spurk et al., 2020). It is in seeking to understand these dynamics that this study investigated 1) the effectiveness of various communication pathways for disseminating ISFM and SWC information. 2) the socioeconomic factors influencing farmers level of knowledge on selected ISFM and SWC technologies. 3) the influence of information packaging on uptake of the selected ISFM and SWC technologies. 4) the communication factors influencing adoption of ISFM and SCW. The selected technologies include combined organic and inorganic fertilizers, mulching, and Zai pits. These technologies were considered because they had been promoted in the study area aside from their ability to simultaneously enhance soil fertility, and conserve soil and water (Mucheru-Muna et al., 2014; Ngetich et al., 2014; Okeyo et al., 2014; Kiboi et al., 2017; Kimaru-Muchai et al., 2020).

1.2 Statement of the problem

Soil fertility decline and high dry spells frequencies during critical stages of crop growth are the two primary biophysical factors limiting agricultural productivity in the drylands of Tharaka-Nithi County. This has translated into chronic food insecurities in the area. The problem could be resolved through the adoption at scale of ISFM and SWC technologies. Despite the high potential of the technologies to ameliorate agricultural productivity problems, the most prominent problem is the low uptake of these technologies by smallholder farmers. Past studies have attributed low adoption to inadequate awareness of the technologies, use of uncoordinated channels of information delivery, and communication gaps between researchers, extension agents, and farmers. Consequently, ISFM and SWC knowledge is currently not optimally used to address soil fertility and water shortage problems. Additionally, there is still inadequate knowledge on the most appropriate pathways for disseminating ISFM and SCW information, and the influence of information packaging on farmer's uptake of ISFM and SWC technologies. This study therefore assessed the influence of communication on the uptake of selected ISFM and SWC technologies in dry parts of Tharaka-Nithi County.

1.3 Objectives

1.3.1 General objective

To evaluate the influence of communication on uptake of integrated soil fertility management and soil water conservation technologies by farmers in Tharaka-Nithi County, Kenya

1.3.2 Specific objectives

1. To assess farmers' perceptions of the effectiveness of selected communication channels for disseminating information on combined organic and inorganic fertilizer, mulch and zai pits technologies;
2. To determine socioeconomic factors influencing farmer's level of knowledge on the use of combined organic and inorganic fertilizer, mulch and zai pits technologies;
3. To establish the influence of information packaging on uptake of combined organic and inorganic fertilizer, mulch and zai pits technologies;
4. To assess the influence of communication factors on uptake of combined organic and inorganic fertilizer, mulch and zai pits technologies.

1.4 Research questions

1. How do farmers perceive the effectiveness of selected communication channels for disseminating information on combined organic and inorganic fertilizer, mulch and zai pits technologies?

2. What are the household socioeconomic factors that influence farmers' knowledge level on the use of combined organic and inorganic fertilizer, mulch and zai pits technologies?
3. How does information packaging influence uptake of combined organic and inorganic fertilizer, mulch and zai pits technologies?
4. How do communication factors influence uptake of combined organic and inorganic fertilizer, mulch and zai pits technologies?

1.5 Justification of the study

In a world driven by rapid change, the rural farmers' information requirement is constantly increasing. For communities to develop sustainably, they need to be equipped with the necessary information particularly on how to enhance agricultural productivity in the wake of varying and changing climatic conditions. The study aimed to improve the communication process between various stakeholders involved in the implementation of integrated soil management and water conservation technologies. This process is of particular importance in the improvement of livelihood for farmers.

Agricultural intensification (raising agricultural yields through improved technologies) and increased diversification into better crops are required for the achievement of an African green revolution, which is one of the Alliance for a Green Revolution in Africa (AGRA's) key goals. (AGRA, 2013). Both of these tactics will certainly necessitate a greater adoption of ISFM and SWC technologies among other things. Despite the crucial role in increasing agricultural output, these technologies use and adoption remain modest. The study will aid extension agents and other stakeholders in better understanding and application of effective communication channels in ISFM and SWC information dissemination to support sustainable agriculture.

Additionally, the study will contribute to the attainment of Sustainable Development Goals (SDGs) of ending hunger, ensuring food security, boosting nutrition, and promoting sustainable agriculture (UN, 2015). This is also in line with AGRA's target of halving food insecurity in at least 20 countries in Africa by 2020 (AGRA, 2013).

Furthermore, the findings of this study will inform future communication methods for agricultural technology that are promoted by researchers, government and international organizations.

1.6 Significance of the study

The findings of this study may aid in the development of appropriate dissemination paths for researchers and extension agents to use in disseminating and communicating ISFM and SWC information and knowledge, allowing for faster upscaling and adoption of soil fertility management research output. Furthermore, smallholder farmers in Tharaka-Nithi county would benefit from improved communication, which will enable them to use ISFM and SWC knowledge to solve diverse soil fertility concerns.

CHAPTER TWO
LITERATURE REVIEW

2.1 Overview

Communication in agriculture is a significant instrument for shaping knowledge and perception, exchanging experience and promoting new technologies, and it is viewed important in effecting change in theory (Leeuwis, 2004). However, lack of adequate communication structures and tools results in poor technology delivery and finally low farmers' uptake of innovations. This chapter reviews relevant literature on ISFM, the types of communication pathways, and their effectiveness on the adoption of ISFM and SWC, communication factors influencing the adoption of ISFM and SWC as well as the influence of information packaging on the adoption of ISFM and SWC information. The chapter also demonstrates the existing gaps that need to be filled through a systematic assembly of evidence.

2.2 Integrated soil fertility management and soil water conservation technologies

Integrated soil fertility management is a system innovation to address limits to long-term agricultural intensification in Africa. ISFM is defined as a set of soil fertility management practices that include fertilizer use, organic inputs, and improved germplasm, as well as knowledge on how to adapt these practices to local conditions in order to maximize agronomic use efficiency of the applied nutrients and increase crop productivity (Vanlauwe et al., 2010; Bationo & Waswa, 2011). ISFM is comprehensive, taking into account socioeconomic factors such as the inputs-outputs market, credit, and value chain techniques (Bationo &Waswa, 2011). The essential premise of this approach is that while each soil fertility management strategy (technology) contributes significantly to improving soil fertility and productivity, none of them on their own are sufficient in achieving all soil fertility requirements on their own (Place et al.,2003; Vanlauwe, 2004).

Following a shift in soil fertility management paradigms that began with the external input paradigm, then Low–Input Sustainable Agriculture (LISA) and finally the Integrated Nutrient Management (INM) and Integrated Nutrient Resource Management

(INRM) concepts (Bationo & Waswa 2011; Vanlauwe, 2004), ISFM was recently proposed as the fourth principle of conservation agriculture (Vanlauwe, 2014).

The most significant feature of ISFM for Africa's smallholder agricultural system is (1) careful application of mineral fertilizers (2) effective use of existing organic resources (animal manure, compost, and green manure) (3) increased use of nitrogen-fixing legumes into cropping systems and, (4) protection of soils, biota and organic matter (Sanginga & Woomer 2009). ISFM is knowledge-intensive therefore, appropriate pathways for disseminating this information should be identified to enhance better understanding and learning by farmers (Mugwe et al., 2019).

2.3 Farmers' perceptions on effectiveness of communication pathways

The role of communication and its impact on farmers' perceptions and behavior towards soil fertility management is an important aspect of innovation adoption. McGuire's model identifies the source, message, and pathway as key factors in communication effectiveness and outlines how each influences the desired communication outcome and persuasion (Kreuter & McClure, 2004). However, according to Hartman et al., (2015), information may reach the intended group more efficiently if communicators choose channels that the community uses frequently.

Radio, farmer field days, extension services, and in certain cases TV programs were considered the most accessible, reliable, informative, and understandable communication media in several rural areas of SSA (Adolwa et al., 2012; Nyambo & Ligate, 2013). Numerous successes have been reported in projects that have worked with farmer groups (Sanginga et al., 2005; Mugwe et al., 2009) compared to individual farmers. Besides, farmer's exchanges, visits, and study tours are some of the novel ways that improve the effectiveness of disseminating research outputs to farmers (Mowo, 2009).

Low adoption rates of integrated soil fertility management strategies, according to Kimaru-Mucha et al., (2013) are owing to insufficient mass communication avenues for knowledge and information dissemination. Fischer (2010) on the other hand, claims that interpersonal communication is more effective than mass media in promoting agricultural innovation adoption. According to Spurk et al. (2014), the most important component in meeting farmer's information needs for investing in the technologies is trust in information providers, type of content, quality, and manner of information delivery. However, the relationship between poor ISFM and SWC technologies adoption and the effectiveness of the existing communication pathways remain unexplored.

Many studies have looked at the frequency with which people interact with various information sources (Adolwa et al., 2012; Kimaru-Muchai et al., 2013; Sousa et al., 2016) but few have focused on how this affects the uptake of organic resource inputs to improve soil fertility and hence crop productivity. As farmers require information to enhance their productivities, their perception of the effectiveness of pathways for propagating information greatly influences the adoption of technologies. Therefore, this study sought to assess farmers' perceptions on the effectiveness of communication pathways for disseminating ISFM.

2.4 Socioeconomic factors influencing farmers' levels of knowledge

Practical knowledge of the application of agricultural technologies is important for enhanced uptake and utilization of ISFM and SWC technologies by farmers (Macharia et al., 2014; Mucheru-Muna et al., 2021). An understanding of a farmer's level of knowledge is crucial as it helps in recognition of the current state of knowledge, allowing indigenous knowledge and scientific knowledge to be blended for effective technology communication and dissemination (Odendo et al., 2010; Lambrecht et al., 2016; Seitova & Stamkulova, 2017). Farmer's level of knowledge is influenced by several factors (Kanyenji et al., 2020).

Farmers who are members to local groups and organizations have a better chance of accessing knowledge and information on soil fertility and soil water conservation since social organizations provide a forum for discussion and exchange of ideas (Macharia et al., 2014; Mucheru-Muna et al., 2021). According to Macharia et al., (2014), group membership positively influenced household's knowledge levels implying that knowledge in the use of combined organic and inorganic fertilizers increased with participation in groups. Similarly, farmers' membership to local organizations positively and significantly influenced access to information on demand-induced extension resulting in improved knowledge levels (Nambiro, 2006).

The age of the household head negatively influenced farmers' knowledge levels (Onweremodu & Mathews, 2007). When compared to younger farmers, older farmers still hold on the traditional practices and are rigid to change, resulting in a lower likelihood of information access and utilization on new technologies. Furthermore, Macharia et al., (2014), found that total farm had detrimental influence on farmer's knowledge and understanding on how to apply combined organic and inorganic fertilizers. Households' socioeconomic factors differ across regions; however, there has been an unclear correlation of how various socio-economic factors influence farmers' level of knowledge of soil and water conservation technologies (Macharia et al., 2014; Mucheru-Muna et al., 2021). This could be due to high heterogeneity among the communities with different people reacting differently in various situations. The heterogeneity has made the effects of various socio-economic factors blurry and unclear for various technologies therefore, it is important to determine the socioeconomic factors that influence farmers' level of knowledge on the use of combined organic and inorganic fertilizer, mulching, and Zai pits in the drylands of Tharaka-Nithi Sub County.

2.5 Influence of information packaging on adoption of ISFM and SWC

Poor links between research-advisory services-farmers, as well as ineffective delivery mechanisms, including poor information packaging and inadequate communication networks, have been blamed for low agricultural production (Adolwa et al., 2017; Adolwa et al., 2018). In a study on policy issues in addressing rice farmers' agricultural information demands in Niger state, Tologbonse et al. (2008) discovered a substantial association between information packaging and farmers' access to information. Concerning information packaging, 57 percent of farmers chose audio cassettes and 23 percent chose extension publications. Audio cassettes were preferred because they were similar to radio and could be listened to repeatedly. The majority of farmers did not grasp the language used in extension publications; hence, they had a lower preference.

According to Rogers (2003), different technologies have different attributes such as relative advantage, compatibility, complexity, observability, and triability that are likely to influence the technology's adoption. Additionally, different technologies have different attributes of knowledge and information requirement sets. These sets are possible to objectively determine the communication requirements if the adoption of the technology in question is to succeed. Because information is packaged differently in different dissemination pathways, the impact of various pathways on technological adoption is likely to vary (Murage et al., 2012). This, therefore, implies the need to assess the influence of information packaging on the adoption of ISFM and SWC to establish farmers' preference for information packaging.

2.6 Communication factors influencing adoption of ISFM and SWC technologies

Effective promotion of ISFM and SWC technologies may require information on communication factors that can accelerate or decelerate adoption (Marteyet et al., 2014; Wiredu et al., 2014). Several studies have argued that perception of information, knowledge, and pathways for disseminating information coupled with lack of proper organization and distribution of agricultural knowledge are the root causes of low technology adoption in SSA (Spurk et al., 2014; Adolwa et al., 2017; Adolwa et al., 2018). Others have attributed low agricultural productivity to ineffective technology delivery systems, inadequate communication systems, and the use of poor communication methodologies (Mapfumo et al., 2013, Spurk et al., 2020). Additionally, Onasanya et al., (2006), found that knowledge about change agents, shortage of inputs, warning attention, noise, erroneous message content, information overload, accessibility of agents, and difficulty in understanding innovations are some of the communication factors that influenced the adoption of innovations at grass root levels in Nigeria.

Similarly, Ofuoku (2013) reported that the adoption of poultry message was significant and positively correlated with communication factors. The communication abilities of the extension agents and the farmers affected the effectiveness of the message conveyed thus resulting in low adoption. Therefore, communication skills of farmers and extension agents should be enhanced for increased adoption of technologies (Isife & Ofuoku, 2008).

Likewise, the frequency of interaction between extension agents and farmers, information accessibility, and sources of information were found to have a substantial effect on the adoption of agricultural innovations in East Nile Khartoum Sudan (Bello & Mohammed, 2017). Farmers who had access to two extension programs had a higher likelihood of adopting agricultural innovations than farmers who had only one extension program. Similarly, farmers who had access to three extension programs had a higher likelihood of adopting agricultural innovations than farmers who had two programs. Besides, farmers who were exposed to many agricultural information sources had a higher level of access to information thus adopted new technologies as compared to those with less access.

2.7 Theoretical framework

The study was informed by two theories: (1) information richness theory and (2) diffusion of innovation theory. These theories aided in understanding the adoption process and the role of communication in the adoption of agricultural innovations.

2.7.1 Diffusion of Innovation Theory

Diffusion of innovation theory explains how a new idea or practice diffuses over time among members of a social system (Rogers, 2003). The theory suggests that different people adopt or reject an innovation depending on perceived attributes such as relative advantages, the complexity of the innovation, compatibility, and time. The theory explains that people in society accept innovation or technology while others do not.

According to this theory, adoption is progressive from knowledge/ awareness to persuasion, decision, implementation, and confirmation (Rogers, 2003). In the first stage, farmers are made aware of the existence of technology. Technology awareness and knowledge is an important prerequisite for its use. Only when an individual has relevant information about the technology can they be persuaded to adopt the technology. Based on the individual's characteristics and perceived advantage of the innovation, farmers decide whether to adopt or reject the innovation. A key component of the diffusion of innovation theory is communication. Innovation diffusion is an information-seeking and information-processing activity. Therefore, communication plays a crucial role in awareness creation, persuasion, and decision-making in the innovation-decision process. However, there is a scarcity of information on the influence of communication individuals' decision on whether to adopt or not adopt agricultural innovations. The theory was thus applicable to the study in that it enabled the researcher to test the uptake of selected technologies to smallholder farmers thus encouraging farmers to adopt ISFM and SWC information that will strengthen their adaptive capacity.

2.7.2 Information Richness Theory

Information richness theory states that the medium of communication determines the richness of information processed (Daft & Lengel, 1984). Information richness refers to the ability to transmit needed information without loss or distortion (Dennis & Kinney, 1998). A communication media that can overcome equivocality by clarifying ambiguous issues and promoting the right interpretation of the message is considered information-rich (Daft & Lengel, 1984). According to information richness theory, four factors are central to any media information richness. These factors include (1) the ability to transmit multiple cues such as vocal inflection and body gestures, (2) mediums capacity for immediate feedback- the promptness of the response, (3) language variety of the media such as numbers and natural language, and (4) personalization- the degree to which intent is tailored to meet the receiver’s needs (Daft & Lengel, 1984; Dennis & Kinney, 1998). A lot of ISFM and SWC information has been produced, but there is little utilization of such information on the part of farmers. Accessibility and utilization of information, therefore, largely depend on communication effectiveness.

2.8 Conceptual framework

The major problem experienced in the study area is low agricultural productivity due to low uptake of existing and proven ISFM and SWC practices. This has been attributed to the use of ineffective communication pathways, unknown farmers' levels of knowledge on the use of the technologies, inappropriate information packaging, and the presence of communication barriers between farmers, extension agents, and researchers. The use of effective communication pathways, understanding socioeconomic characteristics influencing farmers' level of knowledge, proper information packaging, and understanding communication factors that either stimulate or constraint uptake of ISFM and SWC will enhance communication thus reduce the communication gaps between researchers and farmers. This will in turn lead to increased ISFM and SWC uptake and increased agricultural productivity.

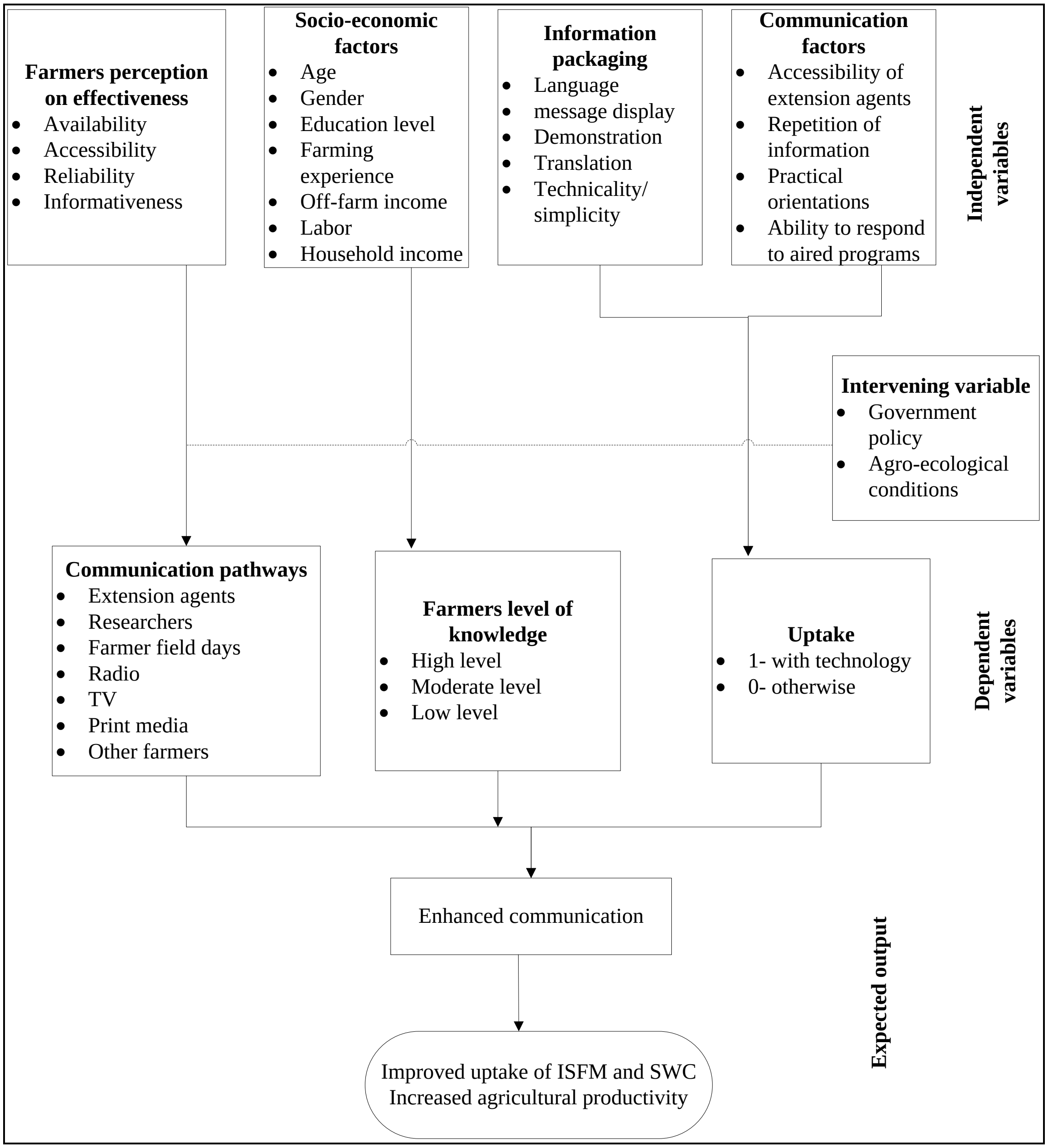

Figure 1 Conceptual framework

2.9 Research gap

Varying and changing climatic conditions and soil fertility decline are currently the primary causes of food insecurity in SSA. Relating to previous studies the use of ISFM and SWC has shown a potential impact on soil productivity (Kiboi et al., 2020). Nevertheless, the low uptake of improved technologies to address these challenges has been persistent over the years. However, few studies have looked at the role of communication on uptake of ISFM and SWC practices particularly in the drylands of

Tharaka-Nithi County. Information gaps also exist on the influence of information packaging on uptake of ISFM and SWC and the communication factors that hinder the adoption of these practices. This study sought to bridge this gap by assessing the farmer's perception of the effectiveness of communication pathways, as well as assessing the influence of information packaging and other related communication factors on uptake of the selected technologies.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Study area

The study was carried out in Tharaka South Sub-County in Tharaka-Nithi County, Kenya (Figure 2). It has an area of 1,569.5 Km^2 and a population of 75,250, with a household population of 18,646 (KNBS, 2019). The County lies between latitude 00˚ 07' and 00˚ 26' South and between longitudes 37˚ 19' and 37˚ 46' East. It lies in agro-ecological zones (AEZ), lower midland (L.M.) 4 and 5 (Mugi-Ngenga et al., 2016). Tharaka South Sub-County receives a bimodal rainfall ranging between 200 and 800 mm per annum, which is low, unreliable, and poorly distributed. The sub-County experiences annual temperatures ranging between 22℃ and 36℃ (Smucker & Winser, 2008). *Ferrasols* are the predominant soils in the study area (Jaetzold et al., 2006). Mixed farming dominates in the sub-county where farmers grow crops (Millet, cowpeas, pigeon peas, green grams, sorghum, cassava, maize, bean, mango, pawpaw, and bananas) and rear livestock (chicken, goats, and cows) (Nderi et al., 2014). Rain-fed agriculture, which is the main livelihood activity, is highly responsive to climate variability which is the major shock experienced in the Sub-County. This has led to low agricultural productivity and high poverty levels of up to 65% (Jaetzold et al., 2006; Kristjanson et al., 2010).

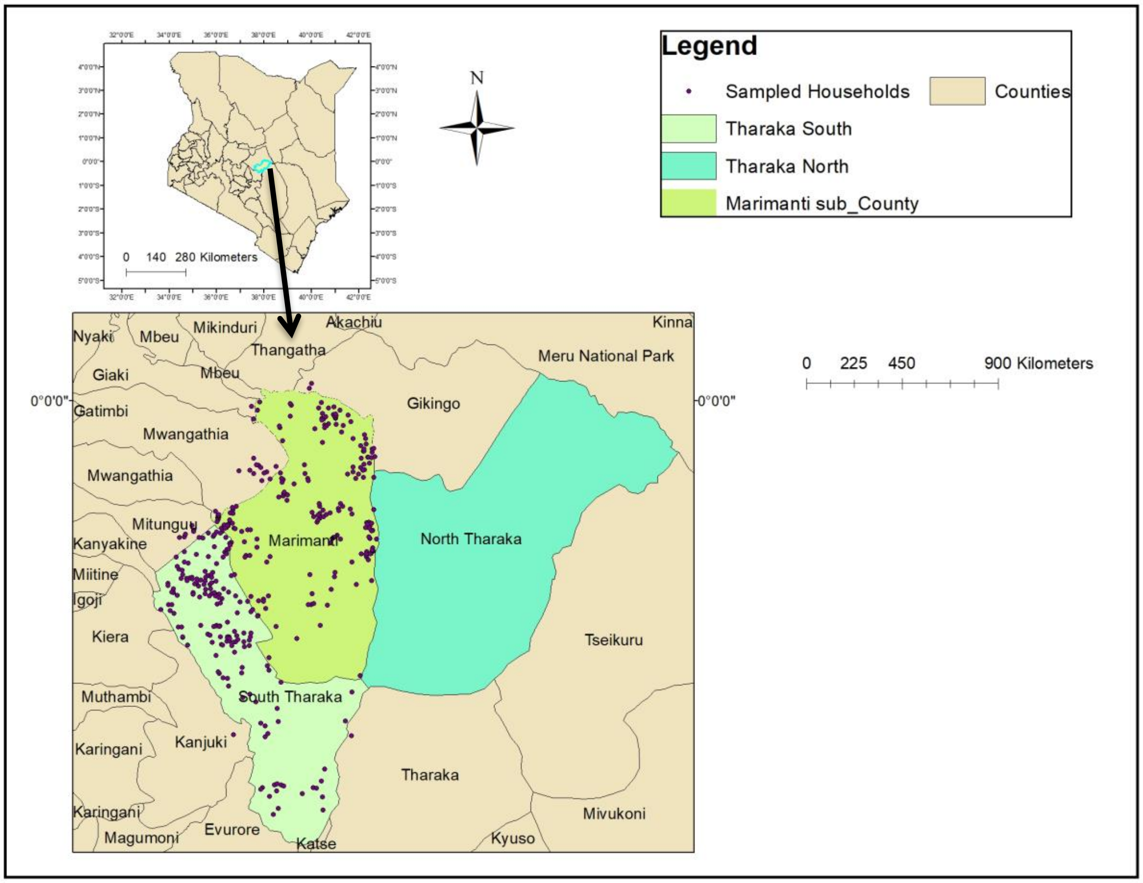

Figure 2 Map of the study area showing sampled households

3.2 Research design

The study used a cross-sectional approach. This design was chosen because it allows the researcher to collect data at a certain point in time. According to Agresti & Finalay (2009), the design enables the use of a variety of survey methods to collect a body of qualitative and quantitative data while also providing quick results at a low cost.

3.3 Target population and sample size

The study targeted smallholder farmers in Tharaka South Sub-County. The sample size was calculated using the following formula by (Cochran, 2007);

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

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

3.4 Sampling procedure

The study employed a combination of purposive sampling, probability proportionate to size, and random sampling techniques in selecting the sample households. Tharaka South Sub-County was purposively selected, the justification being that the selected ISFM and SWC technologies had been promoted in the area (Mucheru-Muna et al., 2014; Ngetich et al., 2014; Okeyo et al., 2014; Kiboi et al., 2017; Kimaru-Muchai et al., 2020). All the three wards in the sub-county (Ciakariga, Marimanti, and Nkondi) were selected to ensure every area within the sub-county was represented. Given the variations in the number of households in the three wards, probability proportionate to size sampling technique was employed to determine the number of households to be interviewed (Table 1). Random sampling technique was then used to select the households. Household records were obtained from the Sub-County agricultural offices. The records were used as a sampling frame from which sampled households were selected using computer-generated random numbers.

Table 1 Number of households sampled and interviewed per ward

Ward	Population 2019	Number of Households	Sample size
Ciakariga	32,531	8,064	173
Marimanti	28,023	6,946	149
Nkondi	14,696	3,636	78
Total	75,250	18,646	400

3.5 Instruments of data collection

Actual data collection was preceded by an exploratory survey. The exploratory survey gave insights on the technologies that were of interest to the farmers and the likely challenges. Data collected during the exploratory survey guided in technology selection and in the development of the data collection tool. The study used both primary and secondary data. The primary data was mainly collected using the interview schedule.

Secondary data was collected from secondary sources such as books, reports, and journal papers. The interview guide addressed the specific objectives of the study.

3.6 Pretesting

3.6.1 Reliability

Reliability refers to the degree to which the survey tool is consistent with the data it collects (Litwin, 1995). To evaluate the consistency of the survey instruments, a split-half reliability test was done. This method eliminates chance error by testing the instrument under different conditions (Mugenda & Mugenda, 2003). The interview schedule was administered to 23 smallholder farmers who were randomly selected. According to Israel (2012), a survey study with a sample size of larger than or equal to 20 can generate meaningful results. The correlation coefficient (*r*) between the halves of the items was calculated using Pearson's product linear correlation coefficient formula. Spearman brown prophecy was used to determine the reliability of the full instrument.

3.6.2 Validity of instruments

Field (2005), states that validity is the capability of a research instrument to measure what it ought to measure so that the difference in individual scores can be taken as representing a true difference in the characteristic under study. To assure validity, the survey instrument was analyzed and evaluated by the supervisors and colleagues to ensure that it measures the study objectives. The advice provided was reflected upon and taken into consideration while revising the interview schedule.

3.7 Data analysis

The collected data was double-checked for accuracy, coded, and then entered into a computer. The data was analyzed with the Statistical Package for Social Sciences (SPSS).

To assess farmers perceptions on effectiveness of selected communication pathways for disseminating information on the selected technologies

In assessing farmer's perceptions on effectiveness, a ten-point scoring scale was used (where 1 was the lowest and 10 the highest) to score farmers' perceptions on effectiveness based on availability, accessibility, reliability, and informativeness of the selected pathways. The data was summarized using descriptive statistics like frequencies and means. One-way ANOVA was then used to analyze data. For means comparison, Turkey's honestly significant difference test was used.

To determine socioeconomic factors influencing farmers level of knowledge on the use of the selected technologies

To assess the farmer's knowledge level, 24 questions were asked each with a true or false answer. Respondents scored (1) for every correct answer and (0) for every wrong answer. The farmer's knowledge was standardized by analyzing its content validity. After obtaining the knowledge index (Eq 3.2), mean (μ), and standard deviation of the index (s.d) were calculated. The respondents were classified into three categories; the respondents having scores in the range of (μ ± s.d) were categorized as having moderate knowledge level, high knowledge level for those with a score greater than (μ ± s.d) and low knowledge level for those having a lower score than (μ ± s.d) (Jha, 2012; Luangduangsitthideth et al., 2019).

$$\text{Knowledge Index (KI)} = \frac{n}{N} \qquad \text{(Eq3.2)}$$

Where, KI = Knowledge index, n = Total score of respondent for correct answer, N = Maximum obtainable score.

With knowledge levels having more than two levels, multinomial logistic regression was appropriate for analysis. The MNL model can be specified as follows;

$$\left(Y = \frac{j}{x}\right) \qquad \text{(Eq 3.3)}$$

$$= \frac{exp(X\beta_J)}{1+\sum_{h=1}^{j} exp(x\beta_h)}, j = 0,1,2,3 \ldots .n$$

Where β_j is the vector of coefficient of explanatory variables x, the base outcome vector coefficient is represented by β_h, j represents the unordered alternatives and y shows the knowledge levels. The log of odds-ratios of selecting each alternative from the equation above will be calculated as;

$$\ln\left[\frac{p_{ij}}{p_{ik}}\right] = x_i\left(\beta_j - \beta_k\right) = x_{i\beta_j\,if\;k=0} \qquad \text{(Eq3.4)}$$

It is appropriate to obtain marginal effects of each exogenous variable dependent on knowledge level of a farmer (Greene, 2003). The marginal effect for each explanatory variable will be calculated as;

$$\frac{dp_i}{dx_i} = p_j\left[\beta_j - \sum_{k=0}^{j} p_k \quad \beta_k\right] = p_j\left[\beta_j - \beta\right] \qquad \text{(Eq3.5)}$$

This is important, as coefficients will have different signs from the marginal effects.

To assess the effect of information packaging and communication factors on adoption of the selected technologies

According to the diffusion of innovation theory, adoption is binary; a farmer either accepts (1) or rejects (0) agricultural innovations. Because of the dichotomous nature of the dependent variable, binary logistic regression was employed to analyze the data. Several studies have used the logistic model to analyze the adoption of different technologies (Mugwe et al., 2009; Macharia et al., 2014; Mugi-Ngenga et al., 2016; Kimaru-Muchai et al., 2020). The model was employed because of its ability to include a large number of explanatory variables and does not have linearity and heteroscedasticity assumptions. The model can be specified as follows (equation 3.6);

$$Pi = F\,(Zi) = \frac{1}{1} + e - (\alpha + \square iXi) \qquad \text{(Eq 3.6)}$$

Where, Pi is the probability of adoption of combined organic and inorganic fertilizers, mulch and Zai pits, Xi denotes the ith explanatory variables, while α and βi represents the parameters to be estimated, and e is the base of the natural logarithm. In terms of odds ratios and log of odds, the expression was as per equation 3.

$$\frac{Pi}{1-Pi} = \mathrm{e}iz \qquad \text{(Eq 3.7)}$$

1− Pi is the probability of households not using the technologies. Hence the natural log was expressed as equation 4.

$$Ln\left(\frac{Pi}{1-Pi}\right) = Zi = \alpha + \beta_1 x_1 + \beta_2 x_2 + \cdots + \beta_n x_n + Ui \qquad \text{(Eq 3.8)}$$

Ui is the error term, randomly distributed, β_1, $\beta_2 \ldots$ β_n are the parameters to be estimated while x_1, $x_2 \ldots$ x_n are the explanatory variables.

CHAPTER FOUR

RESULTS

4.1 Household social demographic characteristics

The results showed that most of the interviewed respondents (67%) were from male-headed households, besides the majority had attained up to and beyond the primary level of education (Table 2). The majority of the respondents were found to own land with title deed (65%), belonged to farmers groups (54%), also a large number had no access to training (65%). Twenty-seven percent of the respondents had access to credit while a majority (68%) perceived their soils as infertile (Table 2).

The interviewed households' mean age was 46 years while the average farming experience was 18 years. Additionally, the average land size was 5 acres, while the mean household size was five persons (Table 2).

Table 2 Household social demographic characteristics

Variables	Categories	Frequencies(percentages)
Gender	Male	268(67)
	Female	132(33)
Education level	Non-formal	31(8)
	Primary	230(58)
	Secondary	86(21)
	Tertiary	53(13)
Access to credit	No	290(73)
	Yes	110(27)
Land ownership	without title deed	140(35)
	with title deed	260(65)
Labor access	No	58(15)
	Yes	342(85)
Soil fertility perceptions	Infertile	215(54)
	Fertile	185(46)
Training	No	219(55)
	Yes	181(45)
Group membership	No	126(32)
	Yes	274(68)

Variables	Minimum	Maximum	Mean	Std. Deviation
Age (continuous)	20.0	82.0	45.478	10.9787
Farming experience(years)	1.0	60.0	18.695	12.2295
HH size (continuous)	1.0	17.0	5.295	2.1852

Values inside parenthesis = percentages, values outside parenthesis = frequencies

4.2 Farmers' perceptions on effectiveness of communication pathways

Results showed that farmers' scores on availability, accessibility, reliability, and informativeness of the selected communication pathways varied across the three technologies. The communication pathway that had the highest score was regarded as the most available, accessible, reliable, and informative pathway.

For combined organic and inorganic fertilizers, other farmers were the most available (4.27), followed by radio (3.80), and farmer field day (3.39). The least available pathways were TV (2.46) and print media (1.95). The most accessible pathway was other farmers (4.08), second-placed was radio (3.70), and followed by extension agents (3.32). Other farmers (4.17) were also the most reliable followed by radio (3.61), extension agents

(3.37bc), and agro-input dealers (3.22), while the least accessible was TV (2.19) and print media (1.72). Concerning informativeness, other farmers (4.14) were the most informative, followed by radio (3.61), extension agents (3.46), and Agro-input dealers (3.46), while the least informative pathways were TV (2.08) and Print media (1.87), (Table 3).

Regarding the dissemination of mulch information, other farmers were the most available (4.73), accessible (4.64), reliable (4.55), and informative (4.50) communication pathway. Radio was perceived as the second most available (3.83), accessible (3.68), reliable (3.57), and informative (3.75) pathway.

Table 3 Farmers' perceptions on effectiveness of the selected communication pathway in disseminating information on combined organic and inorganic fertilizer, mulch and Zai pits

	Combined org and inorg N=400				Mulch N=400				Zai pits N=400			
Pathway	**AV**	**AC**	**RE**	**INFO**	**AV**	**AC**	**RE**	**INFO**	**AV**	**AC**	**RE**	**INFO**
Other farmers	4.27^{a}	4.08^{a}	4.17^{a}	4.14^{a}	4.73^{a}	4.64^{a}	4.55^{a}	4.50^{a}	4.18^{a}	4.08^{a}	4.02^{a}	3.98^{a}
Radio	3.80^{b}	3.70^{b}	3.61^{b}	3.61^{b}	3.83^{b}	3.68^{b}	3.57^{b}	3.75^{b}	3.52^{b}	3.44^{b}	3.36^{b}	3.35^{b}
Field day	3.39^{c}	3.25^{c}	3.03^{d}	3.35^{b}	3.46^{c}	3.28^{c}	3.21c	3.38^{c}	3.17^{c}	3.10^{c}	3.16^{b}	3.2475^{b}
Researchers	3.26^{c}	3.05^{c}	3.12^{cd}	3.34^{b}	3.46^{c}	3.31^{c}	3.27^{bc}	3.36^{c}	3.23^{bc}	3.21^{bc}	3.13^{b}	3.23^{b}
Extension agents	3.22^{c}	3.32^{c}	3.37^{bc}	3.46^{b}	3.64^{bc}	3.48^{bc}	3.54^{bc}	3.63^{bc}	3.46^{bc}	3.44^{b}	3.34^{b}	3.31^{b}
Agro input dealers	3.09^{c}	3.18^{c}	3.22^{cd}	3.46^{b}	3.55^{bc}	3.34^{c}	3.34^{bc}	3.34^{c}	3.23^{bc}	3.18^{bc}	3.14^{b}	3.09^{b}
Agricultural shows	2.73^{d}	2.61^{d}	2.46^{e}	2.63^{c}	2.83^{d}	2.68^{d}	2.64^{d}	2.74^{d}	2.63^{d}	2.65^{d}	2.60^{c}	2.66^{c}
TV	2.46^{d}	2.28^{d}	2.19^{e}	2.08^{d}	2.30^{e}	2.22^{e}	2.18^{e}	2.27^{e}	2.18^{e}	2.13^{e}	2.16^{d}	2.12^{d}
Print media	1.95^{e}	1.92^{e}	1.72^{f}	1.87^{d}	2.05^{e}	1.94^{e}	1.90^{e}	1.93^{e}	1.93^{e}	1.88^{e}	1.86^{d}	1.90^{d}
P	**<.0001**	**<.0001**	**<.0001**	**<.0001**	**<.0001**	**<.0001**	**<.0001**	**<.0001**	**<.0001**	**<.0001**	**<.0001**	**<.0001**

The same superscript in the same column shows no significant difference between pathway means at p= 0.05, AV= availability, AC= accessibility, RE= reliability and INFO= informativeness. N= total number of households interviewed.

There was no significant difference between extension agents, field days, researchers, and agro-input dealers in terms of availability, accessibility, reliability, and informativeness. TV and print media were the least available, accessible, reliable, and informative communication pathways for disseminating information on mulch (Table 3).

In disseminating of Zai pits information, other farmers were perceived to be the most available (4.18), accessible (4.08), reliable (4.02), and informative (3.98) communication pathway. This was followed by radio with a mean of (3.52) availability, (3.44) accessibility, (3.36) reliability, and (3.35) for informativeness (Table 3). However, in terms of availability and accessibility, there was no statistically significant difference between radio, extension agents, researchers, and agro-input dealers. Farmer field days were the fourth most available (3.17) and accessible (3.10) communication pathways. In relation to reliability and informativeness, there was no statistically significant difference between radio, extension agents, farmer field days, researchers, and agro-input dealers. Print media and TV were the least available, accessible, reliable, and informative communication pathways.

Generally, across the three technologies, in terms of availability, accessibility, reliability, and informativeness, all pathways were statically different at $p<0.05$ with a p-value of <.0001. Other farmers were perceived to be the most available, accessible, reliable, and informative communication pathway. Radio was second however, there was no statistically significant difference between extension agents, field days, researchers, and agro-input dealers except for combined organic and inorganic fertilizers. The least available, accessible, reliable, and informative communication pathways were agricultural shows, TV, and print media.

4.3 Farmers' knowledge levels

Results show that the majority of the farmers 52%, 61%, and 58% had moderate knowledge levels for combined organic and inorganic fertilizer, mulch and Zai pits, respectively (Table 4).

Table 4 Farmers' knowledge levels on combined organic and inorganic fertilizer, mulch and Zai pit

Technologies	**Knowledge level**		
	Low	**Moderate**	**High**
Combined organic and inorganic fertilizers	72(18)	209(52)	119(30)
Mulch	68(17)	242(61)	90(22)
Zai pits	92(23)	233(58)	75(19)

Values in parenthesis= percentage, values outside parenthesis= frequencies

Additionally, most farmers (69%) did not know the recommended rates for applying combined organic and inorganic fertilizers. Only 36% were aware that combined organic and fertilizers should be applied half the recommended rates of each that is 30 kg ha^{-1} (Table 5). However, 47% of the farmers were aware of the benefits of the integrated use of organic and inorganic fertilizers. For mulching technology, the majority 80% were aware of the benefits of using mulching. However, 68% did not know the appropriate rate and mode of application. The majority of the farmers knew little about Zai technology especially, the measurements, spacing and its construction (Table 5).

Table 5 Descriptive statistics of farmers' knowledge per question asked

Questions	Frequency/percentage	
	Wrong	Correct
Combined organic and inorganic fertilizers		
1. The recommended rate for applying combined organic and inorganic fertilizers is 60 kg ha^{-1}	274(69)	126(31)
2. Combined organic and fertilizers should be applied ½ the recommended rates of each that is 30 kg ha^{-1}	256(64)	144(36)
3. The rate of applying manure should be 1 handful per planting hole	214(54)	186(46)
4. Fertilizers should be applied as 2.5 g per seed or 5g per two seeds per hole (1 bottle top)	293(73)	107(27)
5. The combined fertilizer and manures should be thoroughly mixed with the soil to avoid scorching of seeds	206(51)	194(49)
6. Appropriate combination of organic and inorganic fertilizer boost agricultural productivity	190(48)	210(52)
7. It is cheaper to use both organic and inorganic fertilizer that inorganic fertilizer	188(47)	212(53)
8. Combining both inorganic and organic fertilizers provide more balanced nutrient supply	187(47)	213(53)
9. The ratio of combining organic and organic fertilizer should be 1:1 or 50/50	186(47)	214(53)
Mulch		
10. Mulching adds nutrients to the soil and improves soil structure	79(20)	321(80)
11. I know the different types of mulching material	261(65)	139(35)
12. Mulch reduces weed growth by reducing the amount of light	234(58)	166(42)
13. Mulching should be applied on the surface to cover the soil	211(53)	189(47)
14. Mulch should be applied after germination of crops	270(68)	130(32)
15. Mulching reduces soil erosion	80(20)	320(80)
16. The recommended rate of application is 5 t ha^{-1}	352(88)	48(12)
17. Mulching conserves water reducing the need for frequent watering	93(23)	307(76)
18. Mulching maintains a more even soil temperatures	61(15)	339(85)
Zai pits		
19. The correct measurements for Zai pits is 20-30 cm width, 10-20 cm depth	237(59)	163(41)
20. The correct spacing (measurements) for Zai pits is 60-80 cm apart	216(54)	184(46)

21. Zai pits should be constructed in an alternating manner	290(73)	110(27)
22. Zai pits reduces run-off and increases water infiltration	139(35)	261(65)
23. Zai pits increase soil fertility	125(31)	275(69)
24. Zai pits should be constantly repaired for efficient use	131(32)	269(67)

Values in parenthesis = percentage, values outside parenthesis= frequency

4.4 Relationship between knowledge level and use of combined organic and inorganic fertilizer, mulch and Zai pit technologies

There was a significant association between the use of combined organic and inorganic fertilizers and levels of knowledge (X^2=16.784, p=0.0001). Majority of the users of combined organic and inorganic fertilizers had moderate knowledge levels, while 19% of the farmers had low knowledge level (Table 6). There was a significant association between use of mulch (X^2=17.953, p=0.0001) and levels of knowledge in the use of mulch (Table 6). Majority (59%) of the farmers who used mulch had moderate knowledge level, 27% had high knowledge level and 14% had low knowledge level There was a significant association between use of Zai pits (X^2=30.186, p=0.0001) and knowledge levels in the use of Zai pits (Table 6). Majority of farmers (63%) had moderate knowledge level and did not use the technology.

Table 6 Relationship between farmers' level of knowledge and use of the technologies

	Combined org+ inorg			**Mulch**			**Zai pits**		
	Non-users n=196	Users n=204	χ^2	Non-users n=88	Users n=312	χ^2	Non-users n=228	Users n=172	χ^2
Low	34(17%)	38(19%)	0.0001	24(27%)	44(14%)	0.0001	63(28%)	29(17%)	0.000
Moderate	121(62%)	88(43%)		57(65%)	185(59%)		143(63%)	90(52%)	
High	41(21%)	78(38%)		7(8%)	83(27%)		22(9%)	53(31%)	

χ^2=chi-square p-value, figures outside parentheses= frequencies

4.5 Household socioeconomics factors influencing farmers' knowledge level on selected ISFM and SWC technologies

4.5.1 Results of univariate analysis of socioeconomic factors influencing knowledge in use of combined organic and inorganic fertilizer, mulch and zai pits technologies

Results of the univariate analysis of socio-economic factors influencing farmer's knowledge level identified six variables that were important in explaining knowledge levels in the use of combined organic and inorganic fertilizers. These variables include education level, land ownership, access to farm equipment, perceptions on soil fertility, perceptions on soil erosion, and farming experience (Table 7). Education level, access to credit, access to farm equipment, perceptions on soil erosion, perceptions on soil fertility, and farmer group membership were the main variables found to significantly influence knowledge level in the use of mulch. Similarly, education level, access to credit, access to farm equipment, land ownership, perceptions on soil fertility, and perceptions on soil erosion were the significant socioeconomic factors that influenced farmer's knowledge level in the use of Zai pits (Table 7).

Table 7 Univariate analysis of socioeconomic factors influencing farmers' knowledge levels in combined organic fertilizer, mulch and zai pits technologies

		Combined org and inorg			***X^2***	**Mulch**			***X^2***	**Zai pits**			***X^2***
Zai pits		Low level (n=72)	Moderate level (n=209)	High level (n=119)		Low level (n=68)	Moderate level (n=242)	High level (n=90)		Low level (n=92)	Moderate level (n=233)	High level (n=75)	
Education level HH	Non-formal	13(42)	13(42%)	5(16%)	0.000	12(39%)	13(42%)	6(19%)	0.002	16(52%)	12(39%)	3(9%)	0.001
	Primary	46(20%)	127(55%)	57(25%)		45(19%)	137(60%)	48(21%)		55(23%)	127(55%)	48(22%)	
	Secondary	8(9%)	51(59%)	27(32%)		7(8%)	59(69%)	20(23%)		13(15%)	60(70%)	13(15%)	
	Tertiary	5(9%)	18(34%)	30(57%)		4(8%)	33(62%)	16(30%)		8(15%)	34(64%)	11(21%)	
Gender HH	Male	43(16%)	139(52%)	86(32%)	Ns	36(13%)	171(64%)	61(23%)	Ns	57(21%)	155(58%)	56(21%)	Ns
	Female	29(22%)	70(53%)	33(25%)		32(24%)	71(54%)	29(22%)		35(27%)	78(59%)	19(14%)	
Off-farm employment	No	52(21%)	127(51)	69(28%)	Ns	11(10%)	55(50%)	44(40%)	0.000	52(21%)	147(59%)	49(20%)	Ns
	Yes	20(13%)	82(54%)	50(33%)		28(20%)	89(64%)	23(16%)		40(26%)	86(57%)	26(17%)	
Access to credit	No	54(19%)	146(50)	90(31%)	Ns	57(19%)	18(64%)	46(17%)	0.000	67(23%)	186(64%)	37(13%)	0.000
	Yes	18(16%)	63(57%)	29(27%)		11(10%)	55(50%)	44(40%)		25(22%)	47(43%)	38(35%)	
Land ownership	With title deed	20(14%)	88(63%)	32(23%)	0.008	28(20%)	89 (64%)	23(16%)	Ns	34(24%)	89(64%)	17(12%)	0.045
	Without title deed	52(20%)	121(47%)	87(33%)		40(15%)	153(59%)	67(26%)		58(22%)	144(55%)	58(23%)	
Access to labor	No	13(22%)	35(60%)	10(18%)	Ns	15(26%)	31(53%)	12(21%)	Ns	20(34%)	31(53%)	7(13%)	Ns
	Yes	59(17%)	174(51%)	109(32%)		53(15%)	211(62%)	78(23%)		72(21%)	202(59%)	68(20%)	
Access to farm equipment	No	32(28%)	75(66%)	7(6%)	0.000	39(34%)	48(42%)	27(24%)	0.000	47(41%)	60(53%)	7(6%)	0.000
	Yes	40(14%)	134(47%)	112(39%)		29(10%)	194(68%)	63(22%)		45(16%)	173(60%)	68(24%)	
Perceptions on soil fertility	Infertile	59(27%)	113(53%)	43(20%)	0.000	47(22%)	101(47%)	67(31%)	0.000	71(33%)	87(40%)	57(27%)	0.000
	Fertile	13(10%)	96(52%)	76(38%)		21(11%)	141(76%)	23(13%)		21(11%)	146(79%)	18(10%)	

HH= household head, X^2=chi square value, Association significant at p=0.005, NS= Not significant

4.5.2 Socioeconomic factors influencing farmers' knowledge level in the use of combined organic and inorganic fertilizer, mulch, and Zai pit technologies

Farming experience predicted (β = 1.053, p= 0.034) how knowledgeable the farmer is on the use of combined organic and inorganic fertilizers, implying that one-year increase in farming experience increases the probability of having a low knowledge level as compared to a high knowledge level by 1.053 times (Table 8). The education level of the household head positively influenced the household's knowledge levels. Households with non-formal education as compared to those with tertiary education where 11.844 times more likely to have low knowledge level as compared to high (β = 11.844 p= 0.009). Similarly, households with primary knowledge level (β = 4.409, p= 0.013) as compared to those who had tertiary education were 4.409 times more likely to have low knowledge levels as compared to high. Equally, households with non-formal education (β = 5.029, p= 0.038) as compared to those with tertiary education were 5.029 times more likely to have moderate knowledge levels as compared to high. Households with primary (β = 3.383, p= 0.002) and secondary education (β = 3.880, p=0.002) as compared to those who had tertiary education were 3.383 and 3.880 times more likely to have moderate knowledge level as compared to high knowledge level respectively (Table 8).

The model showed access to farm equipment to positively influence (β = 10.587, p= 0.0001) farmers' knowledge levels. This implies that farmers with access to farm equipment were 10.587 times more likely to have high knowledge levels as compared to low knowledge levels. Likewise, farmers with access to farm equipment (β = 6.750, p= 0.0001) were 6.750 times more likely to have a high knowledge level as compared to moderate (Table 8). Additionally, livestock keeping positively predicted how knowledgeable a households is (β = 3.461, p= 0.045). This implies that farmers with more number of cattle were more knowledgeable than farmers with less number of cattle. Additionally, farmer's perceptions of soil fertility positively (β = 11.631, p= 0.0001) influenced farmers' knowledge level on combined organic and inorganic fertilizer. This implies that farmers that perceive their farms to be fertile were 11.631 times more likely to have high knowledge levels as compared to low. Farm size positively (β = 1.082, p=

0.041) influenced households knowledge levels in combined organic and inorganic fertilizers (Table 8).

Table 8 Socio-economic factors influencing farmers' knowledge level on combined organic and inorganic fertilizers

High knowledge (Reference)		**Low knowledge level**				**Moderate knowledge level**			
		B	Std. Error	Sig.	Exp (B)	B	Std. Error	Sig.	Exp (B)
Intercept		-3.100	1.319	.019		.184	.918	.841	
Farming experience		.052	.025	**.034****	1.053	.049	.019	**.008*****	1.050
HH size		-.078	.087	.370	.925	-.107	.064	.098	.899
Farm size		.045	.052	.389	1.046	.078	.038	**.041****	1.082
Gender	Male	-.057	.393	.885	.945	-.176	.295	.552	.839
Education level	Non formal	2.472	.950	**.009*****	11.844	1.615	.777	**.038****	5.029
	Primary	1.484	.597	**.013****	4.409	1.219	.389	**.002*****	3.383
	Secondary	.872	.723	.228	2.392	1.356	.443	**.002*****	3.880
Credit Access	No	.674	.441	.126	1.963	.185	.329	.575	1.203
Land ownership	Without tittle deed	-.369	.423	.383	.691	.353	.306	.249	1.423
Labor access	No	.341	.551	.536	1.406	.429	.430	.318	1.536
Farm equipment Access	No	2.360	.528	**.0001*****	10.587	1.910	.452	**.0001*****	6.750
Livestock keeping	No	1.242	.618	**.045****	3.461	-.318	.549	.562	.727
Soil fertility perceptions	Infertile	2.454	.440	**.0001*****	11.631	1.069	.302	**.0001*****	2.913
Training	No	.193	.408	.636	1.212	.044	.302	.883	1.045
Farmer group membership	No	-.416	.437	.341	.659	-.343	.314	.275	.710

***, ** Significance at 1% and 5% respectively

The gender of the household head was a significant negative predictor (β = -0.496 p= 0.073) of farmers' knowledge levels on use of mulch, implying that men were more knowledgeable on use of mulch as compared to their counterparts. Farmers belonging to the farmer group were 3.340 times more likely to have high knowledge levels on mulch as compared to low (β = 3.340, p= 0.019) and 4.464 times more likely to have high knowledge level as compared to moderate(β = 4.464, p= 0.0001) (Table 9). Credit access was a significant factor that positively influenced household knowledge level on mulch. Households with access to credit were 2.937 times more likely to have a high knowledge level as compared to low (β = 3.991, p= 0.002). Similarly, access to credit (β = 1.751, p= 0.0001) increased the likelihood of having high knowledge as compared to moderate by 1.751 times (Table 9).

Table 9 Socio-economic factors influencing farmers' knowledge level on use of mulch

High knowledge (reference)		**Low knowledge level**				**Moderate knowledge level**			
		B	Std. Error	Sig.	Exp (B)	B	Std. Error	Sig.	Exp (B)
Intercept		-2.225	1.329	.094		-.027	.990	.979	
Farming experience		.024	.027	.377	1.024	-.014	.021	.510	.986
HH size		.089	.092	.334	1.093	.071	.071	.317	1.074
Farm size		.036	.052	.490	1.037	.019	.043	.653	1.020
Gender	Male	-.701	.391	**.073***	.496	-.007	.304	.981	.993
Education level	Non formal	.862	.900	.338	2.367	-.155	.727	.831	.856
	Primary	.737	.659	.263	2.091	.345	.409	.399	1.411
	Secondary	-.033	.781	.966	.968	.202	.467	.666	1.224
Credit Access	No	1.384	.452	**.002*** **	3.991	.560	.306	**.067***	1.751
Land ownership	Without tittle deed	.271	.413	.512	1.312	.481	.326	.140	1.618
Labor access	No	.023	.504	.964	1.023	-.196	.412	.634	.822
Farm equipment Access	No	1.077	.419	**.010*** **	2.937	-.408	.343	.234	.665
Livestock keeping	No	.011	.640	.986	1.011	-.056	.523	.915	.946
Soil fertility perceptions	Infertile	-.317	.415	.445	.728	-1.265	.312	**.0001*** **	.282
Training	No	.453	.400	.256	1.574	.090	.304	.766	1.095
Farmer group membership	No	1.206	.512	**.019** **	3.340	1.496	.417	**.0001*** **	4.464

***, **, * Significance at 1%, 5% and 10% respectively

Training positively influenced farmer's knowledge levels on the use of Zai pits. Farmers who accessed training in the last one year (β = 3.375, p=0.004) were 3.375 times more likely to have high knowledge levels as compare to low knowledge level. Similarly, farmers with access to training (β = 2.938, p= 0.003) were 2.938 more likely to have high knowledge levels as compared to moderate knowledge levels (Table 10). Access to credit also positively influenced farmer's knowledge levels on Zai pits. Households with access to credit (β = 2.598, p= 0.026) were 2.598 times more likely to have high knowledge levels as compared to low knowledge. Similarly, households with access to credit (β = 3.171, p= 0.002) were 3.171 more likely to have a high knowledge level as compared to moderate knowledge levels (Table 10).

Education negatively influenced farmers' knowledge level on Zai pits. Households with non-formal education (β = -0.19, p= 0.078) as compared to those with tertiary education level were 0.19 times more likely to have a high knowledge level as compared to moderate knowledge level (Table 10). Similarly, households with primary education level (β = -0.413, p= 0.068) as compared to tertiary education level were 0.413 more likely to have a high knowledge level as compared to moderate knowledge level. Similarly, households with access to farm equipment (β = 6.903, p= 0.0001) were 6.903 times more likely to have a high knowledge level as compared to low and 3.510 times more likely to have high knowledge level as compared to moderate knowledge level (β = 3.510, p= 0.010) (Table 10).

Table 10 Socio-economic factors influencing farmers' knowledge level on Zai pits

High knowledge (reference)		**Low knowledge level**				**Moderate knowledge level**			
		B	Std. Error	Sig.	Exp (B)	B	Std. Error	Sig.	Exp (B)
Intercept		1.926	1.638	.240		3.261	1.458	.025	
Farming experience		.019	.028	.509	1.019	.008	.024	.734	1.008
HH size		-.019	.090	.829	.981	-.008	.076	.917	.992
Farm size		.063	.059	.282	1.065	.025	.053	.637	1.026
Gender	Male	-.424	.414	.305	.654	-.550	.356	.122	.577
	Non formal	.516	1.001	.606	1.676	-1.626	.924	**.078***	.197
Education level	Primary	-.230	.606	.704	.794	-.884	.484	**.068***	.413
	Secondary	-.022	.707	.975	.978	-.290	.556	.602	.748
Credit Access	No	.955	.430	**.026****	2.598	1.154	.364	**.002*****	3.171
Land ownership	Without tittle deed	-.096	.440	.828	.909	.176	.376	.641	1.192
Labor access	No	.484	.569	.395	1.622	.009	.505	.985	1.009
Farm equipment Access	No	1.932	.517	**.0001*****	6.903	1.256	.485	**.010*****	3.510
Livestock keeping	No	-.520	.751	.489	.595	-.372	.630	.554	.689
Soil fertility perceptions	Infertile	.142	.434	.743	1.153	-1.394	.358	**.0001*****	.248
Training	No	1.216	.428	**.004*****	3.375	1.078	.367	**.003*****	2.938
Farmer group membership	No	-.325	.485	.503	.722	.005	.408	.990	1.005

***, **, * Significance at 1%, 5% and 10% respectively

4.6 Univariate results of the influence of information packaging on uptake of combined organic fertilizers, mulch and zai pits technologies

Out of 400 respondents interviewed, 204 (51%) were users and 196 (49%) were classified as non-users of combined organic and inorganic fertilizers. Results showed there is a significant association between message display, technology demonstration, information translation, information sufficiency in terms of quality and quantity, and uptake of combined organic and inorganic fertilizers form (Table 11). The majority of the households, 218 (55%) received information in the audio-visual form while 74% indicated that technologies were demonstrated. More users (88%) indicated that the information translated into a simpler language (Table 11). It is worth noting that there was a significant relationship between information sufficiency in terms of quality and quantity and the use of organic and inorganic fertilizers. The majority of the farmers (52%) indicated that information was not sufficient in terms of quantity while (79%) of the farmers indicated that information was sufficient in terms of quality (Table 11). This shows that farmers had access to quality information, however, the information was not sufficient in terms of quantity and this could negatively influence the adoption of combined organic and inorganic fertilizers.

Mulch

Results in indicated that 78% of the farmers were using mulch technology. Further, there was a significant relationship between language, message display, technology demonstration, and information sufficiency in terms of quality and use of mulch technology. The majority of the farmers (75%) received information in vernacular, (23%) in Swahili and (2%) in English. A majority of households indicated that message was displayed in the audio-visual form (54%), followed by Audio (40%), visual (5%), and print (1%) (Table 11). There was a significant association between information sufficiency in terms of quality and use of mulch. Eighty percent of the farmers who were using mulch indicated that information was sufficient in terms of quality.

Zai pits

Forty three percent of the farmers who were using Zai pits technology while 57% were not using the technology (Table 11). There was a significant association between message display, technology demonstration, information technicality, and information sufficiency in terms of quality and use of Zai pit technology. The majority of the households received information in the audio-visual form (54.5%). Regarding technology demonstration, the majority of farmers (73.8%) indicated that the technology was demonstrated; while 26% indicated that technology was not demonstrated. this implies that technology demonstration is likely to positively influence Zai pit adoption

Table 11 Univariate analysis of information packaging factors influencing uptake of combined organic and inorganic fertilizer, mulch and zai pits technologies

		Combined org and inorg fertilizer			Mulch			Zai pits		
Variables		**Non users N=196**	**Users N=204**	X^2	**Non users N=88**	**Users N=312**	X^2	**Non users N=228**	**Users N=172**	X^2
Language	Vernacular	138(46%)	161(54%)	NS	58(19%)	241(81%)	0.028	166(56%)	133(44%)	NS
	Kiswahili	52(57%)	39(43%)		29(32%)	62(68%)		57(63%)	34(37%)	
	English	6(60%)	4(40%)		1(10%)	9(90%)		5(50%	5(50%)	
Message delivery/ display	Audio	98(61%)	62(39%)		46(29%)	114(71%)		113(71%)	47(29%)	
	Audio-visual	80(37%)	138(63%)	0.000	42(19%)	176(81%)	0.010	98(45%)	120(55%)	0.000
	Visual	18(86%)	3(14%)		0(0%)	21(100%)		16(76%)	5(24%)	
	Print	0(0%)	1(100%)		0(0%)	1(100%)		1(100%)	0(0%)	
Technology demonstration	No	81(77%)	24(23%)	0.000	34(32%)	71(68%)	0.004	77(73%)	28(27%)	0.000
	Yes	115(39%)	180(61%)		54(18%)	241(82%)		151(51%)	144(49%)	
Information technicality	No	149(52%)	137(48%)	NS	66(23%)	220(77%)	NS	183(64%)	103(36%)	0.000
	Yes	47(41%)	67(59%)		22(19%)	92(81%)		45(39%)	69(61%)	
Information translation	No	31(63%)	18(37%)	0.047	14(29%)	35(71%)	NS	32(65%)	17(35%)	NS
	Yes	165(47%)	186(53%)		74(21%)	277(79%)		196(56%)	155(44%)	
Information sufficiency in terms of quantity	No	113(54%)	96(46%)	0.036	47(22%)	162(76%)	NS	127(61%)	82(39%)	NS
	Yes	83(43%)	108(57%)		41(21%)	150(79%)		101(53%)	90(47%)	
Information sufficiency in terms of quality	No	53(63%)	31(36%)	0.005	26(31%)	58(69%)	0.037	61(73%)	23(27%)	0.001
	Yes	143(45%)	173(55%)		62(20%)	254(80%)		167(53%)	149(47%)	

NS= Not significant, X^2= chi square value, sig at p=0.05 Parenthesis are percentages

4.7 Influence of information packaging on uptake of combined organic and inorganic fertilizers, mulch and zai pits technologies

The form of message delivery was significant factor that positively influence adoption of mulch (β = 0.551, p= 0.014) (Table 13) and Zai pits (β = 0.374, p= 0.048) technology (Table 14). Moreover, the audio-visual had the highest number of adopters at 176(81%) and 120(55%) for mulch and Zai pit technologies respectively. This implies that the adoption of mulch and Zai pits is likely to increase by 55.1% and 37.4% respectively when audio-visual materials are used in information dissemination. Technology demonstration positively influenced the adoption of combined organic and inorganic fertilizers (β =1.301, p=0.000) (Table 12) and Zai pits (β =0.535 p=0.050) technology (Table 14). Information technicality positively influenced adoption of Zai pits (β = 0.817, p= 0.001). This implies that the use of clear and simple language with simple interpretation is likely to increase the adoption of Zai pits by 81.7% (Table 14).

Table 12 Binary logistic analysis of the influence of information packaging and uptake of combined organic and inorganic fertilizer

	B	S.E.	Wald	Sig.	Exp(B)	Vif
Language	-.412	.225	3.341	.068	.662	1.072
Message delivery/ display	.108	.199	.295	.587	1.114	1.160
Technology demonstration	1.301	.283	21.175	.0001***	3.674	1.661
Information technicality	.021	.256	.007	.934	1.022	1.388
Information translation	-.057	.368	.024	.878	.945	1.207
Information sufficiency in terms of quantity	.177	.235	.571	.450	1.194	1.182
Information sufficiency in terms of quality	.335	.314	1.134	.287	1.398	1.378
Constant	-1.763	.411	18.442	.000	.171	

*** Significance at 1% respectively, vif= variance inflation factor

Table 13 Binary logistic analysis of the influence of information packaging and uptake of mulch

Mulch	B	S.E.	Wald	Sig.	Exp(B)	Vif
Language	-.390	.236	2.730	.098	.677	1.063
Message delivery/ display	0.551	.224	6.066	.014**	1.736	1.181
Technology demonstration	0.415	.289	2.060	.151	1.514	1.691
Information technicality	.063	.297	.044	.833	1.065	1.389
Information translation	.070	.381	.034	.854	1.073	1.204
Information sufficiency in terms of quality	.334	.304	1.205	.272	1.396	1.372
Information sufficiency in terms of quality	.254	.305	1.142	.287	1.378	1.368
Constant	.281	.392	.512	.474	1.324	

** Significance at 5% respectively, vif= variance inflation factor

Table 14 Binary logistic analysis of the influence of information packaging and uptake of zai pit

Zai pits	B	S.E.	Wald	Sig.	Exp(B)	Vif
Language	-.162	.215	.569	.451	.851	1.066
Message delivery/ display	.374	.189	3.907	.048**	1.454	1.157
Technology demonstration	.535	.273	3.828	.050**	1.707	1.671
Information technicality	.817	.242	11.435	.001***	2.263	1.386
Information sufficiency in terms of quality	.427	.304	1.978	.160	1.533	1.375
Farmer group discussion	.435	.230	3.584	.058	1.546	3.212
Information sufficiency in terms of quantity	.090	.229	.153	.696	1.094	1.181
Constant	-1.778	.322	30.539	.000	.169	

***, ** Significance at 1% and 5% respectively, VIF= variance inflation factor

4.8 Communication factors influencing uptake of combined organic and inorganic fertilizers, mulch and zai pits technologies

As Table 15 below shows, there is a significant association between training (p= 0.019, χ^2 = 5.518), farmer group membership (p= 0.001, χ^2 = 29.583), accessibility of extension agents' after introducing the technology (p= 0.001, χ^2 = 14.287). Practical orientations (p= 0.001, χ^2 = 43.849), attitude towards extension agents (p= 0.001, χ^2 = 26.572), information technicality (p= 0.050, χ^2 = 3.8543), information repetition, and literacy levels and adoption of combined organic and inorganic fertilizers (Table 15).

Practical orientation (p= 0.002, χ^2 = 9.363) and information repetitions are the factors likely to influence adoption of mulch. Similarly, a significant association was noted between information technicality (p= 0.0001, χ^2 = 19.982), training (p= 0.0001, χ^2 = 20.236). Farmer group membership (p= 0.0001, χ^2 = 19.250), extension agent's accessibility after the introducing the technology (p= 0.0001, χ^2 = 27.005), practical orientation (p= 0.0001, χ^2 = 22.760), attitude towards extension agents (p= 0.000, χ^2 = 0.000), information repetition, and literacy levels and adoption of Zai pits (Table 15).

Table 15 Univariate analysis of communication factors influencing uptake of combined organic and inorganic fertilizers, mulch and zai pits technologies

Variables		Combined org and inorg fertilizer			Mulch			Zai pits		
		Non-users N=196	Users N=204	X^2	Non-user N=88	Users N=312	X^2	Non-user N=228	users N=172	X^2
Training	No	118(54%)	100(46%)	0.021	56(26%)	162(74%)	NS	146(67%)	72(33%)	0.000
	Yes	78(43%)	104(57%)		32(18%)	150(82%)		82(45%)	100(55%)	
Farmer group membership	No	87(69%)	39(31%)	0.000	35(28%)	91(72%)	NS	92(73%)	34(27%)	0.000
	Yes	109(40%)	165(60%)		53(19%)	221(81%)		136(50%)	138(50%)	
Farmer group discussion	No	112(67%)	56(33%)	0.000	46(27%)	122(73%)	0.028	114(68%)	54(32%)	0.000
	Yes	84(36%)	148(64%)		42(18%)	190(82%)		114(49%)	118(51%)	
Extension accessibility	No	150(56%)	120(44%)	0.000	61(37%)	103(63%)	NS	178(66%)	92(34%)	0.000
	Yes	46(35%)	84(65%)		27(11%)	209(89%)		50(38%)	80(62%)	
Practical orientation	No	80(77%)	24(23%)	0.000	34(33%)	70(67%)	0.004	80(77%)	24(23%)	0.000
	Yes	116(39%)	180(61%)		54(18%)	242(82%)		148(50%)	148(50%)	
Ability to respond to aired programs	No	175(51%)	170(49%)	NS	80(23%)	265(77%)	NS	206(60%)	139(40%)	0.008
	Yes	21(38%)	34(62%)		8(15%)	47(85%)		22(40%)	33(60%)	
Attitude towards extension	Unfavorable	44(81%)	10(19%)	0.000	15(28%)	39(72%)	NS	43(80%)	11(20%)	0.000
	Neutral	107(43%)	141(57%)		47(19%)	201(81%)		47(19%)	201(81%)	

agents	Favorable	45(46%)	53(54%)		26(27%)	72(73%)		26(27%)	72(73%)	
				T			**t**			**t**
No. of groups		0.801	1.058	-0.258***	0.852	0.955	-0.1028	0.798	1.110	-0.312***
No of extension visits		0.367	0.602	-0.236***	0.568	0.465	0.1034	0.325	0.703	-0.379***
Information repetition		1.724	2.843	-1.119***	2.284	3.747	-1.4627*	1.487	2.813	-1.327***
Literacy		3.443	3.901	-0.458**	3.420	3.75	-0.3295	3.5	3.913	-0.412

NS= Not significant, X^2=Chi square, sig at p=0.05, T= mean difference, ***, ** significant at 1% and 5% respectively

4.9 Logistic regression results of communication factors influencing uptake of combined organic and inorganic fertilizers, mulch and zai pits technologies

Results showed that extension accessibility after introducing the technology, practical orientation, and information repetition had a significant positive influence on the adoption of the combined organic and inorganic fertilizers (Table 16), mulch (Table 17) and Zai pits (Table 18) technologies. Similarly, training positively influenced adoption at (β = 1.026, p= 0.030) under mulch (Table 15) and (β = 1.274, p=0.001) under Zai pits (Table 16). While belonging to a farmer group membership was necessary for adoption of combined use of organic and inorganic fertilizer at (β =0.945, p=0.055) (Table 16) and Zai pits at (β =0.963, p= 0.057) (Table 18).

Table 16 Binary logistic regression results of communication factors influencing uptake of combined organic and inorganic fertilizers

Combined org +inorg	B	S.E.	Wald	Sig.	Exp(B)	Vif
Training	.517	.390	1.756	.185	1.678	3.411
Farmer group membership	.945	.492	3.696	.055*	2.573	4.170
Farmer group discussion	.467	.398	1.378	.240	1.596	3.206
Extension accessibility	.882	.462	3.648	.056*	2.416	3.888
No. of extension visits per season	-.275	.259	1.125	.289	.760	3.934
Information repetition	.160	.054	8.977	.003***	1.174	1.104
Practical orientation	1.094	.294	13.887	.0001***	2.986	1.808
Ability to response to aired program	.258	.342	.568	.451	1.294	1.094
Literacy level	.062	.057	1.211	.271	1.064	1.114
Attitude	.153	.212	.521	.470	1.166	1.343
Constant	-2.335	.405	33.187	.000	.097	

***, * Significance at 1% and 10% respectively, VIF= variance inflation factor

Table 17 Binary logistic regression results of communication factors influencing uptake of mulch

Mulch	B	S.E.	Wald	Sig.	Exp(B)	Vif
Training	1.026	.474	4.687	.030**	2.791	3.415
Farmer group membership	.326	.537	.369	.543	1.386	4.185
No. of farmer group	.010	.235	.002	.965	1.010	2.407
Farmer group discussion	.227	.447	.258	.611	1.255	3.199
Extension accessibility	1.066	.547	3.793	.051*	2.903	3.885
No. of extension visits per season	-.795	.288	7.588	.006	.452	3.933
Practical orientation	.781	.302	6.710	.010***	2.185	1.762
Ability to response to aired program	.707	.447	2.502	.114	2.027	1.086
Literacy level	.035	.065	.287	.592	1.036	1.115
Attitude	-.231	.231	.997	.318	.794	1.341
Information repetition	.209	.061	11.874	.001***	1.232	1.131
Constant	-.231	.408	.322	.570	.793	

***, **,* Significance at 1%, 5% and 10% respectively, VIF= variance inflation factor

Table 18 Binary logistic regression results of communication factors influencing uptake of zai pits

Zai pits	B	S.E.	Wald	Sig.	Exp(B)	Vif
Training	1.274	.384	11.003	.001***	3.576	3.427
Farmer group membership	.963	.506	3.622	.057*	2.619	4.170
Farmer group discussion	-.742	.416	3.182	.074	.476	3.212
Extension accessibility	.855	.450	3.602	.058*	2.351	3.875
No. of extension visits per season	-.151	.264	.327	.567	.860	3.934
Practical orientation	.926	.311	8.854	.003***	2.524	1.780
Ability to response to aired program	.639	.332	3.692	.055*	1.894	1.087
Literacy level	.045	.057	.630	.427	1.046	1.115
Attitude	.314	.221	2.029	.154	1.369	1.342
Information repetition	.259	.061	18.063	.000*	1.296	1.096
Constant	-2.901	.444	42.781	.000	.055	

***,* Significance at 1% and 10% respectively, VIF= variance inflation factor

CHAPTER FIVE

DISCUSSIONS, CONCLUSIONS AND RECOMMENDATIONS

5.1 Household socio-demographic characteristics

The majority of the households were male-headed which implied that at household level, men dominate and make almost all agricultural and farm-related decisions, including what information to access and what ISFM and SWC technologies to adopt. The finding agrees with Kimaru-Muchai et al. (2020) and Mugi-Ngenga et al. (2016), who found that male-headed households were more than the female-headed households in the study area. Most of the households had education up to and beyond the primary level. This implies that farmers had the ability to obtain and comprehend the disseminated information and hence make better decisions on whether to adopt or not to adopt ISFM and SWC technologies.

Access to credit is an essential factor in determining the adoption of technologies, especially the labor-intensive ones such as ISFM and SWC. Results showed that most households were credit-constrained despite government's effort to increase farmer's access to credit (Kiplimo et al., 2015). The low access to credit is attributed to high-interest rates charged on loans, strict loan policies, and lack of collateral (Mbugua, 2013; Kiplimo et al., 2015). The majority of the households had title deeds. Security of land tenure encourages long-term investment; therefore, farmers had an incentive to invest in more sustainable agricultural innovations (Nhemachena & Hassan, 2007). This, thus, implies that respondents were more likely to adopt the ISFM and SWC technologies.

Training is an important vehicle in empowering farmers with the necessary knowledge and skills (Lukuyu et al., 2012). Training is essential in capacity building by enhancing farmer’s access to information; thus, it increases the likelihood of adoption of agricultural innovations (Kimaru-Muchai et al., 2020). The lower number of trained farmers is attributed to a reduction in the number of service providers and training personnel such as extension agents and the cost of training as also reported by (Macharia et al., 2014; Mwaura et al., 2021) in the study area. This implies that majority of the farmers had inadequate information on ISFM and SWC technologies hence less likely to adopt the technologies. The majority of the households belonged to a farmer group. Farmer groups facilitate farmers' exchange of ideas and experiences, and in one way or another, farmers’ are persuaded to adopt technologies. Perception of soil fertility is vital in the adoption of soil improvement technologies such as ISFM and SWC. Farmers who perceive their soils as infertile may adopt ISFM technologies to enhance their soil productivity. Therefore, farmer's sensitization about their soil fertility status is essential.

The respondent's mean age showed that most farmers were in their labor productive age thus are active and can participate in farming activities. These results agree with the findings of Ramaekers et al. (2013), who reported similar age brackets and the farmers were active in farming. The high farming experience is attributed to the high dependency on farming as a primary source of livelihood (Mwaura et al., 2021). The average household size indicated that the majority of the households had labor endowment. A large household offers labor that is essential in the adoption of labor-intensive technologies such as ISFM and SWC technologies.

5.2 Farmers’ perceptions on effectiveness of communication pathways

Communication pathways were evaluated based on Availability, Accessibility, Reliability, and Informativeness. These qualities determine the extent to which a given pathway is considered useful/ effective (Demiryurek, 2010; Adolwa et al., 2012). In choosing communication pathways to utilize, farmers and other stakeholders choose pathways they are familiar with or those they have a personal interaction with. Besides, farmers choose communication pathways based on the satisfaction derived and the ability of the pathway in meeting their needs ((Prokopy et al., 2015; Mase et al., 2015).

Other farmers were perceived to be the most available, accessible, reliable, and informative communication pathways in disseminating information on combined organic and inorganic fertilizer, mulch, and Zai pits. This agrees with results by Gwandu, (2013), who found other farmers to be the most preferred source of ISFM information. Similarly, other farmers were ranked third most accessible, reliable, informative, and comprehensible communication pathways after radio and farmer field days (Adolwa et al., 2012). This can be attributed to the fact that other farmers as a community-based pathway are communicative and interactive thus allow a two-way flow of information (Demiryurek, 2010). Similarly, as compared to other pathways, other farmers are many in numbers thus making them the most available, accessible, reliable, and informative communication pathways. Despite other farmers being the most informative communication pathway, interactions with farmers revealed that they were hesitant in using information gained from their colleagues. Lack of confidence in the quality of information is cited as a major reason for the non-utilization of information exchanged among farmers (Gwandu, 2013). Therefore, to make other farmers an effective communication pathway, there is a need to increase the confidence of information by building farmers' knowledge to improve the quality of information exchanged.

Radio was the second most available, accessible, reliable, and informative communication pathway. This is because a majority of the farmers in the study area possessed a radio. Radio is reported to be the most effective communication pathway in disseminating information in the rural areas and non-illiterate cultures (Mwombe et al., 2014; Rodriguez et al., 2015; Adolwa et al., 2018). Radio is not as interactive as other community-based pathways, however, it has several advantages, key among them is the ability to transmit information in the local dialect, it is portable and stimulates imagination, information reaches a large audience, and also it can convey information very quickly (Norrish et al., 2001).

There was no statistically significant difference between farmer field days, extension agents, researchers, and agro-input dealers in terms of availability, accessibility, reliability, and informativeness. They were ranked third. Despite the importance of extension agents in disseminating agricultural information, they have been reported to become less relevant in terms of soil conservation information dissemination (Stuart et al., 2014). The reduction in the number of extension agents has been cited as a problem Spurk et al. (2014) thus less available, accessible, and reliable pathway. Farmers cited one or zero times contact with extension agents, researchers, and agro-input dealers in the last year. Therefore, extension agents, researchers, agro-input dealers should increase their interaction with farmers for better delivery of ISFM and SWC information.

Print media and TV were the least available, accessible, reliable, and informative communication pathways. Farmers in the study were not connected to electricity making it difficult to operate a TV. Besides, these pathways are disseminative thus do not allow a bi-directional flow of information. They are also expensive and require some level of literacy for them to be effectively utilized (Sanginga & Woomer, 2009; Hassan et al., 2010).

5.3 Social economic factors influencing farmers' level of knowledge in the use of combined organic and inorganic fertilizers, mulch and zai pits technologies

5.3.1 Social economic factors influencing farmers' level of knowledge in the use of combined organic and inorganic fertilizers

Farming experience positively predicted how knowledgeable the farmer is on the use of combined organic and inorganic fertilizers. This implies that a one-year increase in farming experience increases the probability of having a low knowledge level as compared to a high knowledge level. The more experienced the farmer is the less knowledge he is on the use of combined organic and inorganic fertilizers. This is probably because older and experienced farmers tend to be conservative and trust the traditional farming methods than the less experienced and younger farmers (Manda et al., 2016; Mugi-Ngenga et al., 2016). According to Macharia et al. (2014), older farmers are more rigid and reluctant to take risks hence less willing to access and utilize information on new technologies. They will therefore not be interested in learning new knowledge.

The education level of the household head positively influenced the household's knowledge levels. This implies that the more educated a farmer is, the more knowledgeable they are on use of combined organic and inorganic fertilizer. These findings are in tandem with that reported by Cheruiyot (2020). Being informed about technology is normally preceded by an individual's ability to realize the need for information (Csótó, 2010). Education exposes one to awareness and this enhances the adoption and knowledge levels of the farmer (Kimaru-Muchai et al., 2020). Educated farmers seek information, are more likely to process, and realize the need for knowledge in soil conservation technologies as compared to less educated farmers

(Mwungu et al., 2018; Cheruiyot, 2020). The ISFM and SWC technologies are knowledge-intensive hence; education level is linked to information literacy on use of combined organic and inorganic fertilizers (Mucheru-Muna et al., 2021).

Access to farm equipment positively influenced farmer's knowledge levels. This implies that farmers with access to farm equipment were more likely to have high knowledge levels as compared to low knowledge levels. This could be attributed to the technology being labor-intensive and farmers having huge trucks of land hence access to farm equipment would be important if the farmer is to adopt the technology (Marteyet et al., 2014). This in turn influences how knowledgeable a farmer is on use of combined organic and inorganic fertilizers. Additionally, farmers have resources at their disposal to purchase inputs such as fertilizer and manure that are key for this technology. Further, livestock keeping positively predicted how knowledgeable the farmer is on use of combined organic and inorganic fertilizer (Barret, 2010; Mucheru-Muna et al., 2021). This suggests that households with more number of cattle, and who have more manure are more likely to adopt the technology hence will be more knowledgeable than farmers with fewer cattle. Cattle manure is a key resource for ISFM and has been used for a long time in the region (Mugwe et al., 2009). The availability of manure contributed to the adoption of this technology making farmers with livestock to be more knowledgeable.

Farmer's perceptions of soil fertility positively influenced farmers' knowledge level on use of combined organic and inorganic fertilizer. According to Kasefu et al. (2018), farmer's perceptions of soil fertility were consistent with the laboratory analysis results, showing farmer's accuracy in understanding their farms. Farmers can only perceive their farms as fertile if they have used soil fertility improvement technologies Manda et al. (2016), therefore they could be more knowledgeable about the technology. Perceptions of soil fertility positively influence the adoption of ISFM technologies (Mugwe et al., 2009; Kassie et al., 2013). Therefore, there is need to sensitize farmers about their soil fertility status.

Farm size positively influenced household's knowledge levels in use of combined organic and inorganic fertilizers. This implies that an increase in a unit of land increases the probability of having a moderate knowledge level as compared to high.

The smaller the farm size the more knowledgeable the household. This finding agrees with Macharia et al. (2014) who found that farm size influenced farmer's knowledge levels on the use of ISFM. This could be attributed to households' trying to intensify agricultural productivity to reap maximum benefits from their small plots of land. Agricultural intensification requires a lot of information regarding nutrient supply and soil improvement thus creating room for households to learn more about combined organic and inorganic fertilizers thus gaining more knowledge (Macharia et al., 2014).

5.3.2 Social economic factors influencing farmers level of knowledge of mulch application

Gender of the household head, access to credit, access to farm equipment, farmer group membership, and perceptions on soil erosion were significant variables in influencing knowledge levels in the use of mulch. Gender negatively influenced farmers' knowledge levels on use of mulch. This implies that male-headed households as compared to female-headed households were more likely to have a high knowledge level as compared to low. This could be as a result of male-headed households having better access to extension services and agricultural information as compared to their counterparts. According to Nwangi & Kariuki (2015), men are the landowners and make almost all agricultural decisions including what information to access. This could also be attributed to the negative influence of cultural norms and traditions and the lack of appropriate schedules for extension services for females (Aravindakshan et al., 2020). This result also agrees with Macharia et al. (2014) and Cheruiyot (2020) who found that men had better access to information than females.

It is worth noting that farmer group membership positively influenced farmers' knowledge level for use of mulch. Farmers belonging to a farmer group were more likely to be knowledgeable about the use of mulch as compared to farmers who did not belong to farmer groups. Farmer groups and social organizations provide forums for farmers to share experiences, challenges, and exchange of ideas (Kassie et al., 2009). Groups are also seen to play a key role in persuading farmers to try new technologies and sharing new information (Macharia et al., 2014). Additionally, farmer groups provide opportunities for collective bargaining and access to capacity building such as training that enable farmers to access information (Odendo, 2010).

Credit access was a significant factor that positively influenced household knowledge level on use of mulch. Households with access to credit were more likely to have a high knowledge level as compared to low. This could be because, the technology being labor-intensive, access to credit helps farmers to hire labor, purchase inputs, and invest in integrated soil fertility and soil water conservation technologies (Kakaire et al., 2016). Therefore, households with access to credit invest in mulching making them more knowledgeable than households with no access to credit. This could explain the positive influence of access to farm equipment on farmer's knowledge levels.

5.3.3 Socioeconomic factors influencing farmers level of knowledge of zai pits

Training positively influenced farmer's knowledge levels on the use of Zai pits. Farmers who accessed training in the last one year were more likely to have high knowledge levels as compare to low knowledge level. This implies that farmers who had access to training in the last year were more knowledgeable than farmers who had no access to training. This finding is in agreement with observations by Macharia et al. (2014), Danquah et al. (2019), and Kimaru-Muchai et al. (2020) who found that training positively influenced information access and hence the adoption of Zai pits. As noted by Lukuyu et al. (2012) training is a vehicle by which important agricultural information is disseminated and plays a vital role in promoting agricultural technologies. Training has also been reported to be an important component of imparting skills and knowledge hence building the capacity of the target group (Macharia et al., 2014).

Access to credit also positively influenced farmer's knowledge levels on use of Zai pits. Households with access to credit were more knowledgeable on use of Zai pits than farmers who had no access to credit. Several studies have noted that the implementation of Zai pits technology is labor-intensive (Schuler et al., 2016; Etongo et al., 2018). Barro & Lee (2005) noted that it takes about 300 hours/ha to dig Zai pits and another 250 hours/ha to apply fertilizers in the holes (Kabore & Reij, 2004). This implies that farmers with access to credit are more likely to adopt the technology since they can afford the laborers to work for them. This could have in turn influence farmer’s knowledge levels. Further, there was a positive influence of access to farm equipment on the farmer’s level of knowledge. Households with access to farmer equipment more likely to have a high knowledge level as compared to low. Construction of Zai pits requires farmer equipment’s, therefore; farmers with access to farm equipment were more likely to invest in this technology hence more likely to be knowledgeable.

Education negatively influenced farmer's level on use of Zai pits. This implies that the less educated a household is the more knowledgeable they are on the use of Zai pit technology. This could be because high levels of education can lead to individuals having more available occupations thereby, spend less time farming. This could then result to them being less knowledgeable on agricultural technologies. Zai pit is a labor-intensive technology; therefore, educated farmers may shy away from adopting the technology after cost-benefit analysis because the cost of production is high. This finding is in agreement with Kassie et al. (2013), Ndiritu et al. (2014) and Kanyenji et al. (2020) who found education to negatively influence knowledge and adoption of soil improvement technologies.

5.4 Influence of information packaging on adoption of combined organic and inorganic fertilizers, mulch and zai pits technologies

The form of message delivery was significant factor that positively influenced adoption of mulch and Zai pits technologies. Moreover, the use of audio-visual had the highest number of adopters for both mulch and Zai pit technologies. This implies that the adoption of mulch and Zai pits is likely to increase when audio-visual materials are used in information dissemination. According to Anzaku, (2011), “audio-visual materials refer to materials that are used to convey information without complete dependency upon verbal symbols or language”. Audio-visual appeals to senses of sight and hearing, they emphasize the use of non-verbal experience in a learning process (Ashaver & Igyuve, 2013). Audio-visual heightens the farmers’ awareness of the technologies through sight and hearing. According to Akhtar & Falk, (2017), audio-visual materials are important in stimulating interest, encouraging participation, and making learning permanent. Additionally, it enables the farmers to have a long-term memory of what they have seen and heard making the adoption of the technologies easy (Adolwa et al., 2012). These findings are similar to You et al., (2010) who found that learning and adoption of innovations are effective when audio-visual materials were used in information delivery.

Technology demonstration positively influenced the adoption of combined organic and inorganic fertilizers technologies. This implies that technology demonstration is likely to increase the adoption of combined organic and inorganic fertilizers and Zai pits technologies. According to Rogers, (2003), the adoption-decision process is progressive from knowledge to persuasion, decision, implementation, and confirmation (evaluation of technology effectiveness). Technology demonstration helps inform multiple stages of the decision-adoption process, particularly, by fostering strong attitudes towards the technologies and providing farmers with pertinent information that helps them make better decisions (Singh et al., 2018). Demonstration is more of hands-on and helps farmers to see rather than reading and hearing. This finding relates to Dhamale et al., (2016) and Singh et al., (2018) who reported a positive influence of technology demonstration on the adoption of agricultural technologies and innovations.

Information technicality positively influenced adoption of Zai pits. The majority of the households indicated that information was not technical. This implies that the use of clear and simple language with simple interpretation is likely to increase the adoption of Zai pits. According to Isifie & Ufuoko (2008), the use of simple language establishes comprehension and promotes the right interpretation of message and feedback. Therefore, extension agents and other stakeholders should avoid the use of jargon when disseminating agricultural information to farmers. This result agrees with Onasanya, (2006) who found out that difficulty in understanding information passed across hinders the actuation of agricultural innovations.

5.5 Communication factors influencing adoption of combined organic and inorganic fertilizers, mulch and Zai pits technologies

Accessibility of extension agents after introducing the technology positively influenced the adoption of combined organic and inorganic fertilizer, mulch, and Zai pits. This implied that the accessibility of extension agents is likely to increase the adoption of the technologies. This is ascribed to the knowledge disseminated by the extension officer on the benefits of investing in these technologies. Most farmers tend to rely on agricultural extension agents because of their genuine display of expertise (Prokopy et al., 2015). Additionally, the farmers can ask questions and seek clarification on the challenges they experience in the adoption-decision process (Vanlauwe et al., 2017). The findings are similar to Ofuoku (2013), who reported on the effectiveness of the extension services in the adoption of best farming practices. Extension agents help farmers in various capacities, including; technology transfer, advising farmers, and facilitation, whereby farmers are given an opportunity to define the main issues affecting them and come up with their solutions (Tologbonse et al., 2008).

Practical orientations positively influenced the adoption of all the technologies (combined organic and inorganic fertilizer, mulch, and Zai pits). This finding meant that having practical orientations such as technology demonstration is likely to increase this technology’s adoption. Practical orientations and technology demonstration fosters positive attitudes towards the technologies and also enables farmers to make a better decision on whether to adopt or not to adopt the technologies. This is a convincing technique for majority of the farmers as they are able to see the performance of the technologies practically (Adolwa et al., 2012). The results are consistent with a study done in Zimbabwe by Gwandu et al. (2013) which found that interactive platforms compel farmers’ participation leading to the adoption of credible techniques. Moreover, it was observed to facilitate the practical application of the knowledge and quick adoption of the best technologies (Singh et al., 2018).

Information repetition positively influenced adoption of combined organic and inorganic fertilizer, mulch, and Zai pits. This implies that an increase in the number of times the farmer has heard about the technology is likely to increase adoption. This is because of the constant reminder to the farmers of the best technologies to adopt and the advantages of adopting them. Besides, it puts emphasis on the technologies hence capturing the attention of the farmers (Misiko & Tittonell, 2011). Information technicality positively influenced adoption of Zai pits technology. Zai pit is a technical and knowledge-intensive technology; therefore, the use of clear and simple language with simple interpretation is likely to increase farmers' adoption. According to Isifie & Ufuoko (2008), simple language establishes comprehension and promotes the correct interpretation of messages and feedback. Therefore, extension agents and other stakeholders should avoid the use of scientific jargon when disseminating agricultural information to farmers. This result agrees with Onasanya (2006), who found out that difficulty in understanding information passed across hinders the actuation of agricultural innovations.

Training positively influenced adoption of mulch and Zai pits. This could be attributed to the interaction of the smallholder farmers with the training officers. Training is important in imparting knowledge and skills that are important in the adoption of agricultural technologies (Lukuyu et al., 2012). It provides a platform for farmers to make inquiries and clarification. Mulching faces competition from animals because farmers opt to use crop remains to feed animals rather than using them as mulch (Valbuena et al., 2012). Therefore, training plays an essential role in sensitizing farmers on the benefits of investing in mulching technology than feeding animals. Similarly, Zai pit is a knowledge-intensive technology; therefore, training is important for its adoption. The significant effect of training on the adoption of mulch and Zai pits technologies relates to the findings by Macharia et al. (2014). Also, Gwandu et al. (2013) found that the interaction of farmers with their trainers had a significant effect on the adoption of the selected technologies.

Farmer group membership positively influenced adoption of combined organic and inorganic fertilizers and Zai pits. This meant that belonging to a farmer group is likely to increase adoption of the two technologies. This is because group membership enables the exposure of farmers to knowledge on the best technologies to adopt. In farmer groups, farmers exchange ideas, share experiences and benefits of investing in the technologies, thus enhancing adoption of the technologies. This finding is similar to the results by Vanlauwe et al. (2014). Additionally, farmer group discussions enable the dissemination of information at the lowest level of the education ladder (Mugwe et al., 2009). Besides, Muchai et al. (2014) also reported a significant effect of group membership on the adoption of soil fertility management technologies. The study further argues that farmer groups are essential in persuading farmers to try new technologies. The findings concur with Bationo & Waswa (2011) findings whereby the groups influenced the adoption behavior.

5.6 Conclusions and recommendations

The study sought to evaluate the influence of communication on uptake of selected climate-smart agricultural practices among smallholder farmers in the drylands of Tharaka-Nithi County.

The first objective was to assess farmer's perceptions of the effectiveness of selected communication pathways for disseminating information on combined organic and inorganic fertilizers, mulch, and Zai pits. Other farmers followed by radio were the most available, accessible, reliable, and informative communication pathways across the three technologies. Therefore, they could be effective communication pathways for disseminating agricultural information in the dry lands of Tharaka-Nithi County. On other hand, agricultural shows, TV, and print media were the least available, accessible, reliable, and informative communication pathways. Therefore, to make other farmers an effective communication pathway, the County government of Tharaka Nithi should intensify training to building farmers' knowledge to improve the quality of information exchanged and that will build the confidence in utilizing information exchanged among farmers.

The second objective was to determine household social-economic factors influencing farmer's knowledge levels on combined organic and inorganic fertilizer, mulch, and Zai pits. The socio-economic factors that influenced knowledge level of the knowledge-intensive technologies were education level, gender, farming experience, perceptions on soil fertility, farmer group membership, access to training, farm size, access to credit, livestock keeping, and access to farm equipment. This implies the need to come up with an all-inclusive policy that can be employed in improving farmer's level of knowledge through the use of more innovative methods of information dissemination. This can be done by strengthening the existing farmer groups, enhancing extension services, and formulating gender-friendly policies. The study also brought to attention areas of weakness that need to be addressed as far as the technologies are concerned. For instance, most of the farmers were not aware of the recommended rates for applying combined organic and inorganic fertilizer, the different types of mulching materials, and the recommended time for mulch application. Besides, the majority did not know how to construct Zai pit and the benefits of using these technologies. This study, therefore, provides a reference point for choosing suitable topics for farmers. This will enhance communication by disseminating information that is adequate and responsive to farmers' needs.

Objective three was to establish the influence of information packaging on uptake of the selected soil and water conservation technologies. Result showed mode of information display, technology demonstrations and information technicality to influence uptake of the technologies. Therefore, extension agents and other stakeholders should emphasize the use of audio-visual materials and technologies demonstration when disseminating information on ISFM and SWC technologies for increased adoption.

Objective four was to assess the influence of communication factors on uptake of combined organic and inorganic fertilizers, mulch, and Zai pits. Practical orientations, accessibility of extension agents after the introducing the technology and information repetition were among the factors that influenced the adoption of combined organic and inorganic fertilizers, mulching and Zai pits. Training was essential for mulch and Zai pit technologies, while farmer group membership was necessary for combined organic and inorganic and Zai pit technologies. Therefore, extension agents should increase their interactions with farmers after introducing technologies because they play a key role in persuading farmers to use the selected technologies. Extension agents and other stakeholders should consider the use of demonstrations and a simple and clear message to increase adoption of ISFM and SWC technologies by farmers. Additionally, farmers should join farmers' groups and constantly be reminded of the available technologies and the benefits of their use for enhanced agricultural productivity and livelihood.

Recommendation for further research

1. The study only focused on three ISFM and SWC technologies, future research can look into more technologies to examine how communication affects their adoption.

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APPENDIX 1: INTERVIEW SCHEDULE

Questions are addressed to household head/ farm decision maker who should preferably be the respondent.

Date of interview:_ _/_ _/2019 Sub county..
Village: ……………………...

Time the interview will start_ _:_ _ GPS coordinates: _ _º_ _’_ _’’ S _ _º_ _’_ _’’ E

Phone Number: ……………………....................

Core var. no	**Variable labels**	***Variable values and rules***
	Household Demographic and Socioeconomic Characteristics	
1	Name of the household head ________________________________	
2	Relationship of the respondent to the household head	*1=Household head* *2=Spouse of the household head* *3=Grown up child* *4=Relative* *5= Other (specify)*

3	Household type ____________	*1=□Nuclear* *2=□Extended* *3=□Polygamous* *4=□Female headed (widow, never married, divorced)* *5=□(male headed)* *6=□Not yet married males/Females*
4	Gender of household head (Decision maker of farm operations) __________	*Tick where applicable* *1=□Male* *2=□female*
5	Age of household head ________ years	
6	Educational levels of the Household Head _________	*1=□non formal education* *2=□primary education* *3=□secondary education* *4=□tertiary education (Specify)*
7	Gender of the household member involved in implementing the ISFM and SWC technology _____	*1=Male* *2= Female* *3= both*
8	How many years of farming experience _____ years	

9.	Occupation of the household head	*1- farming* *2- business* *3- employed*
10.	Level of income (Ksh)	*1. 0-5000* *2. 5001-10000* *3. 10001- 15000* *above 15001*
11.	Are you currently a member of any farmers group or local organization in this village?	*1- yes* *2- no*
12.	What is your total farm size? ___________acres	
13.	How much of your land is cultivated? ________acres	
14.	Land ownership	*1. Own with a title deed* *2. Own without a title deed* *3. Rented in* *4. Rented out*
15.	Do you know about the following ISFM and SWC technologies?	*Indicate* *1= yes* *0=no*
	Use of organic + inorganic fertilizers [ ]	
	Mulching [ ]	
	Zai pits [ ]	
16.	Do you use the following ISFM and SWC technologies?	*Indicate* *1= yes* *0=no*
	Use of organic + inorganic fertilizers [ ]	
	Mulching [ ]	

	Zai pits [ ]	
	Farmers perception on effectiveness of communication pathways for disseminating information on selected integrated soil and water conservation practices	
17.	From what sources do you receive information about soil water conservation and soil fertility management?	☐ Researchers ☐ Agro-input dealers ☐ Field days ☐ Agricultural shows and exhibitions ☐ Farmers trainings and workshops ☐ Government extension services ☐ Other farmers ☐ Your own experience ☐ Radio/ TV ☐ Print media Any other specify

18. Using a ten-point scoring scale, *where 1 is the lowest and 10 is the highest*, please score the level of availability, accessibility, reliability, and informativeness of communication pathways used in disseminating ISFM and SWC information. Where

Availability- presence of the communication pathways when the farmer needs it

Accessibility-is the pathway easy to use or obtain

Reliability- is the pathway present at every time of need

Informativeness- is the information sufficient in terms of quality and quantity

Communication pathway	Technologies	Availability	Accessibility	Reliability	Informativeness
Researchers	Organic + inorganic fertilizers				
	Mulching				
	Zai pits				
Extension agents	Organic +inorganic fertilizers				
	Mulching				
	Zai pits				
Field days	Organic + inorganic fertilizers				
	Mulching				
	Zai pits				
Agro-inputs dealers	Organic + inorganic fertilizers				
	Mulching				
	Zai pits				
Other farmers	Organic +				

	inorganic fertilizers				
	Mulching				
	Zai pits				
Shows and farmers trainings	Organic + inorganic fertilizers				
	Mulching				
	Zai pits				
Radio	Organic + inorganic fertilizers				
	Mulching				
	Zai pits				
TV	Organic + inorganic fertilizers				
	Mulching				
	Zai pits				
Print media	Organic + inorganic fertilizers				
	Mulching				
	Zai pits				

19. Please answer the questions below in practical knowledge on the following ISFM and SWC technologies (indicate if the statement is true or false)

Questions	True/false
Combined organic and inorganic fertilizers	
1. The recommended rate for applying combined organic and inorganic fertilizers is 60 kg ha^{-1}	
2. Combined organic and fertilizers should be applied ½ the recommended rates of each that is 30 kg ha^{-1}	
3. The rate of applying manure should be 1 handful per planting hole	
4. Fertilizers should be applied as 2.5 g per seed or 5g per two seeds per hole (1 bottle top)	
5. The combined fertilizer and manures should be thoroughly mixed with the soil to avoid scorching of seeds	
6. Appropriate combination of organic and inorganic fertilizer boost agricultural productivity	
7. It is cheaper to use both organic and inorganic fertilizer that inorganic fertilizer	
8. Combining both inorganic and organic fertilizers provide more balanced nutrient supply	
9. The ratio of combining organic and organic fertilizer should be 1:1 or 50/50	
Mulch	
10. Mulching adds nutrients to the soil and improves soil structure	
11. I know the different types of mulching material	
12. Mulch reduces weed growth by reducing the amount of light	
13. Mulching should be applied on the surface to cover the soil	
14. Mulch should be applied after germination of crops	
15. Mulching reduces soil erosion	
16. The recommended rate of application is 5 t ha^{-1}	
17. Mulching conserves water reducing the need for frequent watering	
18. Mulching maintains a more even soil temperatures	
Zai pits	
19. The correct measurements for Zai pits is 20-30 cm width, 10-20 cm depth	
20. The correct spacing (measurements) for Zai pits is 60-80 cm apart	
21. Zai pits should be constructed in an alternating manner	
22. Zai pits reduces run-off and increases water infiltration	
23. Zai pits increase soil fertility	
24. Zai pits should be constantly repaired for efficient use	

Influence of information packaging on uptake of combined organic + inorganic fertilizer, mulching and tied ridges		
20.	Which language was used to disseminate selected ISFM and SWC information?	*1 English* *2 Kiswahili* 3 *vernacular*
21.	How was the message delivered?	*1. audio* *2. visual* *3. audio- visual* 4. *print*
22.	Were the technologies demonstrated?	1. *yes* 0. *No*
23.	Was the information technical to understand? (were there use of jargons)	*1. technical* 2. *not technical*
24.	Was the information translated into a simpler form?	*1. yes* *0. No*
25.	Is the information sufficient in terms of quantity? 8	*1. yes* 0. *No*
26.	Are you a member of a farmer group?	*1. yes* *0. No*
27.	If yes, do you discuss information on ISFM and SWC	*1. yes* *0. No*
Communication factors influencing uptake of combined organic + inorganic fertilizer, mulching and tied ridges		

28.	Are the extension agents accessible after introduction of the technology?	*1. yes* 0. *No*
29.	If yes how many visits per season? ___________	
30.	How many times have you heard information on the selected technologies (number of times) 1. Combined organic + inorganic fertilizers ________ 2. Mulching ________ 3. zai pits ________	
31.	Was the information delivered in a practical way? (Were there demonstrations?)	*1.yes* *0. No*
32.	Are you able to respond to aired programs?	*1. yes* *0. No*
33.	How many people in your household are able to read and write? ________numbers	
34.	What is your attitude towards extension agents	*1= favourable* *2=neutral* *3= unfavourable*