



Research article

Communication factors influencing adoption of soil and water conservation technologies in the dry zones of Tharaka-Nithi County, Kenya



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ABSTRACT

Integrated soil fertility and soil water conservation technologies are possible solutions to the low per capita food production in Sub-Saharan Africa (SSA). Nonetheless, the rate of adoption of these technologies by smallholder farmers has stagnated over the years despite being recommended. This has been attributed to the existence of wide communication gaps among researchers, extension agents, and farmers. Therefore, this study aimed to assess the influence of communication factors on the adoption of the selected technologies among smallholder farmers in the drylands of Tharaka-Nithi County. We used a cross-sectional survey design and collected data using an interview schedule from 400 randomly selected farming households. Binary logistic regression was employed for data analysis. Results showed that accessibility of extension agents after introducing the technology significantly influenced the adoption of combined organic and inorganic fertilizers ($p = 0.056$), mulch ($p = 0.051$), and Zai pit ($p = 0.058$). Similarly, practical orientation significantly influenced the adoption of combined organic and inorganic fertilizers ($p = 0.001$), mulch ($p = 0.010$), and Zai pit ($p = 0.003$). Information repetition significantly influenced the adoption of combined organic and inorganic fertilizers, mulch, and Zai pit at p -value 0.003, 0.001, and 0.001, respectively. Training was essential for mulch and Zai pit technologies at ($p = 0.030$) and ($p = 0.001$) respectively, while farmer group membership significantly influenced adoption for combined organic and inorganic fertilizers ($p = 0.045$) and Zai pit ($p = 0.057$) technologies. Extension agents should increase their interactions with farmers after the introduction of technologies. Equally use of demonstrations should be encouraged during the dissemination of these technologies among the farmers as they enhance the chances of adoption of the technologies.

1. Introduction

Diminishing soil fertility and climate change are major threats to sustainable agricultural production globally and in Sub-Saharan Africa (SSA) (Vanlauwe and Giller, 2006; Thompson et al., 2010). These have led to low agricultural productivity, food insecurities, and a rise in poverty levels, especially in the arid and semi-arid lands (ASALs) which entirely depend on rain-fed agriculture (Yazar and 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 and Von Braun, 2013). High dry spell frequencies which subject crops to soil moisture stress, especially at the critical stages of crop growth, compounds the low agricultural productivity (Ali-Olubandwa et al., 2011; Ngetich et al., 2012, 2014; Jayne et al., 2014; Oduor et al., 2020). It has been projected that by 2050 the yields from main crops such as maize, sorghum, and millet will have reduced by 8–22% unless sustainable techniques are adapted to curb the impacts of climate variability and declining soil fertility (Schlenker and 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

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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). 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 to maximize agronomic use efficiency of the applied nutrients and increase crop productivity (Vanlauwe et al., 2010; Bationo and Waswa, 2011). Integrated soil fertility management technologies have the potential to improve the quality and productivity of soil, leading to sustainable yield increase (Mugwe et al., 2009; Mucheru-Muna et al., 2010, 2014; Zhang et al., 2021). 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 (Place et al., 2003; Vanlauwe, 2004). 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., 2017). Despite the evidence suggesting positive returns in yields, adoption of these novel technologies by smallholder farmers has stagnated over the years (Kassie et al., 2013; Kamau et al., 2014). Improper information dissemination is among the significant causes of low technology adoption among the farmers (Adolwa et al., 2012). Poor communication of the technology performance and benefits to the farmers has created wide communication gaps between the change agents and the farmers (Adolwa et al., 2018; Spurk et al., 2020). Eventually, the adoption of the technologies has remained low.

Communication and knowledge sharing is vital in adoption and sustainability of any agricultural innovations (Babu et al., 2012; Ashraf et al., 2015). Effective communication is considered indispensable, especially in explaining the benefits of investing in ISFM and SWC technologies because they are not only knowledge-intensive but challenging to differentiate from the effects of season-specific factors such as rainfall (Vanlauwe et al., 2017; Spurk et al., 2020). The efficacy of up-scaling the use of ISFM and SWC hinges upon the effectiveness of communication and the tools used in the dissemination of research findings. Ironically, non-adoption of these technologies persists with the presence of information and communication pathways through which they can be disseminated (Adolwa et al., 2018). However, there is no definite explanation for this inconsistency (Meijer et al., 2015).

Effective promotion of ISFM and SWC technologies require information on communication factors that can accelerate or decelerate adoption (Martey 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 is the root cause of low technology adoption in SSA (Spurk et al., 2014; Adolwa et al., 2017, 2018). Others have attributed low agricultural productivity to ineffective technology delivery systems, poor information packaging, inadequate communication systems, and the use of poor communication methodologies (Mapfumo et al., 2013; Spurk et al., 2020). It is in seeking to understand these dynamics that we investigated communication factors that influence the adoption of the selected ISFM and SWC technologies among smallholders in the drier parts of Tharaka-Nithi County, Kenya. The selected technologies included 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).

According to Rogers (2003), different technologies have different attributes such as relative advantage, compatibility, complexity, observability, and trialability 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. This is why we sought to understand communication factors that influence the adoption of the specific ISFM and SWC technologies. We defined adoption as the application of the technology by users. It is either the respondent was using the specific technology (1) or otherwise (0). Because of the dummy nature of the dependent variable, binary logistic regression was used for data analysis.

1.1. Theoretical and conceptual 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.

Information richness theory states that the medium of communication determines the richness of information processed (Daft and Lengel, 1983). Information richness refers to the ability to transmit needed information without loss or distortion (Dennis and 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 and Lengel, 1983). 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 receivers' needs (Daft and Lengel, 1983; Dennis and 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.

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 communication factors that influence an individual's decision on whether to adopt or not adopt agricultural innovations. Figure 1 gives a summary of the role of communication in the technology adoption process.

2. Materials and methods

2.1. 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 km² and a population of 75,250, with a household population of 18,646 (KNBS,

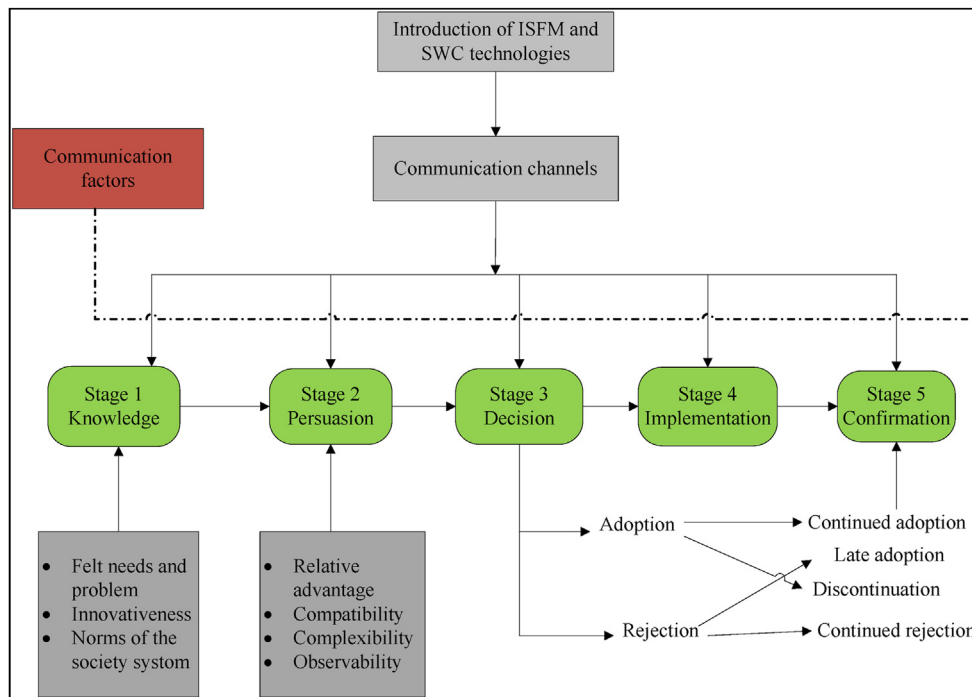


Figure 1. Conceptual framework showing the interaction of communication factors with the diffusion of innovation theory.

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, and inner lowland 5 (IL5) (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 °C (Smucker and

Wisner, 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, mangoes, pawpaw, and bananas) and rear livestock such as 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

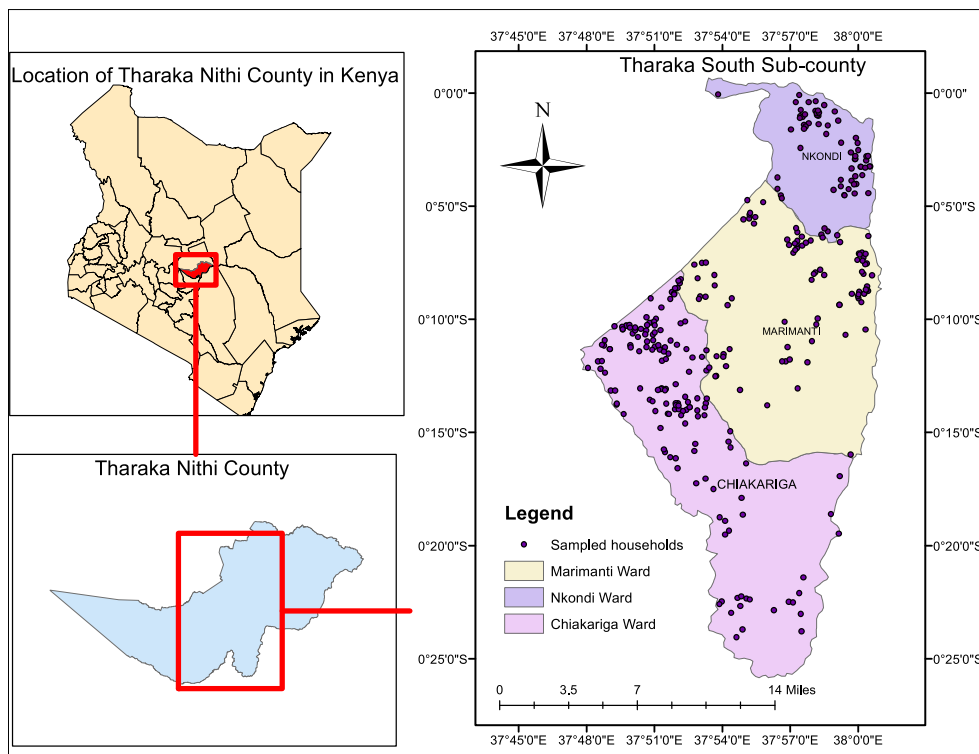


Figure 2. Map of the study area showing sampled households.

has led to low agricultural productivity and high poverty levels of up to 65% (Jaetzold et al., 2006; Kristjanson et al., 2010).

2.2. Study design and sampling procedure

The study employed a cross-sectional survey design. We employed a combination of multi-stage sampling, probability proportionate to size, and random sampling techniques in selecting the sample households. In the first stage, Tharaka South Sub-County was purposively selected. This was because 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). In the second stage, 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 wards, probability proportionate to size sampling technique was used to determine the number of households to be interviewed (Table 1). In the third stage, a random sampling technique was 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. Four hundred (400) farming households constituted the study's total sample size, which was determined using Cochran (2007) as per Eq. (1).

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

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.

2.3. 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 data collection tool was pretested to ascertain its validity and reliability. This was achieved by administering an interview schedule to 30 smallholder farmers who were randomly selected. We conducted face-to-face interviews with the help of well-trained enumerators. Necessary adjustments and re-modifications were made to improve the tool. A semi-structured interview schedule was used to collect the data. The interview schedule captured information on the socio-economic characteristics of the households as well as aspects concerning communication factors.

2.4. Ethical considerations

We followed all the ethical guidelines provided by the office of research at the University of Embu. Informed consent was obtained from the farmers, and participation was voluntary. Enumerators were briefed on matters of; professionalism, privacy, and anonymity of the respondent, voluntary participation, respect and dignity, and etiquette according to research ethics principles.

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

2.5. Statistical analysis

Data analysis was done in SPSS version 24. Descriptive statistics such as frequencies and means were used to summarize the data. 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 has no assumptions of linearity and heteroscedasticity. The model can be specified as follows (Eq. (2));

$$P_i = F(Z_i) = \frac{1}{1 + e^{-(\alpha + \beta X_i)}} \quad (2)$$

where, P_i is the probability of adoption of combined organic and inorganic fertilizers, mulch and Zai pits, X_i represents the i^{th} explanatory variables, α and β_i are 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 Eq. (3).

$$\frac{P_i}{1 - P_i} = e^{iZ} \quad (3)$$

$1 - P_i$ is the probability of households not using the technologies. Hence the natural log was expressed as Eq. (4).

$$\ln\left(\frac{P_i}{1 - P_i}\right) = Z_i = \alpha + \beta_1 x_1 + \beta_2 x_2 + \dots + \beta_n x_n + U_i \quad (4)$$

U_i is the error term, randomly distributed $\beta_1, \beta_2, \dots, \beta_n$ are the parameters to be estimated while x_1, x_2, \dots, x_n are the explanatory variables.

2.6. Variables description and measurement

2.6.1. Dependent variable

The dependent variable in this study is the adoption of combined organic and inorganic fertilizer, mulch, and Zai pit. Adoption is the application of the technology by users. Adoption was a dummy variable where 1 = farmers using the specific technologies and 0 = farmers not using the specific technologies (Table 2). The technologies were described as follows:

Combined organic and inorganic fertilizers: this is the use of well-cured animal manure and inorganic fertilizers. Animal manure is solid and liquid waste from livestock and poultry. Studies show that the application of combined organic and inorganic fertilizers creates positive synergistic effects that improve soil fertility leading to increased crop production (Mucheru-Muna et al., 2007, 2014; Abera et al., 2018). Integrated use of combined organic fertilizers improves soil structure hence soil moisture conservation. It has been reported to increase water use efficiency by 207% (Liu et al., 2013).

Mulching is the use of organic materials such as crop residues and cut grass placed on the surface to cover the soil. Mulching is an important agronomic practice that plays a crucial role in conserving soil moisture by reducing run-off and reducing evaporation from the surface resulting in enhanced water use efficiency and crop production (Ngetich et al., 2014; Lal, 2015; Jiménez et al., 2017). The use of mulch has been reported to increase soil water holding capacity by 18–35% and soil moisture retention at low suction from 29% to 70%, 11 years after establishing the plots (Mulumba and Lal, 2008). Mulch also enhances soil fertility after the decay of the crop residue (Huo et al., 2017).

Zai pit refers to planting holes dug into the soil measuring 20–30 cm width, 10–20 cm depth with a spacing of 60–80 cm apart (Danjuma and Mohammed, 2015). Zai technology is an essential technique of

Table 2. Variables description and measurement.

Variable	Variable description and measurement
Dependent variable	
Adoption of selected technologies	Combined organic and inorganic fertilizer; 1 = using the technology, 0 = otherwise Mulch; 1 = using the technology, 0 = otherwise Zai pits; 1 = using the technology, 0 = otherwise
Explanatory variables	
Accessibility of extension agents	This is the accessibility of extension agents after the introducing the technology, a dummy variable: (1 = yes, 0 = no) and if yes, the number of visits per season (continuous)
Information repetition	This is the number of times the respondent has heard about the technology (continuous)
Practical orientations	This is whether the technologies were demonstrated or not, a dummy variable: (1 = yes, 0 = no)
Information technicality	This is the use of technical language that is difficult to understand, e.g., use of jargons, a dummy variable; (1 = technical, 0 = not technical)
Ability to respond to aired programs	This is whether the respondent is able to respond to aired programs or not, a dummy variable: (1 = yes, 0 = no)
Attitude towards extension agents	This is the respondents attitude towards extension agents, a categorical variable: (1 = unfavorable, 2 = neutral, 3 = favorable)
Literacy	This is the number of people in a household that are able to read and write; (continuous)
Training on ISFM and SWC technologies	This is whether the respondent had access to training on the technologies in the past one year, it was a dummy variable where (1 = received training, 0 = otherwise)
Farmer group membership	This is whether the respondent belonged to farmer group that discussed ISFM and SWC technologies, a dummy variable: (1 = yes, 0 = no)

conserving soil moisture and enhancing soil fertility in the arid and semi-arid areas and has shown to result in increased yields up to 500% when well executed (Danjuma and Mohammed, 2015; Kimaru-Muchai et al., 2020).

2.6.2. Explanatory variables

The explanatory variables' selection was primarily based on the theoretical framework and empirical evidence from past studies. The communication factors considered in the study were accessibility of extension agents after the introduction of the technology, information repetition, practical orientations, information technicality, and ability to respond to aired programs, attitude towards extension agents, training, literacy, and farmer group membership (Table 2). A description of the explanatory variables and the hypothesized influence on the dependent variable is given below:

- i. **Accessibility of the extension agents after introducing the technology** is essential in enhancing the accuracy of the implementation of the technology (Challa and Tilahun, 2014). Farmers can ask questions and seek clarifications on the challenges they experience in the adoption decision process (Vanlauwe et al., 2017). Therefore, it is hypothesized that the accessibility of extension agents will positively influence the adoption of the selected technologies.
- ii. **Information repetition** is the number of times that the farmers hear about technology. The constant reminder of the farmer of the benefits of adopting a technology positively influences the technology's adoption.
- iii. **Practical orientations** and technology demonstration are important communication factor in enhancing technology adoption as it helps farmers to see rather than reading and hearing. Technology demonstration informs multiple stages in the adoption decision process, thus fostering the adoption of the technologies (Rogers, 2003).
- iv. **Information technicality** refers to the use of technical language such as jargon and ambiguous language is important in determining adoption of agricultural technologies. The use of clear language promotes the proper interpretation of the message, thus increasing the likelihood of technology adoption (Isife and Ofuoku, 2008).
- v. **Ability to respond to aired programs:** Communication media such as radio and T.V.s are important communication channels for disseminating agricultural information (Adolwa et al., 2018). However, farmers' ability to seek clarification and respond to the

aired program determines the effectiveness of such programs in enhancing agricultural technologies adoption (Gwandu et al., 2013).

- vi. **Literacy** and education level determines individuals' ability to access, obtain and comprehend agricultural information (Kimaru-Muchai et al., 2020). For knowledge-intensive technologies such as ISFM and SWC, farmers' literacy level is an important communication factor that is likely to influence the adoption of these technologies.
- vii. **Training on ISFM and SWC technologies:** Training is a vehicle through which important agricultural information is communicated to farmers. Training is essential in imparting skills and knowledge necessary for the technology adoption process (Lukuyu et al., 2012). Studies have shown that access to training and the number of times the farmer has been trained on a technology to positively influence agricultural innovation adoption (Macharia et al., 2014; Danquah et al., 2019).

3. Results and discussion

3.1. Household socio-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 3). 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 3).

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 3).

The majority of the households were male-headed, implying that at the 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. Our 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. The low numbers of females in the study area could be due to the detrimental impact of cultural norms and customs, where women are not allowed to own land and make major decisions (Aravindakshan et al., 2020). Most of the households had education up to and beyond the primary level. This implies that farmers could obtain and

Table 3. Households socio-demographic characteristics.

Variables	Variable description	Categories	Frequencies (percentages)		
Gender	Binary variable = 1 if the house head is male; 0 female	Male	268 (67)		
		Female	132 (33)		
Education level	Categorical variable = 1 if the household head has non-formal education; 2 primary level; 3 secondary level; 4 tertiary level	Non-formal	31 (8)		
		Primary	230 (58)		
		Secondary	86 (21)		
		Tertiary	53 (13)		
Access to credit	Binary variable = 1 if the respondent has access to credit in the last one year; 0 otherwise	No	290 (73)		
		Yes	110 (27)		
Land ownership	Binary variable = 1 if the respondent has title deed; 0 without title deed	without title deed	140 (35)		
		with title deed	260 (65)		
Labor access	Binary variable = 1 if the respondent has access to labor (both family and hired); 0 otherwise	No	58 (15)		
		Yes	342 (85)		
Soil fertility perceptions	Binary variable = 1 if the respondent perceives his/her land to be fertile; 0 infertile	Infertile	215 (54)		
		Fertile	185 (46)		
Training	Binary variable = 1 if the respondent has received training on soil and water conservation technologies in the last one year; 0 otherwise	No	219 (55)		
		Yes	181 (45)		
Group membership	Binary variable = 1 if the respondent belongs to farmer group; 0 otherwise	No	126 (32)		
		Yes	274 (68)		
Variables	Variable description	Minimum	Maximum	Mean	Std. Dev
Age (years)	Continuous variable	20.0	82.0	45.478	10.9787
Farming experience	Continuous variable (years)	1.0	60.0	18.695	12.2295
HH size	Continuous variable	1.0	17.0	5.295	2.1852

Values in parenthesis = percentages, values outside parenthesis = frequencies N = 400.

comprehend the disseminated information and hence make better decisions on whether to adopt or reject 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 the government's effort to increase farmers' access to credit (Kiplimo et al., 2015). We attributed the low access to credit 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 and 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 farmers' access to information; thus, it increases the likelihood of adoption of agricultural innovations (Kimaru-Muchai et al., 2020). We attributed the lower number of trained farmers 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. 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. Additionally, group participation and other social forums could provide access to agricultural information via extension connections and other farmers' interactions, where they can exchange ideas and exhibit agricultural innovations in practice (Kassie et al., 2013). Perception of soil fertility is vital in the adoption of soil improvement technologies such as ISFM and SWC. According to Kafesu et al. (2018), farmers' perceptions of soil fertility were consistent with the laboratory analysis results, showing farmers' accuracy in understanding their farms. Farmers who perceive their soils as infertile may adopt ISFM technologies to enhance their soil

productivity (Mugwe et al., 2009; Kassie et al., 2013). Therefore, farmers' sensitization about their soil fertility status is essential.

The respondent's mean age showed that most farmers were middle-aged, implying that they 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. We attributed the high farming experience 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.

3.2. Awareness and adoption of the selected ISFM and SWC technologies

Results showed that most of the interviewed households were aware of the technologies, but not all were using them. For instance, seventy-seven percent of the households were aware of combined organic and inorganic fertilizer technology, but only 51% were using the technology (Table 4). Ninety-two percent of the respondents were aware of the mulching technology, but 78% were using the technology. For Zai pit technology, 76% were aware, but 43% were using the technology (Table 4).

Table 4. Farmers awareness and adoption of the selected ISFM and SWC technologies.

Technologies	Awareness		Adoption	
	Yes	No	Yes	No
Combined organic and inorganic fertilizer	307 (77)	93 (23)	204 (51)	196 (49)
Mulch	368 (92)	32 (8)	312 (78)	88 (22)
Zai pits	305 (76)	95 (24)	172 (43)	228 (57)

Values in parenthesis = percentages, values outside parenthesis = frequencies.

Table 5. Univariate results of communication factors influencing adoption of combined org and inorg fertilizer, mulch, and Zai pits.

Variables		Combined org and Inorg fertilizer			Mulch			Zai pits		
		Non-adopters N = 196	Adopters N = 204	χ^2	Non-adopters N = 88	Adopters N = 312	χ^2	Non-adopters N = 228	Adopters N = 72	χ^2
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 agents	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)	
	Favorable	45 (46)	53 (54)		26 (27)	72 (73)		26 (27)	72 (73)	
Information technicality	No	149 (52)	137 (48)	NS	66 (23)	220 (77)	NS	183 (64)	103 (36)	0.001
	Yes	47 (41)	67 (59)		22 (19)	92 (81)		45 (39)	69 (61)	
Training	No	118 (54)	100 (46)	0.021	56 (26)	162 (74)	NS	146 (67)	72 (33)	0.0001
	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)	0.0001
	Yes	109 (40)	165 (60)		53 (19)	221 (81)		136 (50)	138 (50)	
		t-value			t-value			t-value		
Extension frequency	0.367	0.602	-0.236*	0.568	0.465	0.103	0.325	0.703	-0.379*	
Information repetition	1.724	2.843	-1.119*	2.284	3.747	-1.463*	1.487	2.813	-1.327*	
Literacy	3.443	3.901	-0.458**	3.420	3.75	-0.330	3.5	3.913	-0.412	

Values in parenthesis are percentages.

Despite the high rate of awareness of the technologies, a smaller percentage was using the technologies. Differences in awareness and adoption rates could be attributed to the difference in technology attributes and farmers' characteristics. This is consistent with the notion of diffusion of innovation theory, which acknowledges that there may be a lag between when farmers first learn about an innovation and when they implement it. Technology awareness and knowledge is an essential precondition for technology adoption. According to the diffusion of innovation theory with the existence of technology, an individual's ability to adopt the technology heavily relies on communication effectiveness (Rogers, 2003). Technology adoption is only possible when farmers have in-depth information on the benefits of using the technology. We attributed low adoption to the existence of communication factors that constrain the adoption by farmers.

3.3. Communication factors influencing adoption of combined organic and inorganic fertilizers, mulch and Zai pits

As Table 5 below shows, there is a significant association between training (p = 0.019, $\chi^2 = 5.518$), farmer group membership (p = 0.001,

$\chi^2 = 29.583$), accessibility of extension agents' after introducing the technology (p = 0.001, $\chi^2 = 14.287$), practical orientations (p = 0.001, $\chi^2 = 43.849$), attitude towards extension agents (p = 0.001, $\chi^2 = 26.572$), information technicality (p = 0.050, $\chi^2 = 3.8543$), information repetition, and literacy levels and adoption of combined organic and inorganic fertilizers (Table 5).

Practical orientation (p = 0.002, $\chi^2 = 9.363$) and information repetitions are the factors likely to influence adoption of mulch. Similarly, a significant association was noted between information technicality (p = 0.0001, $\chi^2 = 19.982$), training (p = 0.0001, $\chi^2 = 20.236$), farmer group membership (p = 0.0001, $\chi^2 = 19.250$), extension agent's accessibility after the introducing the technology (p = 0.0001, $\chi^2 = 27.005$), practical orientation (p = 0.0001, $\chi^2 = 22.760$), attitude towards extension agents (p = 0.000, $\chi^2 = 0.000$), information repetition, and literacy levels and adoption of Zai pits (Table 5).

The binary logistic regression model correctly explained 76.8% for combined organic and inorganic fertilizers, 82.3% for mulch, and 77.1% for Zai pit technologies. Results show that extension accessibility after introducing the technology, practical orientation, and information repetition had a significant positive influence on the adoption of the

Table 6. Communication factors influencing adoption of combined org + Inorg fertilizers, mulch, and Zai pits.

	Combined org + inorg	Vif	Mulch	Vif	Zai pits	Vif
Extension accessibility	.882 (.462)***	2.416	1.066 (.547)***	2.903	.855 (.450)***	2.351
Information repetition	.160 (.054)*	1.174	.209 (.061)*	1.232	.259 (.061)*	1.296
Practical orientation	1.094 (.294)*	2.986	.781 (.302)*	2.185	.926 (.311)*	2.524
Ability to respond to the aired program	.258 (.342)	1.294	.707 (.447)	2.027	.639 (.332)	1.894
Information technicality	.021 (.256)	1.388	.063 (.297)	1.389	.817 (.242)*	1.386
Literacy	.062 (.057)	1.064	.035 (.065)	1.036	.045 (.057)	1.046
Training	.517 (.390)	1.678	1.026 (.474)**	2.791	1.274 (.384)*	3.576
Farmer group membership	.945 (.492)**	2.573	.326 (.537)	1.386	.963 (.506)***	2.619
Attitude	.153 (.212)	1.166	-.231 (.231)	.794	.314 (.221)	1.369

Values in parenthesis = standard error, values outside parenthesis = coefficients, *, **, *** Significance at 1%, 5% and 10%, respectively, Vif = variance inflation factor.

combined organic and inorganic fertilizers, mulch and Zai pits technologies. Similarly, training positively influenced adoption at ($\beta = 1.026$, $p = 0.030$) under mulch and ($\beta = 1.274$, $p = 0.001$) under Zai pits while belonging to a farmer group membership was necessary for adoption of combined use of organic and inorganic fertilizer and Zai pits at ($\beta = 0.945$, $p = 0.055$) and ($\beta = 0.963$, $p = 0.057$), respectively (Table 6).

Accessibility of extension agents after introducing the technology positively influenced the adoption of combined organic and inorganic fertilizer, mulch, and Zai pits. This implies 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). However, for most of the farming community, access to extension services remains a challenge (Baloch and Thapa, 2014). Accessibility to extension services is important as farmers can ask questions and seek clarification on the challenges they experience in the adoption-decision process (Vanlauwe et al., 2017). Extension services fill in the gaps in farmers' knowledge about better farming practices and application methods. The findings are similar to Ofuoku (2013), Mponela et al. (2016), and Donkor et al. (2019) 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 allowed to define the main issues affecting them and come up with their solutions (Tologbonse et al., 2008). Conversely, according to Chirwa et al. (2008), extension contacts may not always result in greater technology use. This can happen when extension agents take a preference for working with low-income families who lack the wherewithal to integrate new technology.

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. According to Rogers (2003), the adoption-decision process is progressive from knowledge to persuasion, decision, implementation, and confirmation. 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 to make better decisions (Singh et al., 2018). Technology demonstration is more hands-on and helps farmers to see rather than reading and hearing. It is a convincing technique for most farmers as they can practically see the technologies' performance (Adolwa et al., 2012). Additionally, as noted by Bossink (2015), one of the most effective ways to enhance technology acceptance is to use demonstration plots because it influences the desired change in rural people's behavior, creates optimal learning environments, and give opportunities for effective communication and interaction between extension workers and farmers. The results are consistent with a study by Dhamale et al. (2016) and Singh et al. (2018), who reported a positive influence of practical orientation on the adoption of agricultural technologies and innovations.

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 and 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 and 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 et al.,

(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. It suggests that specialized training imparts an in-depth understanding of how to use technology. 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). These findings are in line with those of Kassie et al. (2013), who found that farmer groups and other rural institutions provide channels for agricultural innovation information to reach farmers, increasing economies of scale to lower the cost of information transmission. 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.

4. Conclusion

Practical orientations, accessibility of extension agents after the introduction of the technology, and information repetition were among the communication 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.

Declarations

Author contribution statement

Maureen Wairimu Njenga: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Wrote the paper.

Jayne Njeri Mugwe; Hezron Mogaka; George Nyabuga: Conceived and designed the experiments; Performed the experiments; Wrote the paper.

Milka Kiboi; Felix Ngetich; Monicah Mucheru-Muna; Isaya Sijali: Conceived and designed the experiments; Wrote the paper.

Daniel Mugendi: Conceived and designed the experiments; Contributed reagents, materials, analysis tools or data; Wrote the paper.

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Data availability statement

Data will be made available on request.

Declaration of interests statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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