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Determinants of adoption of integrated soil fertility management practices among coffee producers in Mid-Northern Uganda

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ABSTRACT

Coffee accounts for over 40% of total Ugandan exports. Coffee subsector created employment opportunities thus improved living standards of farmers. Despite significant role played by coffee, its production in Uganda is generally low, attributed to infertile and highly weathered soils in different parts of the country. To increase soil fertility, smallholder farmers are encouraged to adopt integrated soil fertility management (ISFM) practices. Notably, previous studies shown low adoption intensity of ISFM practices. The study, therefore, aimed to determine adoption intensity and factors affecting adoption intensity of ISFM practices in new coffee-growing regions of Mid-Northern Uganda. Data were collected from 202 farmers in Oyam and Nwoya districts, using semi-structured questionnaires. Adoption index (AI) and Tobit regression model were used to determine adoption intensity of ISFM practices and their determinants, respectively. Results show that adoption intensity of ISFM practices was 0.52. Results from Tobit model showed that farm size, access to agricultural insurance, input support, formal employment had positive and significant effect on adoption intensity, whereas household size had inverse and significant effect on adoption intensity. Our study recommends that farmers be trained on ways of accessing credit, agricultural insurance, while government should subsidize farm inputs for timely acquisition by coffee farmers.

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Introduction

Coffee is cultivated by smallholder growers in Africa, Asia and America who rely on coffee as their major source of income (Bongers et al., 2015). Coffee is grown in Ethiopia, Uganda, Kenya, Tanzania, Rwanda and Burundi in East and Central Africa. In Uganda, coffee accounts for more than 40% of the total value of exports. There are two main coffee species produced in Uganda: Arabica and Robusta (UBOS, 2018). The main coffee-producing regions are the eastern and western regions, with altitudes of 1400–2000 m above sea level, mild climate, average temperature of less than 19 °C and annual precipitation of 1000 mm (UCDA, 2012). In addition, Uganda has a dual production system with approximately 300 large-scale coffee estates and over 700,000 smallholder producers, which accounts for 75% of the land planted under coffee production (Otieno et al., 2019).

The Uganda Coffee Development Authority (UCDA) introduced coffee as a perennial crop in mid–northern Uganda between 2001 and 2005 with the objective of opening up opportunities for increasing income for farming households and widening the regional spread of coffee production (Mbowa et al., 2014). The Lango and Acholi sub regions generally have flat topography, predominantly sandy loam soils, temperatures of 25–35 °C and receive approximately 1000–1500 mm of rainfall per annum with a bimodal rainfall pattern from March to June and from July to November, conditions that favor coffee production in the area (Kagezi et al., 2018). Moreover, the Oyam and Nwoya districts each contribute to more than

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12 percent of the total acreage under coffee production (Odokonyero et al., 2014). However, most of the fields in these areas are poorly managed, with more than 80% of them having no manure, bands, trenches, cover crops and are lowly weeded and mulched, whereas intercropping is rarely practiced, resulting in infertile and highly weathered soils (Odokonyero et al., 2014). This has resulted in declining coffee production, not only in north eastern Uganda but also in other regions. A recent study conducted in Northern Uganda by Wang et al. (2015) noted that coffee had a yield gap of 1026 kg/ha, which represented a 52% yield gap, attributed to poor soils in Northern Uganda. Similarly, a study conducted in western Uganda by Ronalds et al. (2023) noted that coffee farmers continue to report declining yields as a result of infertile soils.

Integrated soil fertility management (ISFM) has been defined by many scholars; for instance, Odendo et al. (2009) and Okalebo (2002) defined it as the key approach in raising productivity levels in agricultural systems while maintaining the natural resource base. It includes the use of inorganic fertilizers, organic inputs and improved germplasm, combined with knowledge on how to adapt these practices to local conditions, aiming at maximizing agronomic use efficiency of the applied nutrients and improving crop productivity (Vanlauwe et al., 2010). In Brazil, positive experiences with the adoption of cover crops in coffee Production using signal grass, which improves water infiltration, nutrient availability and soil carbon sequestration (Production & In, 2011). Similarly, in Ethiopia, the addition of organic materials plays a key role in nutrient availability, soil water content, nutrient recycling and addition of nutrients to the stock to boost soil fertility (Agegnehu & Amede, 2017). As such, ISFM practices are solutions to infertile soil among coffee producers.

Despite the significant roles of ISFM practices in increasing soil fertility to improve crop productivity, studies from other countries have shown that farmers tend to be reluctant to adopt the ISFM practices, resulting into low farm productivity. For instance, a study conducted in Kenya by Mugwe et al. (2009) to ascertain the determinants of farmers' decisions to adopt ISFM practices reported that only 46.22% of the farmers adopted ISFM practices. Anang et al. (2021) conducted a study to determine the adoption of crop protection and soil fertility management practices in Ghana. They found that fertilizer, inoculant and herbicides were adopted by 54%, 43% and 70% of farmers, respectively. Nonetheless, Odendo et al. (2009) observed that organic fertilizer, manure and compost were adopted by 17.4%, 34.7% and 12.3% of farmers, respectively, while only 26.4% of farmers adopted all three ISFM practices in Kenya. Kwadzo and Quayson (2021) considered minimum tillage, crop rotation, inorganic fertilizers and leguminous crops as ISFM practices and found that only 26.66% adopted all practices in Ghana. From these studies, it is evident that farmers do not adopt all ISFM practices. In Uganda, there is declining soil fertility due to continuous nutrients mining by small holder farmers (Nabyonga et al., 2022), the effect of this is reflected in declining crop yields that farmers obtain, as a solution to this intervention have recommended for farmers to adopt ISFM practices (Stewart et al., 2020). To improve coffee productivity in Uganda, there is need to understand the level and determinants of adoption of the ISFM practices. However, the studies on the ISFM practices tend to be limited in Uganda. The state of adoption of ISFM practices has not been adequately studied, especially in Mid-Northern Uganda, where coffee is promoted as a cash crop with the potential of improving the livelihoods of smallholder farmers. Therefore, this study aims to determine the adoption intensity of ISFM practices and the factors affecting it. Knowledge of the adoption intensity for ISFM practices will be of vital importance in guiding the government on policy implementation and farmers' training targeting increased coffee productivity.

Conceptual framework

Our conceptual framework in Figure 1 describes the causal relationship between the adoption intensity of ISFM practices and socioeconomic factors influencing the adoption of ISFM practices. Specifically, this study considered farmers' socio-demographic characteristics (education level, farming experience, household size, distance to the nearest market and formal employment), institutional factors (access to credit, extension services and agricultural insurance) and farm characteristics (farm size and farm inputs from the UCDA). These factors are presumed to influence the adoption intensity of ISFM practices. As such, the predictor variable is the adoption intensity of ISFM practices, and the explanatory variables are education level, farming experience, household size, distance to the nearest market, formal employment,

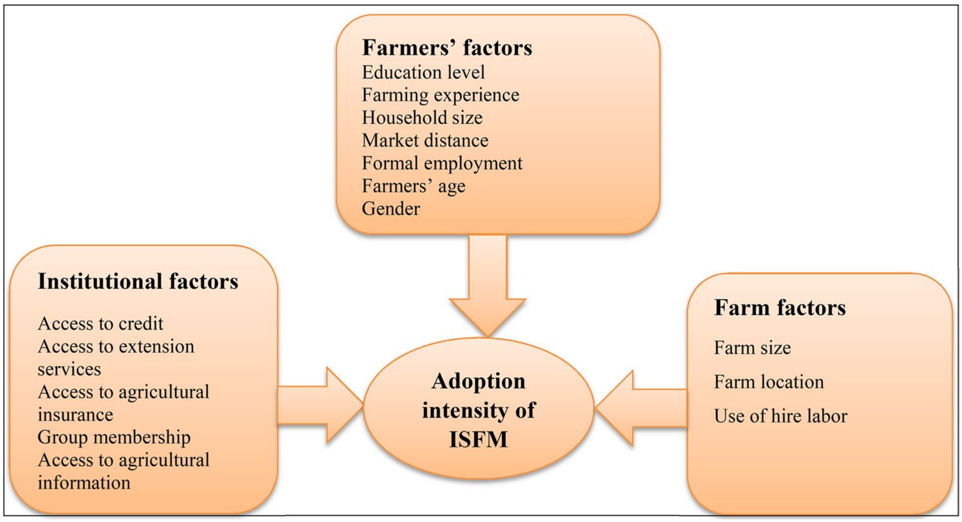

Figure 1. PartLabel-upper conceptual framework; modified from Ntshangase et al. (2018).

access to credit, access to extension services, access to agricultural insurance, farm size, farm location and input support.

Literature review

Integrated soil fertility management practices

ISFM involves the simultaneous integration of individual soil management practices with the overall aim of exploiting the complementarity effects that exist among these multiple technologies (Place et al., 2003). It includes the use of improved germplasm, organic inputs and mineral fertilizers and strongly emphasizes the complementarities and synergies that can arise when these technologies are jointly applied (Lambrecht et al., 2016). This implies that each soil fertility management practice significantly contributes to enhancing soil fertility and productivity; thus, they should be used in combination (Kufa et al., 2011).

Bationo et al. (2008) stated that the most important aspects of ISFM in smallholder farming systems in Africa include the use of mineral fertilizers, efficient management of available organic resources, incorporation of nitrogen-fixing legumes, and protection of soils, biota and organic matter. Similarly, a study conducted by Sari and Nugroho (2016) revealed that coffee plants require good soil fertility for their survival, which can be achieved through good soil fertility management.

In Brazil, positive experiences of using cover crops in coffee production have been reported, for example, with Signal Grass, which improves water infiltration, nutrient availability and soil carbon sequestration (Production & In, 2011). Intercropping with food and cash crops, such as banana, sweet potato, taro, cassava, yam, beans, cowpea and horse grams between rows of coffee plants, is mostly used because of land scarcity and land pressure. This enables farmers to achieve a better combination of food and cash crops. However, competition for water, nutrients and light leads to reduced coffee growth and low coffee yields.

A study done by Adimassu et al. (2013) reported that Ethiopian farmers use soil management practices, such as the application of organic manure and compost and inorganic fertilizers (liming), mulching, ditches, agroforestry (AF) and crop rotations to boost crop yields. This came after realizing that these practices are key to improving soil fertility among different crops. They encourage farmers to continue adopting these practices to increase their yields.

Similarly, Pinard et al. (2014) reported that in Burundi, Uganda, Tanzania, western Kenya, and the eastern Democratic Republic of Congo (DRC), coffee is sometimes grown in association with AF tree species, including *Leucaena leucocephala*, *Calliandra calothyrsus*, *Tephrosia vogerii* and banana. The use of nitrogen-fixing trees increases litter decomposition and nitrogen availability through tree biomass, which helps to stabilize soils against erosion, reduces soil disturbance and improves soil chemical and physical properties (Mulumba & Lal, 2008).

In Rwanda, soils are characterized by nitrogen deficiency and high aluminum toxicity, and farmers benefit from adopting AF to improve coffee productivity. Thus, bananas interplanted with coffee have been reported to increase coffee yields (van Asten et al., 2011). Both organic and chemical fertilizers are used in coffee farming, which are usually prepared by mixing grasses, crop residues, and animal manure in compost. Inorganic fertilizers include NPK (20-10-10) or NPK (17-17-17), which are applied in two doses during March and September to reduce the potential for leaching (Cyamweshi et al., 2014).

Factors influencing adoption intensity of ISFM practices

Existing literature has reported that different socio-economic factors affect the adoption intensity of ISFM practices. Many scholars have found that age is factor affecting the adoption of agricultural technology. Based on the existing literature, older farmers are less likely to adopt new technologies. This suggests that age and adoption of agricultural technology may be negatively related. On the other hand, older farmers are more experienced and informed about the types of technology available to adopt on their farms. Bilaliib Udimal et al. (2017) conducted a study aimed at determining the factors influencing technology adoption among rice farmers in western Ghana, using both probit and binary logit models. The results from the probit model showed that older farmers had a 56.58% lower probability of adopting agricultural technologies. However, Wordofa et al. (2021) reported that an increase in farmers' age by one unit is associated with a 3.2% higher probability of adopting agricultural technology in Ethiopia. This indicates that age may also have a positive effect on the adoption of agricultural technology. Similar findings were reported by Mwaura et al. (2021).

The number of family members has been found to be one of the factors that determine the adoption of agricultural technology. Existing literature has reported that families with many members would divert their finances to food purchases and fail to adopt technologies, such as inorganic fertilizers. On the other hand, families with many members can provide labor on farms, which prompts them to adopt labor-intensive technologies. A recent study by Massresha *et al*. (2021) found that household size has a negative and significant influence on the adoption of agricultural technologies in Ethiopia. Similarly, Ketema and Kebede (2017) reported an inverse relationship between household size and adoption intensity of inorganic fertilizers among maize farmers in Eastern Ethiopia. On the other hand, Maguza et al. and Abbeam et al. reported a positive influence of household size on adoption of agricultural technologies.

Farmers located near trading areas can easily purchase inorganic fertilizers and adopt them on their farms. Additionally, farmers located near district headquarters were able to access farm training and workshops targeting the adoption of agricultural technology. Similarly, the shorter the distance to the input or output markets, the easier it is for the farmer to access the technology. Ogada et al. (2014) applied a binary logistic model to determine the factors affecting the adoption of inorganic fertilizers and improved maize seed varieties in Kenya. They reported that distance to the market was negatively associated with the adoption of both improved maize seed varieties and inorganic fertilizers. Specifically, farmers who were located near the trading centers had a 1% and 0.1% higher probability of adoption of improved maize seeds and inorganic fertilizers, respectively. Zegeye et al. (2022) apply a binary logit model to determine the determinants of technology adoption in Ethiopia. They reported that the distance to the plots and distance to the market had an inverse effect on the adoption of agricultural technologies. They also reported that farmers located far away from the plots and markets had 0.4% and 20% lower probabilities of adopting agricultural technology.

Farming experience has been found to be one of the socioeconomic variables that affect the adoption of agricultural technology. Experienced farmers know the kind of agricultural technology that suits their farms because of the differences in ecological and soil requirements across different areas. They have also created networks and links as they have been farming for a long time. This helps them acquire information on the existence and benefits of new technology in the market. Thus, they can easily adopt new technologies. This suggests that farming experience may positively affect the adoption of agricultural technology. On the other hand, the existing literature shows that as farmers gain more experience, they tend to only adopt the technologies they are familiar with, as they become reluctant to adopt any new technology in the market. A study done by Ainembabazi and Mugisha (2014) reported a U-shaped relationship between the adoption of agricultural technology and farming experience, suggesting that as farmers gain experience, they tend to adopt agricultural technology up to a point in which they are satisfied with the benefits of the adopted technology and thus become reluctant to adopt a new technology in the market.

Agricultural extension is method for disseminating information about the benefits of agricultural technologies in the modern world. Farmers who have access to extensions are therefore able to access information about any new or improved technology (Midamba & Ouko, 2024). From the findings of the study conducted by Ntshangase *et al*. (2018), it is clear that the number of extension visits is positively related to the adoption of agricultural technologies in Natal. Similarly, Ragasa *et al*. (2013) noted that one strategy to improve the adoption of agricultural technologies is to increase the number of extension agents. Additionally, Takahashi *et al*. (2020) acknowledged that to increase farm productivity through the adoption of agricultural technologies in Sub-Saharan Africa, African governments should focus on increasing the number of extension agents so that they can disseminate information on the adoption of agricultural technologies, training and demonstrating how to apply different technologies to increase farm yields.

Farmers who have access to credit can purchase agricultural technologies that are expensive and hence adopt them on their farms. As such, farmers with access to credit are more likely to adopt a given technology. Past studies, such as Mohamed and Temu (2008) study to determine access to credit and its effects on technology adoption in Zanzibar, reported that agricultural credit plays a significant role in the adoption of agricultural technologies. In addition, Gebeyehu conducted a study in Ethiopia reported that credit constraints were impediment to the adoption of inorganic fertilizers among smallholder farmers. Similarly, Bilaliib Udimal et al. (2017) applied both probit and logit models to determine the factors affecting the adoption of improved rice varieties in Ghana. Both modes show that access to credit increases the adoption of agricultural technologies.

Many studies have reported both negative and positive relationships between group membership and the adoption of agricultural technology. A positive association occurs when farmers join the right groups, such as farmers' production groups where they come together and share farm productivity ideas, such as adoption of hybrid seeds, inorganic fertilizers, organic fertilizers, cover crops and trench lines. On the other hand, when farmers join other groups, such as savings groups, they end up saving their finances and become reluctant to adopt a given technology. Mwaura et al. (2021) conducted a study on 300 farmers in Kenya to determine the effect of group membership on the adoption of manure, fertilizer, intercropping and mulching using a Tobit regression model. They found that farmers who belonged to farmer groups had 10.5% and 13.1% higher probabilities of adopting mulch, mature and fertilizer, respectively. A similar study by Misango et al. (2022) determined the factors affecting the adoption of integrated pest management practices in Rwanda and found that belonging to farmers' groups was associated with a 24.6% higher probability of adopting integrated pest management practices.

In conclusion, the results of these studies are not universally accepted. This is because these studies reported different results. The signs and coefficients in the majority of these studies are different; thus, conclusions cannot be made based on past literature, a situation that calls for more empirical studies to fully understand the factors that influence the adoption of agricultural technologies. Nonetheless, these studies have not incorporated most ISFM practices. Therefore, this study aimed to determine the factors that influence the adoption of integrated ISFM practices.

Materials and methods

Approval and consent

This research was approved by Gulu University Research Ethical Committee. Reference number, GUREC-2021-46: Adoption intensity of ISFM practices among smallholder coffee farmers in Oyam and Nwoya districts. A written informed consent document was developed and approved by GUREC to be used in the enrollment of participants, the consent form explains the research and the purpose to the respondents and the respondents consent by signing the document when they agree to participate in the research.

Study area

The study was conducted in Lango and Acholi sub-regions of Mid-Northern Uganda, in the districts of Oyam (Lango sub-region) and Nwoya (Acholi sub-region) Figure 2, where coffee production is being promoted. The Acholi sub region has a generally flat topography with sandy loam soils. It receives 800–1500 mm of rain per annum, with a bimodal rainfall pattern from March to June in the first season and July to November in the second season. In contrast, the Lango sub region receives approximately 1000–1500 mm of rainfall per annum at temperatures of 25–35 °C (Ongoma et al., 2018). Oyam district has 12 sub-counties, 62 parishes and 891 villages, and is bordered by districts of Omoro in the north, Pader in the North east, Nwoya in the North West, Kole in the east, Apac in the south and Masindi in the west. Nwoya district has eight sub-counties and 95 Parishes (UBOS, 2018). It is bordered by Amuru in the north, Pakwach in the west, Omoro in the east, and Masindi in the south (Swaibu, Odokonyero, et al., 2014; Swaibu, Tonny, et al., 2014). The people in the study area are mainly smallholder farmers who engage in both crop and animal production. The districts were selected because they are the main coffee-producing districts in the sub-region, and many interventions have been implemented, such as training on good agronomic practices (GAPS) and distribution of inputs like fertilizer; only large-scale farms have taken up the practices and are attaining good coffee yields.

Sampling procedure

This study adopts multistage and simple random sampling techniques. In the first stage, the Oyam and Nwoya districts were purposively selected for this study because of the high prevalence of coffee farmers compared to other districts in the region. In addition, these two districts have benefited from many interventions, such as training on GAPS, distribution of fertilizers and many technology development sites (TDS) have been established, making them suitable for the study. In the second stage of the multistage sampling, six sub-counties were purposively sampled because they are the

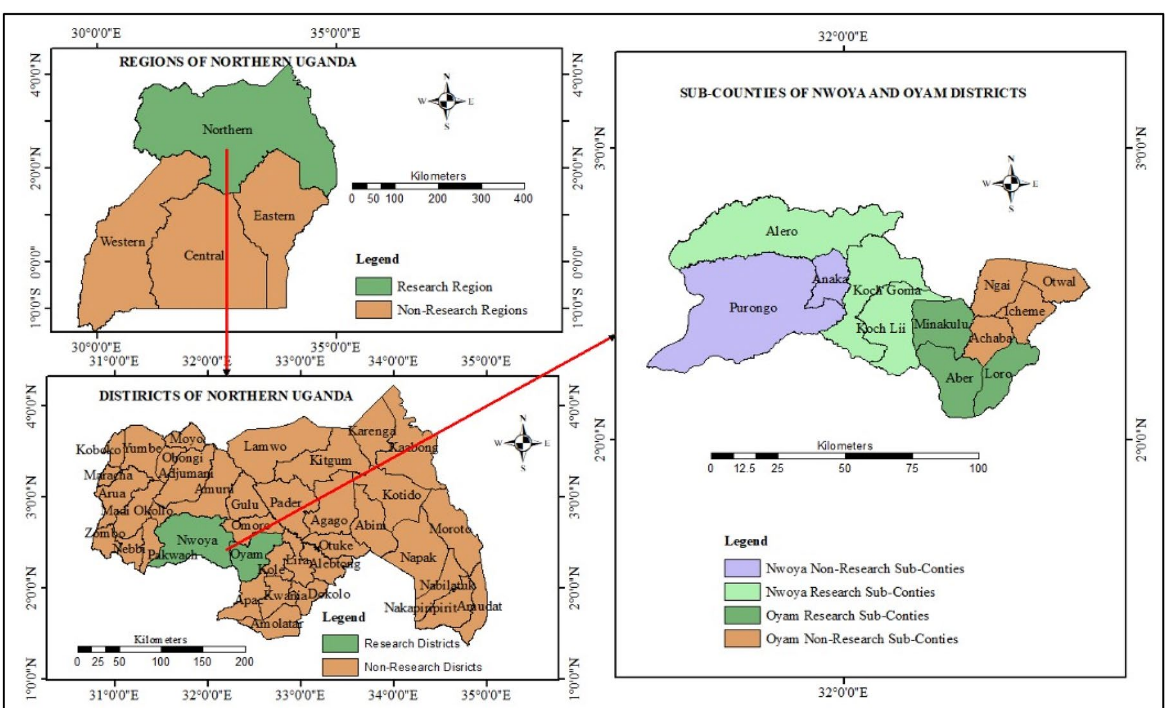

Figure 2. PartLabel-upper location of the study area.

leading sub-counties in coffee production in the two districts. Specifically, in the Oyam district, Loro, Aber and Minakulu sub-counties were considered for the study, while in the Nwoya district, Kochgoma, Lungulu and Alero sub-counties were all considered for data collection. To avoid bias in respondents' participation, simple random sampling was used to obtain a total sample of 202 farmers. We obtained a list of all coffee farmers from district production officers to help easily trace them. The sample size was determined using the following formula developed by Yamane: $n = \frac{N}{\left[1 + N\left(e^2\right)\right]}$

$$n = \frac{400}{1 + 400\left(0.05^2\right)}$$

$$n = 202$$

where

n is the sample size

N is the population size of coffee farmers (400)

e is the level of precision (0.05)

Data sources

Before the actual data collection, pre-testing was performed on 10 selected farmers in Lira district to ensure the appropriateness, clarity, relevancy and reliability of the questionnaire in line with the study objectives. Data were collected using face-to-face interviews between trained research assistants and respondents. The questionnaire consisted of both open- and closed-ended questions to help obtain the appropriate data needed to answer the research questions. The questionnaire was divided into three sections. The first section covered socio-demographic factors, such as respondents' age, gender, marital status, farm size, education level and access to information. The second section focuses on the extent of adoption of ISFM practices, such as the use of manure, mulching shade trees, cover crops, inorganic fertilizers, reasons for adoption/not adoption and land acreage under adoption. Finally, section three covered output variables, such as the quantity harvested and unit price.

Analytical techniques

This study used an adoption index (AI) to determine the adoption intensity of ISFM practices. This model measured the extent of adoption at the time of the survey. It is mostly preferred in cases where there are multiple practices in a study (Sarker, 2016). As we considered 11 practices, the AI was suitable for this study. As such, it was used to measure the extent of the adoption of ISFM practices among farmers. Farmers who adopt all practices would score 1, which is equal to 100%, while those who do not adopt any practice would score 0. Many scholars have adopted an AI in their studies to measure the level of adoption of agricultural technologies. Ketema and Kebede (2017) used AI to measure the level of use of inorganic fertilizers in Eastern Ethiopia, and Adunea and Fekadu (2019) applied AI to assess the level of adoption of agricultural technologies in Ethiopia. Mishra and R.G. Upadhyay (2018) uses an AI to determine the level of adoption of agricultural technologies in India. The AI is specified as;

$$AI = \sum_{i-1}^{n} \frac{NP}{TP} \left(\text{Adopters score 1, non} - \text{adopters score 0}\right)$$

where

NP represents number of ISFM practices adopted

TP represents the total number of ISFM practices promoted

The Tobit model was used to assess the influence of socioeconomic factors on the adoption of ISFM practices. The Tobit regression model, also known as a censored regression model, was first suggested in a pioneering work by Tobin (1958) to analyze household expenditure on durable goods (University

Table 1. Tobit model explanatory variables.

Variables	Category	Unit of measure	Expected sign
Education level	Continuous	Years spent in school	+
Farming experience	Continuous	Years in farming	±
Access to extension services	Dummy	1 – access, 0 – otherwise	+
Farm size	Continuous	Acres	±
Access to agric. Insurance	Dummy	1 – access, 0 – otherwise	+
Distance to the nearest market	Continuous	Kilometers	±
Household size	Continuous	Number of people	+
Formal employment	Dummy	1 – Yes, 0 – otherwise	+
Access to credit	Dummy	1 – Access, 0 – otherwise	+
Input support	Dummy	1 – Yes, 0 – otherwise	+

of Ghana 2017). The model is designed to estimate the relationship between variables when there is either left- or right-censoring in the dependent variable. Since the adoption intensity scores ranged from 0 to 1, the Tobit regression model was used to determine the socioeconomic factors that influence the adoption of ISFM practices. According to Tobin (1958), the Tobit regression model is specified as

$$AI_{ij}^{*} = X_{ij}\beta_i + u_i$$

Subject to:

$$AI_{ij} = 0 \text{ if } AI_{ij}^{*} < 0$$

$$AI_{ij} = AI_{ij}^{*} \text{ if } 0 \leq AI_{ij}^{*} \leq 1$$

$$AI_{ij} = 1 \text{ if } AI_{ij}^{*} > 1$$

where

AI = dependent variable (adoption intensity). The explained variable is bounded between zero (0) to one (1), with zero indicating no adoption and one indicating full adoption. *X* is a vector of explanatory variables that can potentially influence adoption intensity.

Table 1 presents a description of the explanatory variables used in this study and their *a priori* expectations. β_i is a vector of the coefficients associated with the explanatory variables included in the Tobit model.

Results and discussion

Socio-demographic characteristics of the farmers

Table 2 presents the results of the sociodemographic characteristics of the farmers. Accordingly, the results showed that the mean age of the farmers was 56.35 years. This implies that the majority of the farmers were in their active age. There was no significant difference in the mean age of the farmers in the two study districts. The average number of years spent in school was 9.10 years, implying that the majority of the framers did not attain post-secondary education. There was no statistically significant difference in the number of years spent in school by the farmers in the two districts. The results further indicated that the mean household size was nine household members, with no statistical difference between the two districts. Farmers had a mean of 29.38 years of coffee farming. However, there was an insignificant difference in farming experience between farmers in the two districts.

The mean total land size was 9.62 acres, out of which farmers allocated 18.20% to coffee production. This is common practice among sub-Saharan African smallholder farmers. They attempt to minimize risks by apportioning their land to different crops. However, farmers in the Nwoya district had significantly ($p < 0.01$) more acres of land than their counterparts in Oyam. Generally, farmers are located 8.87 km

Table 2. Socio-demographic characteristics of the farmers.

Variables	Measurement unit	Pooled N = 202	Oyam N = 120	Nwoya N = 82	Mean difference (absolute)	p Value
Age	Years	56.35 (14.50)	55.75 (14.58)	57.23 (14.42)	1.48	0.447
Education	Years	9.10 (4.80)	9.50 (4.13)	8.50 (5.60)	0.97	0.159
Household size	Number	9.00 (4.61)	9.20 (4.70)	8.70 (4.53)	0.53	0.424
Farming experience	Years	29.38 (14.48)	29.03 (13.25)	29.90 (16.19)	0.87	0.676
Total land size	Acres	9.62 (15.50)	7.04 (4.66)	13.40 (23.17)	6.37	0.003**
Coffee farm size	Acres	1.75 (1.56)	1.72 (0.90)	1.78 (2.23)	0.07	0.771
Input distance	Kilometers	8.87 (7.75)	12.05 (8.04)	3.50 (2.20)	9.04	0.000***
Gender	Male	178 (88.12)	113 (94.17)	65 (79.27)	48	0.001***
	Female	24 (11.88)	9 (5.83)	17 (20.73)	8	
Access to extension	Has access	200 (99.01)	120 (100.00)	80 (97.56)	40	0.086*
	No access	2 (0.99)	0 (0.00)	2 (2.44)	2	
Access to credit	Has access	156 (77.23	112 (93.33)	44 (53.66)	68	0.000***
	No access	46 (22.77)	8 (6.67)	38 (46.34)	30	
Group membership	Member	178 (88.12)	115 (95.83)	63 (76.83)	52	0.000***
	Not member	24 (11.88)	5 (4.17)	19 (23.17)	14	
Access to agricultural insurance	Has access	16 (7.92)	13 (10.83)	3 (3.66)	10	0.064*
	No access	186 (92.08)	107 (89.17)	79 (96.34)	28	
Main occupation	Farming	138 (68.32)	75 (62.50)	63 (6.83)	12	0.167
	Formal job	43 (21.29)	30 (25.00)	13 (15.85)	17	
	Casual job	8 (3.96)	5 (4.17)	3 (3.66)	2	
	Business	13 (6.44)	10 (8.33)	3 (3.66)	7	
Marital status	Married	173 (85.64)	111 (92.50)	62 (76.61)	49	0.000***
	Single	4 (1.98)	4 (3.33)	0 (0.00)	4	
	Divorced	6 (2.97)	0 (0.00)	6 (7.32)	6	
	Widowed	19 (9.41)	5 (4.17)	14 (17.07)	9	

Note. N: number of participants
*, ** and *** represents the statistical significance at 10%, 5% and 1% respectively.

Table 3. Descriptive statistics for the ISFM practices adopted by the farmers.

ISFM practices	No. of farmer (Oyam) N = 120	Percentage (%)	No. of farmers (Nwoya) N = 82	Percentage (%)	Pooled N = 202	Percentage (%)	p Value
Cover crops	107	89.17	61	74.40	168	83.17	0.005***
Agroforestry	110	91.67	79	96.34	189	93.56	0.183
Inorganic fertilizers	19	15.83	13	15.85	32	15.84	0.996
Organic fertilizers	69	57.50	31	37.80	100	49.50	0.006***
Trenches	29	24.17	19	23.17	48	23.76	0.870
Mulching	79	65.83	44	53.66	123	60.89	0.081*
Regular weeding	117	97.50	80	97.56	197	97.52	0.978
Crop rotation	72	60.00	42	51.22	114	56.44	0.216
Minimum tillage	44	36.67	33	40.24	77	38.12	0.607
Zero tillage	13	10.83	32	39.02	45	22.28	0.000***
Trash lines	15	12.50	57	69.51	72	35.64	0.000***

* and *** represents the statistical significance at 10% and 1% respectively.

away from the markets. However, farmers in the Oyam district were significantly ($p < 0.01$) far away from the markets than those in the Nwoya district.

The results further showed that the majority of the farmers (88.12%) were male. The difference in sex between the two districts was significant at the 1% level. Most farmers (99%) had access to extension services. The difference in access to extension services is statistically significant at the 5% level of significance. Similarly, 77% of farmers had access to credit; the difference was also statistically significant at the 1% level of significance.

Integrated soil fertility management practices adopted by the farmers

Table 3 presents the ISFM practices adopted by coffee farmers. Specifically, this study considered cover crops, AF, inorganic fertilizers, organic fertilizers, trenches, mulching, regular weeding, crop rotation, minimum tillage, zero tillage and trash lines. Based on the results, the highly adopted ISFM practices included regular weeding (97.52%), AF (93.56%), cover crops (83.17%) and mulching (61%). However, few farmers have adopted inorganic fertilizers, zero tillage, trenches and trash lines. Specifically, only 15.84%, 22.28%, 23.76% and 35.64% of farmers adopted these practices, respectively.

Table 4. Adoption intensity of integrated soil fertility management practices.

Adoption intensity range	Number of farmers (Oyam) $N = 120$	Percentage (%)	Number of farmers (Nwoya) $N = 82$	Percentage (%)	Pooled $N = 202$	Percentage (%)	Cumulative percentage (%)
0.00–0.50	65	54.17	36	43.90	101	50.00	50.00
0.51–0.60	12	10.00	10	12.20	22	10.88	60.88
0.61–0.70	14	11.67	11	13.41	25	12.38	72.26
0.71–0.80	15	12.50	13	15.85	28	13.86	87.12
0.81–0.90	9	7.50	8	9.76	17	8.42	95.54
≥ 0.91	5	4.16	4	4.88	9	4.46	100.00
Mean	0.51		0.54		0.52		
Minimum	0.18		0.18		0.18		
Maximum	1.00		0.91		1.00		
Mean diff	0.030						
p Value	0.2517						

In terms of adoption across the two districts, the results (Table 3) showed that cover crops were significantly adopted by many farmers in Oyam ($p < 0.01$) than in the Nwoya district. Although many farmers in Oyam than in Nwoya district adopted AF and inorganic fertilizers, the difference in the number of farmers who adopted these practices was not statistically significant. At the 1% level of significance, organic fertilizers were significantly adopted by many farmers in Oyam than in the Nwoya district. There was no significant difference in the number of farmers who adopted trenches between the two districts. However, the results further showed that mulching was significantly ($p < 0.10$) adopted by many farmers in the Oyam District than in Nwoya. Many farmers in Oyam have adopted regular weeding, crop rotation and minimum tillage. The difference in the number of farmers who adopted these practices between the two districts was not statistically significant. Finally, the results clearly show that zero tillage and trash lines were significantly ($p < 0.01$) adopted by many farmers in the Nwoya district compared to Oyam district.

Adoption intensity of integrated soil fertility management practices

The results Table 4 show that the mean adoption intensity was 0.52. The minimum and maximum adoption intensity were 0.18 and 1.00, respectively. Accordingly, the results further showed that 50% of all farmers were able to score up to 0.50, while only 4.46% of the farmers attained above 0.91 adoption intensity. The mean adoption intensity for farmers in Oyam District was 0.51, while for Nwoya District, the adoption intensity was 0.54. Even though farmers in Nwoya had a higher adoption intensity than their counterparts in Oyam District, the results showed that the difference was statistically insignificant. Based on these results, the adoption intensity for ISFM practices was generally low, with the majority of farmers scoring low adoption intensity.

The results further showed that the mean adoption intensity was generally low. The low adoption intensity was attributed to the low number of practices adopted by the farmers. In terms of adoption across the districts, farmers in Nwoya District had a higher adoption intensity than their counterparts in Oyam District; however, the difference was statistically insignificant. A similar pattern was observed in the number of practices adopted by farmers in the two districts. The difference in adoption intensities between the two districts was attributed to the fact that farmers in Nwoya district were located near trading centers, implying that they could access these practices more easily and in a timely manner than their counterparts who were located in villages far away from the trading centers. Additionally, these farmers could easily access agricultural information, agricultural technology, farm inputs and better markets, resulting in increased adoption of these practices.

In terms of the distribution of adoption intensity among the farmers, the results indicated that the majority of farmers (54.20%) achieved up to 50% adoption intensity. Further analysis of the distribution of adoption intensity across farmers showed that only 4.2% of the farmers were able to score above 90% adoption intensity. This is in line with the results of previous studies (e.g. Koppmair et al. (2017); Mugwe et al. (2009); Mwangi and Kariuki (2015); Pan et al. (2018); Takahashi et al. (2020); Wordofa et al. (2021); Workineh et al. (2020). Based on the findings of these studies, it is evident that farmers fail to achieve a 100% adoption intensity for different technologies.

Factors affecting adoption intensity of integrated soil fertility management practices

Pre-estimation test results

Prior to Tobit regression for the factors affecting the adoption of ISFM practices, we ran pre-estimation tests to ascertain that the variables included in the analysis would not have heteroscedasticity, multicollinearity or omission issues. The variance inflation factor (VIF) analysis results (Table 5) indicated that the mean VIF was 1.20, with the maximum and minimum VIF being 1.42 and 1.07, respectively. This was however, arrived at after removing some variables which had higher multicollinearity coefficients, e.g. age and farming experience. According to Akinwande et al. (2015), Danso-Abbeam et al. (2017) and Ouko et al. (2022), VIF should not be more than 10 and should not be less than 1. Therefore, the VIF of the study falls within the acceptable range, indicating the absence of multicollinearity among the independent variables. Other test results included the omitted variable (OV) and the Cook–Weisberg test of heteroscedasticity. The Cook–Weisberg test of heteroscedasticity results showed an insignificant value of 0.857, while the OV test results showed an insignificant value of 0.371. These results indicate the absence of heteroscedasticity and OVs (Saqib et al., 2018; Malyarets et al., 2018). Therefore, study proceeded to run the Tobit model.

Determinants of adoption of ISFM practices

The results from the Tobit model on model fitness indicate that the value of pseudo R-squared was 39% (Table 6). This is within the 'extremely good' category of pseudo R-squared according to Mbachu et al. (2012). The log-likelihood ratio was −38.454, which was acceptable. Similarly, the model was significant at the 1% level, implying that all the regression coefficients were not equal to zero. Based on these results, the study concluded that the model was sufficient to present results on the factors affecting the adoption intensity of ISFM practices.

Table 5. Pre-estimation test results.

Variables	VIF	1/VIF
Market distance	1.42	0.70
education	1.29	0.77
Credit	1.27	0.78
Inputs	1.23	0.81
Family size	1.21	0.82
Formal employment	1.21	0.83
Farming experience	1.17	0.85
Land size	1.12	0.89
Extension	1.07	0.93
Access to insurance	1.04	0.96
Mean VIF		1.20
Other tests		
Cook–Weisberg test of heteroscedasticity		0.857
Omitted variable (OV) test		0.371

VIF: variance inflation factor; OV: omitted variable

Table 6. Socio-economic factors affecting adoption of ISFM practices.

Variables	Coefficient	Standard errors	$p > t$
Education	0.027	0.031	0.389
Land allocated to coffee	0.098	0.024	0.000***
Access to credit	0.094	0.050	0.056*
Access to agricultural insurance	0.174	0.068	0.011**
Access to UCDA inputs	0.074	0.044	0.099*
Distance to the nearest market	−0.019	0.027	0.486
Access to extension	−0.032	0.061	0.598
Household size	−0.070	0.033	0.034**
Farming experience	−0.099	0.034	0.558
Formal employment	0.101	0.048	0.036**
Constant	0.488	0.148	0.001***

LR Chi^2 (13) = 49.96, Pseudo R^2 = 0.3938, Log-likelihood ratio = −38.454, Prob > Chi^2 = 0.000, N = 202.
*, ** and *** represents the statistical significance at 10, 5 and 1%, respectively.

Knowledge of the factors affecting the adoption of ISFM practices is helpful in guiding the government in formulating policies to increase coffee productivity. Based on the results, land size positively and significantly influenced the adoption intensity of ISFM practices. An increase in land size by one unit would result in a 2.7% increase in adoption intensity. The positive influence of coffee farm size on adoption intensity was attributed to the fact that farmers with large portions of land were able to increase their yields because of the benefits of economies of scale. This resulted in a high income, which they later used to purchase some of the practices, such as inorganic fertilizers. Similar findings were reported by Bilaliib Udimal et al. (2017), who found that farm size has a positive and significant association with the adoption of agricultural technologies among rice farmers in Ghana. Additionally, a recent study done by Massresha et al. (2021) found that farm size was positively related to the adoption of agricultural technology in Ethiopia. Similar results were reported by Mekonnen (2017), who observed that farmers in Ethiopia with large portions of land could adopt inorganic fertilizers more easily than their counterparts with small portions of land. Similar findings were reported by Mwaura et al. (2021). However, attributed to poor farm management, Ntshangase et al. (2018) reported that farmers with a large portion of land were less likely to adopt agricultural technology in Natal.

Similarly, farmers who had access to credit services had a significantly higher adoption intensity than those who did not have access to credit. The adoption of these practices is not only labor-intensive but also requires capital. In addition, the application of these practices is highly labor-intensive, implying that families with few members had to hire labor from their farmers. As a result, farmers who had access to credit were able to adopt the practices easily and in a timely manner, resulting in higher adoption intensity than their counterparts who did not have access to credit. This is in line with the findings of Bilaliib Udimal et al. (2017), who found that rice farmers who had access to credit had 56.58% higher adoption intensity than their counterparts who did not have access to credit. Zegeye et al. (2022) applied a binary logit model to determine the determinants of farmers' decisions to adopt agricultural technology in Ethiopia. They found that farmers with access to credit had a 48.5% higher probability of adopting agricultural technology because they would use their finances to purchase inorganic fertilizers and hire farm labor to apply them to farms. In Northern Uganda, Midamba et al. (2024) also posed that credit increases adoption of sustainable agricultural practices.

The results further showed that farmers who had access to agricultural insurance had significantly higher adoption intensity than their fellows who did not have access to agricultural insurance. This implies that agricultural insurance increases adoption intensity. When farmers pay insurance for their crops, they are able to receive refunds when their crops do not perform well due to incidences, such as high pests and disease infestation, natural calamities, such as prolonged drought resulting in low yields, and excessive rainfall that destroys coffee. The refund would help the farmer purchase ISFM practices and adopt them on their farms. The findings of this study are in line with the findings reported by Nshakira-Rukundo et al. (2021) who found out that farmers who have access to agricultural credit were more likely to adopt agricultural technologies than those who did not have access to agricultural credit. Similarly, Marcela and Torres (2016) reported a positive relationship between agricultural insurance and adoption of agricultural technologies among wheat farmers in Chile. Additionally, a recent study by Wei et al. (2021) observed that crop insurance boosts readiness to embrace agricultural technology in three ways: motivation, ability and opportunity.

Farmers who received farm inputs (seeds, fertilizers and pesticides) from the UCDA had significantly higher adoption intensities than those who did not receive inputs from the UCDA. The farm inputs from the UCDA helped reduce farm production costs. This helped farmers use their capital for the adoption of ISFM practices. In addition, farmers who received inputs from UCDA were able to use the money they used for seed purchase to hire farm labor to apply ISFM practices. Similar findings were reported by Kassle et al., who found a positive and significant association between input subsidy and the adoption of natural resource management technologies among farmers in Malawi. Koppmair et al. (2017) reported a similar observation in their study, which aimed to determine the effect of a farm input subsidy program on the adoption of inorganic fertilizer and improved maize seeds in Malawi. They reported that farmers who were enrolled under the farm input subsidy program were more likely to adopt organic fertilizers and improved maize seeds than their counterparts who were not registered under the subsidy program.

There was a negative and significant association between household size and adoption intensity of ISFM practices. A unit increase in household size results in a 7% decrease in adoption intensity. This was attributed to the fact that large households spent money on purchasing food for their families rather than on adopting practices. Farmers considered food as the basic need, and hence, they allocated their money to food as opposed to adopting ISFM practices for coffee production. This agrees with the findings of Massresha et al. (2021) that household size has a negative and significant influence on the adoption of agricultural technologies in Ethiopia. Similarly, a recent study by Ketema and Kebede (2017) reported an inverse relationship between household size and adoption intensity of inorganic fertilizers among maize farmers in Eastern Ethiopia. However, Maguza et al. (2016) and Abbeam et al. (2017) reported a positive influence of household size on the adoption of agricultural technologies, attributed to overdependence.

Lastly, the results showed that formally employed farmers had significantly higher adoption intensities than their counterparts did not in formal employment. Formal employment helped farmers access loans they used to purchase and adopt ISFM practices. Additionally, formally employed farmers were able to obtain the finances needed to hire labor on their farms to apply labor-intensive technologies, such as inorganic fertilizers. Similar findings were reported by Diiro (2013), who found that off-farm income has a positive and statistically significant effect on adoption intensity among maize farmers in Uganda. Similarly, Heijnen et al. (2013) reported that farmers who earned off-farm income had a higher adoption intensity of capital-intensive and risky technologies in Washington DC.

Conclusion and recommendation

In Uganda, coffee production and exports contribute to the GDP, create employment, improve living standards and reduce household poverty among smallholder farmers. Despite the significant role of coffee, its production in Uganda is generally low. This has been attributed to infertile and weathered soils in different parts of the country. However, one of the major proposed solutions to solving the problems of soil infertility is the adoption of integrated ISFM practices, which help boost soil fertility. As such, farmers have been encouraged to adopt ISFM practices, especially in areas, such as Oyam and Nwoya districts, where coffee yields are low because of infertile soils. However, limited information is available about the current level of adoption of these practices and the factors that affect the adoption intensity of ISFM practices. To fill this research gap, this study characterized coffee farmers and determines factors that affect adoption intensity for ISFM practices in Uganda. Based on the results, this study concluded that the adoption intensity for ISFM practices is generally low. Further, the results from Tobit regression model, showed that land size allocated to coffee, access to credit, access to agricultural insurance and formal employment increased adoption intensity, while household size reduced adoption intensity for ISFM practices.

Policy recommendations

- The results showed that farmers who had access to credit had a higher adoption intensity than their counterparts who did not have access to credit, based on this, this study recommended that smallholder farmers should be encouraged to access agricultural credit including loans from financial institutions that offer loans at low interest rates. This will help them adopt practices such as purchasing inorganic fertilizers, which in turn would increase coffee yields.
- Similarly, the positive association between adoption intensity and access to agricultural insurance suggests that farmers who had access to agricultural insurance had a higher adoption intensity. As such, this study recommends that farmers should be encouraged to pay insurance for their coffee so that they can receive income even during incidences of calamities, such as drought, pests and disease, as well as excessive rainfall. This will increase adoption intensity, resulting in increased yields among farmers.
- Most farmers did not adopt ISFM practices because of a lack of information about these practices, as well as being expensive to purchase, such as inorganic fertilizers. As such, this study recommends that extension officers disseminate information on the adoption of these practices. Additionally, the Ministry of Agriculture, Animal Industry and Fisheries should subsidize the prices of inorganic fertilizers to help farmers to adopt them.

- Farmers who received input support from the UCDA had a higher adoption intensity than their counterparts who did not receive input. This suggests that subsidizing the prices of farm inputs, such as fertilizers, seeds and pesticides, will help increase the adoption of ISFM practices. As such, this study recommends that the government subsidize farm input.
- Credit should be extended to purchase seeds of cover crops or green manures, manure instead of fertilizers that have risen in price since the Ukraine–Russia war.

Limitations of the study

The limitation of this study relies on the fact that it did not include key biophysical, e.g. soil fertility indicators or their proxies and farm-level variables, such as livestock or tropical livestock units in the model estimation, yet these are variables, which may have significant effects on the adoption of ISFM practices.

Author contributions

Beatrice Alela Conceived, designed, carried out the research and wrote the article; Dick Chune Midamba analyzed and interpreted the data and writing, and contributed significantly to the overall structure and flow of the manuscript; Enos Kule and Basil Mugonola provided technical guidance, reviewed the objectives and survey methods and improved the coherence of the content. All authors contributed equally to organizing the special issue, editorial work and writing of this manuscript. All the authors have read and agreed to the published version of the manuscript.

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Data availability

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