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SOCIOLOGY | RESEARCH ARTICLE

Determinants of adoption of sustainable agricultural practices among maize producers in Northern Uganda

Dick Chune Midamba[1*], Mary Kwesiga[1] and Kevin Okoth Ouko[2]

Abstract: Sustainable agricultural practices (SAPs) increase crop productivity. This is achieved by increasing soil fertility, preserving moisture in the soil, and reducing pest and disease build-up, among other significant roles. Strikingly, maize farmers are still deeply rooted into the traditional methods of production which do not consider the adoption of SAPs. As such, they report low maize yields. Similarly, despite government efforts to increase the adoption rate, farmers remain reluctant to adopt SAPs. Therefore, this study aims to determine the adoption intensity of SAPs and its determinants using data collected from 101 randomly selected farmers in Northern Uganda. The adoption index (AI) and Tobit model approaches were used to determine the adoption intensity and its determinants, respectively. Based on the results, adoption intensity stood at 70%, while the determinants of adoption of the selected SAPs were education level ($P < 0.05$), household size ($P < 0.05$), farm size ($P < 0.01$), ICT use ($P < 0.05$), access to market information ($P < 0.01$), extension

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Dick Chune Midamba [In the picture], is a PhD Candidate in Agricultural Economics at Maseno University. Midamba holds an MSc in Agri – Enterprises Development and a Bsc. in Agricultural Economics. His research expertise includes food systems, technology adoption, crop diversification, and economic efficiency. The second author is Mary Kwesiga. Mary is a female Ugandan national holding a Bachelor's degree in AgriEntrepreneurship and Communication Management from Gulu University. The third author is Kevin Okoth Ouko, who is a Research Associate Consultant at WorldFish. He recently completed a PhD in Food Security and Sustainable Agriculture. He also holds an MSc in Agricultural and Applied Economics. His research expertise includes food systems, climate change, technology adoption, aquaculture value chains, and gender and social inclusions. The findings from this study are helpful in increasing the level of adoption of sustainable agricultural practices, which in the long run increases food production among smallholder farmers.

PUBLIC INTEREST STATEMENT

The population in Sub-Saharan Africa continues to growing steadily. However, as the population grows, the demand for food also increases. Agriculture, which is the mother of food consumed by humans, has a great role to play so as to bridge the gap between food demand and the population growth. Adoption of sustainable agricultural practices has been reported to have significant benefits to agriculture such as increasing soil fertility, soil and water conservation, post-harvest loss reduction, pests and diseases. Therefore, farmers who adopt such practices report higher yields than their counterparts who depend on traditional methods of studies. However, low adoption of sustainable agricultural practices has been recorded in different regions of SSA. The study therefore determined the level of adoption of SAPs and their determinants. The findings of the study suggest different policies to be implemented in order to boost maize productivity.

visits (P < 0.05), and credit access (P < 0.10). The study recommended that small-holder farmers' use of ICT in accessing information on the adoption of SAPs among other agricultural information, strengthening adult literacy programs, increasing extension visits, and encouraging farmers to access credit from low interest rates financial institutions would help in increasing the level of adoption of SAPs.

Subjects: Asian Studies; Socio-Legal Studies; Sociology

Keywords: productivity; farming households; food security; tobit model; smallholder farmers

1. Background

Globally, it is estimated that the current world population of 7.6 billion is expected to increase by 1 billion by the year 2030 (UNDESA, 2015). This is closely ascribed to the growing world population, especially in African countries (Basedau et al. 2021). Strikingly, as the world population increases, the demand for food also increases significantly, which renders many people food insecure (United Nations, 2021). Globally, it is estimated that around 783 million people are food insecure, a situation which is not in line with the Sustainable Development Goals 1 and 2 (SDGs). According to the recent reports released by World Bank (2023), food insecurity has greatly increased between the years 2019 and 2022 globally. This, therefore, implies that the agricultural sector, which is the mother of consumed foods, has a big role to play in terms of food provision.

In Sub-Saharan Africa [SSA], agriculture contributes 20% of the total GDP. It also employs 67% of the population (Rapsomanikis, 2015). In Uganda, the role of agriculture cannot be assumed. The sector provides food to majority of households and raw materials for agro-based firms while also employing majority of the working class (MAAIF, 2020). In terms of GDP contribution, the sector contributed 21% of the total country's GDP in 2019/2020. This figure increased to 24.1% in 2021/2022 and is expected to go up again in 2022/2023 financial year. This implies that the country entirely depends on agriculture.

However, agricultural productivity depends on several factors, including the adoption of sustainable agricultural practices (SAPS). Coulibaly et al. (2021) defines sustainable agricultural practices as "The agricultural practices which meet society's food and textile needs in the present without compromising the ability of future generations to meet their own needs". SAPs play several roles in ensuring that optimum crop yield is achieved at the farm level (Guddanti, 2015; Thakur et al., 2023). For instance, use of inorganic and organic fertilizers helps to improve soil fertility (Ogada et al., 2014; Place et al., 2003; Sinyolo & Mudhara, 2018). Similarly, the use of hybrid and improved seeds increases resistance to pests and diseases and makes crops survive in low rainfall zones while taking the shortest time possible to mature (Jimi et al., 2019; Jin et al., 2022; Muzari et al., 2012). Recommended spacing in maize production provides crops with sufficient space to increase farm productivity (Ainembabazi & Mugisha, 2014). Similarly, adoption of postharvest handling practices helps to reduce postharvest losses in crops (Shee et al., 2019; Sugri et al., 2021). Mulching, cover crops, and crop rotation also play significant roles in preserving soil moisture and reducing the build-up of pests and diseases in crops (Mulumba & Lal, 2008; Nzeyimana et al., 2017). Moreover, pesticide use reduces pests and diseases build up in crops (E. O. Acheampong et al., 2021). SAPs therefore play significant roles in crop production.

With the current trends in modern agriculture, it is expected that smallholder maize farmers should divert from the traditional production methods to modern ways of farming which, include full adoption of SAPs. However, many smallholder farmers, especially in developing countries, have not fully adopted the SAPs. They are still deeply rooted into the traditional farming methods which have passed with time. This is evident in many studies conducted in Sub-Saharan Africa, for instance, in Uganda, Mastenbroek et al. (2021) and Mugisha and Diiro (2010) reported that the majority of farmers still adopt SAPs at a modest rate. In Ghana, Danso-Abbeam et al. (2017) noted that only 40% of farmers adopted improved seed varieties, while the rest used traditionally preserved seeds. Similarly, Pham et al. (2021) reported that the adoption of sustainable agricultural practices was at a modest rate. Moreover, Jin et al. (2022) observed declining farm yield from smallholder farmers in Tanzania, which was also attributed to the reluctance to adopt sustainable agricultural practices. These results are also in line with the findings of Feyisa (2020) and Wordofa et al. (2021), who noted that most farmers in Ethiopia are still struggling with technology adoption. In Kenya, improved seeds and inorganic fertilizers, despite their contribution to crop productivity, are rarely adopted by farmers (Ogada et al., 2014). In Uganda, from 1,101,000 hectares of land under maize production, only 36,248 hectares (3.3%) are under fertilizer (AGRA, 2018). Based on these studies, it is evident that the adoption of SAPs remains low in sub-Saharan African countries.

In SSA, maize which is the major source of calorie has been reporting sub-optimal yields of 1.6 t/ha against the global yield of 5.0 t/ha (Yarnell, 2008). In Uganda, the crop records 23,177 hg/ha against the projected yield of 25,271.5 hg/ha, representing a yield gap of 2,094.5 hg/ha (Epule et al., 2021). This is also ascribed to low adoption of SAPs. To increase maize productivity, which currently declines, the government has been implementing several agricultural interventions to increase the adoption of SAPs. These include hiring more qualified extension agents to foster training and demonstrations of the adoption of SAPs, supply of farm inputs such as fertilizers to smallholder farmers, investing in agricultural research and development, and funding agricultural universities to train students, among others (MAAIF, 2020). However, the efforts of such interventions remain darkened as maize productivity in this low-income country steadily declines (MAAIF, 2020). As such, there is a need to understand the state of adoption of SAPs and the factors driving it, as it gives clues to the government on areas that need policy adjustment. There are several studies that provide results on the rate of adoption of SAPs globally, such as P. P. Acheampong et al. (2022), Benitez-Altuna et al. (2021), Ekanem et al. (2020), Gebeyehu (2016), Issa et al. (2017), Massresha et al. (2021a), and Mwangi and Kariuki (2015), and Nagar et al. (2021), and Wordofa et al. (2021), and Xu et al. (2022), and Zegeye, Fikire et al. (2022). However, these studies present contradictory results on the state of adoption of agricultural technologies as further discussed in the literature review section. This is attributed to the differences in the locations of these studies as well as the methods used. Hence, adoption is region based rather than generalization based on findings from existing studies. Similarly, few studies discuss the adoption of SAPs in Northern Uganda, an area which record 70–80% of the population operating below the poverty line (UBOS, 2018c).

Therefore, the study considers the most significant SAPs and determines their rate of adoption as well as the determinants. Hence, the main objective of the study is to assess the intensity and determinants of adoption of SAPs in maize production. The crop considered is maize because it is a stable food that is produced in nearly all regions in Uganda, and it can be produced both as a cash and food crop. In addition to providing policy recommendations for improving maize productivity in Northern Uganda, this study also significantly contributes to the existing literature on the adoption of sustainable agricultural practices in developing economies. The rest chapters present related studies on adoption of SAPs, methodological procedures used, findings, and discussion while also providing policy recommendations to boost the level of adoption of SAPs.

2. Specific objectives of the study

(1) To determine the adoption intensity of sustainable agricultural practices

(2) To assess the determinants of adoption of sustainable agricultural practices

3. Literature review

3.1. Determinants of adoption of agricultural technologies

Several studies have been conducted on the determinants of adoption of agricultural technologies. These studies, however, present different results based on the methods and locations of the study. A study conducted by Bilaliib Udimal et al. (2017) on the determinants of adoption of agricultural technologies reported a negative effect of age on the adoption of agricultural technologies in Northern Ghana. On the other hand, Wordofa et al. (2021) reported contradicting results which showed a positive effect of age on the adoption of agricultural technologies in Eastern Ethiopia.

Similarly, a study conducted in China by Hu et al. (2022), aiming at determining the covariates responsible for agricultural technology usage among smallholder farmers reported that farmers with large portions of land are more likely to adopt new agricultural technologies. Contrary to this, Massresha et al. (2021a) conducted a study in Ethiopia aiming at determining the perception and determinants of adoption of agricultural technologies among rural farmers. Their results indicated that farm size negatively influence the adoption of new agricultural technologies.

Jaza et al. (2018) reported a positive but insignificant influence of household size on the adoption of technologies among farmers in Cameron. Strikingly, a study by Wordofa et al. (2021) observed a positive and significant effect of household size on the adoption of agricultural technologies in Eastern Ethiopia. Contrary to the two studies, results from a study by Temu and E (2008) noted that the number of family members had a negative and significant relationship with adoption of agricultural technologies, implying that as the number of family members increases, there is less probability of adoption of agricultural technologies.

Strikingly, extension visits, which theoretically are believed to increase the level of adoption of agricultural technologies, were reported to have a negative influence of technology adoption by Olasunkanmi et al. (2022). On the other hand, Ekepu and Tirivanhu (2016) conducted a study on adoption of agricultural technologies among smallholder farmers in Soroti, Uganda, and indicated that the more the farmers were visited by the extension agents, the higher the probability of them adopting sustainable agricultural practices.

Market distance plays a significant role in accessing agricultural technologies. Theoretically, being located near the market increases the probability of adopting any given technology. Strikingly, Massresha et al. (2021b) reported a positive influence of market distance on adoption of technologies among farmers in Amhara, Ethiopia, implying that farmers located far away from the market would easily adopt the SAPs than their counterparts near the trading centres. On the other hand, a study in Ethiopia by Zegeye, Fikire et al. (2022) reported that the closer the farmer is located to the markets, the higher the probability of adopting a given technology due to the ease of access.

Theoretically, credit is believed to increase adoption of SAPs. This is because, it eases timely purchase of SAPs such as fertilizers (Gebeyehu, 2019). Against this, findings from the study done by Okonji and Awolu (2020) in Nigeria using Binary Logit model suggest that credit reduces adoption of SAPs. On the same note, the findings from the study conducted in Nigeria by Regassa et al. (2023) reported higher adoption intensity of SAPs among credit users than non-credit users. Thus, the study concluded that credit increases adoption of agricultural practices.

In their study on gender difference on adoption of agricultural technologies in Ethiopia, Neway and Zegeye (2022) reported that female farmers have low access to education and land and as a result, their adoption level is lower than that of men who have access to land and education. Similar findings were also observed in a study conducted by Gebre et al. (2019) in Ethiopia. On the other hand, using Binary logit to estimate the covariates responsible for the adoption of SAPs, Lemma and Degefa (2023) found out that gender has an insignificant influence on the adoption of SAPs.

Other significant studies with contradictory results on the state of adoption of agricultural technologies include; P. P. Acheampong et al. (2022), Benitez-Altuna et al. (2021), Ekanem et al. (2020), Gebeyehu (2016), Issa et al. (2017), Massresha et al. (2021a), and Mwangi and Kariuki (2015), and Nagar et al. (2021), and Wordofa et al. (2021), and Xu et al. (2022), and Zegeye, Fikire et al. (2022). These studies present varied levels of adoption intensities of agricultural technologies as well as the determinants based on methods and study areas.

In summary, these studies have outlined some of the covariates responsible for adoption of agricultural technologies among farmers in different areas. However, it is clearly evident that these studies present conflicting results on the factors affecting adoption of SAPs. This is closely attributed to many factors including the areas and the methodological approaches used in the studies. Based on this, there is a need for more studies, especially in particular areas of interest which directly require policy recommendations to increase the adoption level so as to increase crop productivity. Thus, this study aims at determining the covariates responsible for the adoption of sustainable agricultural technologies in Northern Uganda, a region characterized by low maize productivity and high level of food insecurity (UBOS, 2018c).

3.2. Theoretical framework

While there are several theories and models of adoption such as Theory of Diffusion of Innovation (TDI), Technology Acceptance Model (TAM), Unified Theory of Acceptance and Use of Technology (UTAUT), Technology Readiness (TR), Theory of Planned Behaviour (TPB), and Utility Maximization Theory (Dissanayake et al., 2022), the study adopted the Random Utility Model due to its practical application to the farmer situation (Atube et al., 2021; Ngoma et al., 2016). Random Utility Model Theory indicates that the farmers' adoption decision is based on the perceived benefits of any given technology (Arslan et al., 2014; Joseph, 2017). Prior to the adoption of any SAP, information about the existence of a technology is accessed by the farmers. The farmer then analyses the technology over the current ones while considering other factors such as the costs of the technology, trialability and relative advantage (Scott et al., 2008). Consequently, a farmer would then adopt any given technology if they perceive such a technology as beneficial. A rational smallholder farmer *i* with an aim of increasing his maize output with a decision to adopt a SAP from a set of *J* alternatives. If this farmer obtains utility U_{iMT} from choosing *MT*, J^{th} option and $j = 1 \ldots ..J$. The farmer will adopt the SAP which gives him the highest utility (He chooses *MT* if $U_{iMT} > U_{ik}$) (Ngoma et al., 2016). They would adopt a technology if the expected benefit when using such a technology is cumulatively higher than the expected benefits when not in use under certain constraints. This gives him the highest utility (Atube et al., 2021; Gebeyehu, 2016). Random Utility Model (RUM) is specified in the equation below:

$$Uj = \beta' jXi + \varepsilon i$$

In the above equation, *Uj* is the perceived utility of a given agricultural technology, is it also hypothesized that the adoption decision is influenced by socio-economic factors which are represented by *Xi*, while β*j* are parameters to be estimated, ε*i* represents the error term.

3.3. Conceptual framework

The study's conceptual framework is presented in Figure 1. The framework describes the relationship between the adoption of SAPs and hypothesized independent variables. The explanatory variables are categorized into three categories; socio-economic, institutional, and demographic factors (David & Abbyssinia, 2017; Feliciano, 2022). Under demographic factors, the study considered gender, age, household size, marital status, education level, and distance to the market. On institutional factors, we had access to credit, extension visits, access to market information, group membership, and use of ICT in farming. Farm size, farm output, and assets were categorized under socio-economic factors (Danso-Abbeam et al., 2017). It is hypothesized that these factors can either positively or negatively influence farmers' decision to adopt SAPs. Their influence on the adoption of sustainable agricultural practices is further discussed in the literature review section.

4. Materials and methods

4.1. Description of the area of study

The study was conducted in the Gulu district (Figure 2). The district is located in Northern Uganda, with latitudes and longitudes of 2.8186° N and 32.4467° E, respectively, having an elevation of 1,100 m (UBOS, 2017, 2018c, 2018a). The district has four Parishes and 35 villages. In terms of population, Gulu district has a total of 326,600 people, mainly composed of Acholi tribe (UBOS, 2020). It covers 1,872 km^2, with its

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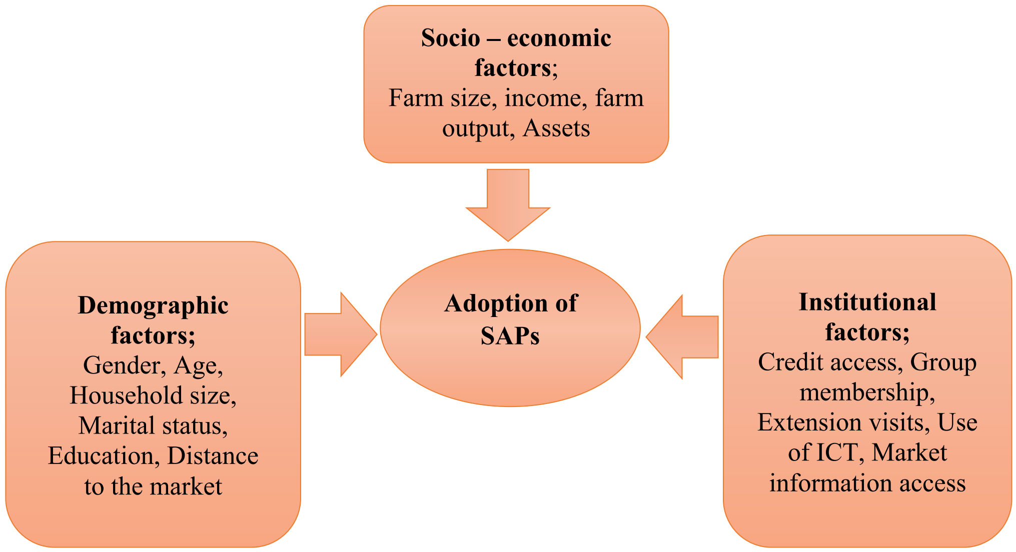

Figure 1. Conceptual framework.

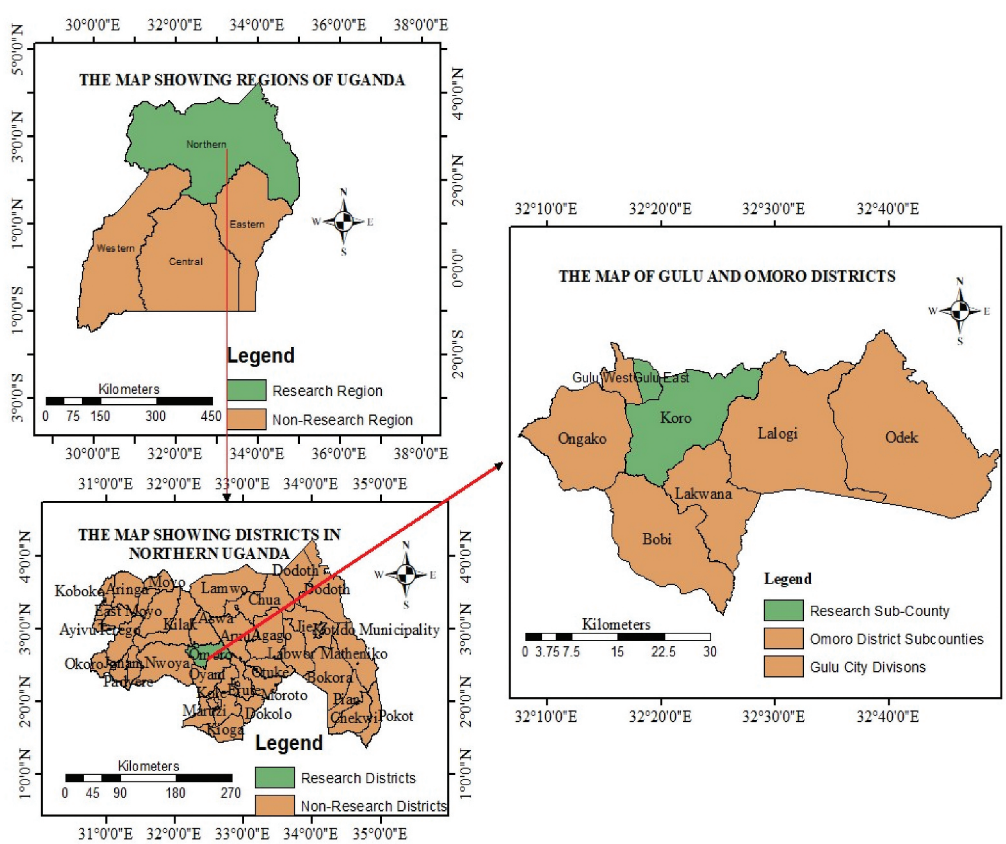

Figure 2. Study area.

headquarters in Gulu Town, which is surrounded by intensive agricultural activities (UBOS, 2018b). Gulu district was selected for this study because of the low maize productivity reported in the area (MAAIF, 2017, 2020). In addition, the high population of 325,600 people in Gulu district calls for more food production in this district. As such, it requires more studies to boost food production (UBOS, 2018b). Lastly, the reason for the purposive selection of Northern Uganda for this study is due to the fact that 70–80% of its population live below the poverty line, hence there are high levels of food insecurity and malnutrition (UBOS, 2017, 2018c, 2018a). In terms of economic activity, subsistence agriculture is the dominant source of livelihood for the majority of the population. The farmers depend on a small portion of land which is on averagely less than 2 ha and mainly composed of sandy soils (Atube et al., 2021). Massive investment in agriculture in Gulu is made possible by the rain that starts from March to November, mainly unimodal. However, the peak rainfall month is May, with the rains going up to 5.6 inches. It has a high temperature which can go as high as 40°C (MAAIF, 2020). Farmers produce both food (maize, cassava, beans, nuts) and cash (cotton, tobacco, bananas, sugarcane) crops, mainly under rain-fed agriculture in Gulu district. Food crops are mainly produced for consumption, while cash crops play income generation roles.

4.2. Sampling and sample size

Multistage and random sampling approaches were adopted in the study. Multistage sampling was preferred because it allows researchers to easily and promptly collect data from respondents (Kaliba et al., 2021; Obisesan, 2014; Ray, 2020; Sedgwick, 2015). In the first stage, Northern region of Uganda was purposively considered for the study due to the high temperatures which can go as high as 40°C (Uganda Bureau of Statistics (UBOS), 2022). We then narrowed to Gulu district in the second stage due to lots of agricultural activities in the area including cash and food crop production, agricultural advisory services, livestock production, among others (MAAIF, 2020). Due to the high number of maize farmers (target respondents), Pece, Laroh, Bobi, and Awach villages were finally sampled for the study. Since the farmers were located deep in the villages, we obtained a sampling frame (Table 1) from the district production officer. The list consisted of all farmers, their locations, and contacts for easy access. Farmers were then given equal chances of participating in the study without biasness of any kind (Arnab, 2017). We began our data collection at Pece, followed by Laroh. Bobi and Awach were the last. During data collection, all ethical considerations were well taken care of. A total of 101 farmers were sampled using Cochran's (1963) formula which is illustrated below. P being the population proportion, Z represents 95% confidence level (1.96), while e is the error term.

$$n = \frac{Z^2 P(1-P)}{e^2}$$

4.3. Data sources

We developed a data collection tool for this study. The study tool was pretested in Lira district to ascertain its validity, reliability, and relevance (Hilton, 2017). After the pretest, some questions were reordered while others were removed from the tool. The tool was then sent to the Gulu University Head of Department to ascertain that it captured all the variables adequately. The data from pretesting were used to adjust the tool but not for the study. Primary data were then collected from the maize farmers using the adjusted tool. The tool comprised of three sections. Section A captured farmers' socio-demographic characteristics such as age, gender, education level, farm size, and household size. Section B covered variables related to SAP adoption. The last section captured the variables on farm inputs and output. Open interviews were conducted for data collection with the help of research assistants. However, from pretesting, we realized that the majority of the farmers had difficulties in reading and writing, and as such, the research assistants asked the questions and recorded the responses accurately. The data were then entered into the SPSS template, cleaned, and exported to Stata version 15 for analysis.

Table 1. Sampling frame

Villages	Sampled farmers
Laroh	25
Pece	25
Bobi	25
Awach	26

4.4. Econometric analysis

The adoption index (AI), recommended and used by Kenamu and Maguza-tembo (2016), Ogada et al. (2014), and Takahashi et al. (2020), was used to determine the adoption intensity of SAPs among smallholder farmers. The practices considered included hybrid seeds, inorganic fertilizers, pesticides, cover crops, mulching, crop rotation, post-harvest handling, and spacing. While there are other significant SAPs, these ones play significant roles in crop production (Arslan et al., 2014; E. O. Acheampong et al., 2021). A farmer would be considered as a full adopter if he adopts all the eight practices, hence scoring 100%. A medium adoption is when the farmer adopts four of the eight practices, scoring 50%. Adoption Index has been widely used in studies where the number of technologies considered in the study are many. Mwaura et al. (2021) used it to determine the adoption intensity of soil fertility management practices in Kenya, Kwawu et al. (2021) applied adoption index to determine the adoption intensity of agricultural technologies in Ghana, while Ketema and Kebede (2017) applied adoption index to estimate adoption intensity of inorganic fertilizers in Ethiopia. A simple adoption index formula is presented below.

$$Adoption\ Index(AI) = \frac{Total\ number\ of\ practices\ adopted\ by\ the\ farmer}{Total\ number\ of\ practices\ in\ the\ package}$$

After determining the adoption intensity above, Tobit regression model, developed by Tobin (1958), was then used to explain the relationship between the hypothesized factors affecting the adoption of SAPs and adoption intensity. This is because the dependent variable was in the form of percentages with lower and upper limits. Based on the literature presented by Danso-Abbeam et al. (2017) and Tipi et al. (2009), the Tobit model is suitable for handling dependent variables with lower and upper limits. Other studies that adopted the Tobit model in agriculture include Chune et al. (2022), Hakim et al. (2021), Kalinda et al. (2014), Ketema and Kebede (2017), and Mekuria and Mekonnen (2018), and Namome (2018), and Tipi et al. (2010). Table 2 presents the independent variables for the study. The tobit model is specified in the Equation below:

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

Subject to:

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

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

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

Where;

AI = Adoption intensity; X_i is a vector of explanatory variables that can potentially influence adoption intensity (Table 2). β_i is a vector of parameter coefficients associated with the explanatory variables and U_i is the error term.

5. Results and discussion

5.1. Socio-demographic characteristics of the farmers

Table 3 presents the socio-demographic characteristics of the maize farmers. Based on the results, the mean age of the farmers was 40.25 years, implying that the majority of the farmers were in the active age of production where they could adopt as many SAPs as possible. Farmers spent a mean of 7 years in school, implying that the majority had not attained post-secondary education level. In terms of family size, farmers reported a mean of six household members per household. This indicates that farmers should adopt SAPs to increase maize productivity and provide food for their families. The results further showed that the farmers were located 4 km away from the trading areas. Being that they were located near the trading areas, accessing farm inputs and output was easy for them. The

Table 2. Independent variables

Independent variable	Measurement	Description
Maize yield	Kilograms	Farmers who report high yield are encouraged to adopt SAPs more than their fellows with low yield
Gender	1—Male, 0—Otherwise	Male farmers adopt the SAPs easily than their female counterparts
Household size	Number	Large households focus on food purchase hence low adoption rate than small households
Farm size	Acres	Farm size increases the adoption rate due to the commercialization
Access to credit	1—Has access, 0—Otherwise	Credit helps in purchasing fertilizers, pesticides which increases the adoption rate
Access to extension	1—Has access, 0—Otherwise	Farmers with access to extension adopt the SAPs easily than their counterparts.
Access to market info	1—Access, 0—Otherwise	Farmers who have access to market information adopt SAPs easily than their counterparts
Group membership	1—Member, 0—Otherwise	Group members share ideas on adoption of SAPs, hence increases the adoption rate
Education level	1—Secondary, 0—Otherwise 1—Tertiary, 0—Otherwise	Highly educated farmers adopt SAPs more than farmers with low education levels.
ICT use Market distance Farm income	1—Yes, 0—Otherwise Kilometers Ugandan Shillings	Farmers who use ICT access adoption information easily, hence higher adoption rate. Farmers located near the trading areas have higher chances of adopting SAPs Farm income increases adoption of SAPs

Table 3. Socio-demographic characteristics of the farmers

Variables	Mean	Standard deviation	Min	Max
Continuous variables				
Age	40.25	10.95	22	58
Education	7.30	3.35	5	12
Household size	5.84	3.50	1	10
Market distance	3.89	1.76	0.25	10
Experience	13.09	10.25	1	25
Farm size	5.32	2.05	0.25	10
Dummy variables				
Male	0.54	0.25	0	1
Credit access	0.60	0.15	0	1
Extension access	0.88	0.34	0	1
Group member	0.70	0.45	0	1
Access to market information ICT use in farming Non-farm income	0.95 0.64 0.62	0.32 0.48 0.48	0 0 0	1 1 1

Table 4. SAPs and their adoption frequency

SAPs practices	Frequency (F)	Percentage (%)	Major reasons for adoption
Hybrid seeds	68	67.33	Improve farm yield
Recommended spacing	76	75.25	Improves crop productivity
Pesticides	48	47.25	Destroy pests infestation
Inorganic fertilizers	45	44.55	Increase soil fertility
Cover crops	25	24.75	Prevent run off while preserving the soil
Mulching	56	55.44	Retains soils moisture
Crop rotation	54	53.46	Prevents pests build up
Post-Harvest handling	23	22.77	Reduces Post-Harvest Losses

mean years of experience among the farmers stood at 13.0 years, implying that the majority of the farmers were well experienced in farming, and thus, the adoption of SAPs is expected to be high. In terms of farm size under maize production, the farmers depended on 5.32 acres of land. The results further showed that 54% of the respondents were males. In terms of institutional arrangements, the majority of the farmers had access to credit (60%), extension services (88%), and market information (95%). The majority of the farmers (64%) used ICT in farming. These included use of smartphones in accessing farming information such as farm inputs, weather, and market prices, among others.

5.2. SAPs adopted by the farmers and their frequencies

Table 4 presents the results of the adoption of SAPs. The results indicate that hybrid seeds were adopted by 67.33% of the farmers. More than 75% of the farmers applied the recommended spacing in maize production, this may be closely attributed to the roles of extension agents in training the farmers on spacing (Abdallah & Abdul-Rahaman, 2019). In terms of pesticide use, only 47.25% of the farmers used pesticides in maize production. Strikingly, only 44.55% of farmers adopted inorganic fertilizers. This may be attributed to the high cost of fertilizers, which prevented many farmers from its adoption, as reported by Bayite-kasule (2005), Heijnen et al. (2013), Ketema and Kebede (2017), and Tubert-Brohman et al. (2013), and Sinyolo and Mudhara (2018). In their study, they reported that one of the major limitations to the adoption of fertilizer is its high cost, especially in SSA. Mulching and cover crops were adopted by 55.44% and 24.75% of farmers, respectively. Lastly, crop rotation and post-harvest handling practices attracted only 53.46% and 22.77% of farmers, respectively. These results are in line with the findings of Oyetunde-Usman et al. (2021), who reported high adoption of inorganic fertilizers (80%) and mixed cropping (77.0%) and low adoption of improved seeds (14%) and organic manure (49%). Similarly, very low adoption of agricultural technologies was recorded by Amankwah (2023) in Nigeria. He noted low adoption of improved seeds (9%), inorganic fertilizer (43%), and organic fertilizer (43%). Other studies with similar state of adoption of SAPs include Hu et al. (2022), Jin et al. (2022), and Pham et al. (2021). Based on these results, it is clear that the adoption rate was above average. However, many interventions are still needed to increase it to full adoption.

5.3. Adoption intensity of SAPs

Adoption intensity refers to the level of use of the SAPs. Determining the adoption intensity of the SAPs is highly significant in addressing the problems of decreasing maize productivity in SSA. The adoption intensity of the maize farmers is presented in Table 5. The results show that the adoption intensity stood at 70%, which is a good rate. However, farmers need to adopt all SAPs to achieve full adoption. In terms of distribution, 23% of the farmers scored up to a 50% adoption intensity. The majority of farmers operated between 0.50 and 0.70 adoption intensity, while only 20.8% of the farmers had an above 0.91 adoption intensity. The minimum and maximum adoption intensities are 0 and 1,

Table 5. Adoption intensity of SAPs			
Intensity range (0–1)	**Frequency (N)**	**Percentage (%)**	**Cumulative frequency**
<0.50	23	22.77	22.77
0.50–0.60 0.61–0.70 0.71–0.80	25 20 5	24.75 19.80 4.95	47.52 67.32 72.27
0.81–0.90	7	6.93	79.20
>0.91	21	20.80	100.00
Mean adoption intensity	0.70		
Min	0		
Max	1		

respectively, implying that there were full adopters as well as farmers who did not adopt any of the practices. The adoption intensity reported in this study is in line with the findings of Mwaura et al. (2021), who reported that 78% adoption intensity among smallholder farmers in Kenya. In Ghana, Bilaliib Udimal et al. (2017) also reported that farmers do not adopt all practices, leading to sub-optimal levels of crop productivity. Low adoption was also reported in the studies conducted by Baglan et al. (2020), Donkoh and Awuni (2015), Prokopy et al. (2019), and Workineh et al. (2020). In their studies, these scholars noted above average adoption intensity of agricultural technologies. They attributed the low adoption of the technologies to information asymmetry and high input costs.

5.4. Multicollinearity and other test results

A multicollinearity test was conducted to ensure that the independent variables included in Tobit model were not correlated with each other. According to Akinwande et al. (2015), Sinyolo and Mudhara (2018), Nagawa et al. (2020), and Opolot et al. (2018), and Ouko et al. (2022), the acceptable VIF should not be less than 1 and not more than 10. As presented in Table 6, the least VIF was 1.07, while the highest is 1.72. Similarly, the mean VIF was 1.32. The variables which had coefficient higher than 10 were dropped, hence leading us to consider 10 independent variables which met the accepted VIF threshold (Table 6). As shown in Table 6, OV (omitted variables) test was also conducted to ensure that there was no

Table 6. VIF and other pre-estimation test results		
Explanatory variables	**VIF**	**1/VIF**
Education (Secondary)	1.08	0.927
Education (Tertiary)	1.29	0.773
Household size	1.09	0.918
Farm size	1.36	0.735
ICT use	1.08	0.921
Market info access	1.27	0.787
Group membership	1.72	0.581
Extension visits	1.60	0.623
Credit	1.61	0.620
Maize harvest	1.07	0.936
Mean VIF	**1.32**	
Other tests		
OV test Prob > F	0.7868	
Cook-Weisberg test Prob > F	0.3343	

Table 7. Determinants of adoption of SAPs

Explanatory variables	Coefficients	Standard errors	P-value	Conditional marginal effects
Education (Secondary)	−0.032	0.103	0.756	−0.032
Education (Tertiary)	0.238	0.108	0.031**	0.222**
Household size	−0.180	0.082	0.032**	−0.167**
Farm size	0.191	0.069	0.007***	0.178***
ICT use	0.179	0.080	0.028**	0.167**
Market info access	0.278	0.105	0.010***	0.259***
Group membership	0.080	0.087	0.358	0.074
Extension visits	0.272	0.116	0.021**	0.253**
Credit	0.182	0.112	0.100*	0.170*
Maize harvest	0.025	0.029	0.382	0.023
Constant	−1.108	0.316	0.000***	-
Model fit				
Prob>F	0.000			
Pseudo R^2	0.34			
Observations	101			
Significance levels	****,**,*** signifies significance at 10, 5 and 1% respectively***			

omission of explanatory variables. The insignificant value of 0.786 indicates that there was no omission of variables. Similarly, we tested for the presence of heteroscedasticity in the data. The results from the Cook–Weisberg test indicated an insignificant value of 0.334, which implies that there was no heteroscedasticity. Having met the threshold, indicating the absence of multicollinearity among independent variables, heteroscedasticity, and omission of variables, the study then proceeded to present the results of the determinants of adoption of SAPs.

5.5. Determinants of adoption of SAPs

The determinants of SAP adoption are presented in Table 7. Understanding the determinants of SAPs adoption is important for guiding policymakers on relevant policies that increase the rate of adoption of agricultural technologies. The variable education was categorized into tertiary and secondary education levels. At the secondary level, the coefficient is negative, but statistically insignificant. However, as the level of education proceeds to tertiary, the magnitude and coefficient changes and becomes positive and significant at the 5% level. This implies that education has a positive and significant effect on the adoption of SAPs, as hypothesized based on literature review. The positive effect of education on adoption of SAPs is attributed to the skills, knowledge, and networking earned in school. As such, educated farmers have more skills and networks than non-educated ones, leading to high adoption of the SAPs. Paltasingh (2016) found out that education has a positive and significant relationship with the adoption of agricultural technologies. Feyisa (2020) also noted a positive effect of education on technology adoption in Ethiopia. In India, Paltasingh and Goyari (2018) found increased adoption of modern agricultural technologies among highly educated farmers than non - educated farmers. However, a study by Bilaliib Udimal et al. (2017) indicated that highly educated farmers tend to be left behind in terms of adoption of agricultural technologies in Ghana.

The number of family members had a negative and significant ($P < 0.05$) effect on the adoption of SAPs. Larger families tend to over-concentrate on food purchases more than adoption of SAPs. Therefore, they end up apportioning their finances on food and school fee payments, among others. In the long run, they are left with little finances to purchase agricultural technologies. This results into low funds for purchasing hybrid seeds, fertilizers, and pesticides. Additionally, as the number of family members increases, the dependency ratio also increases, resulting into apportion of finances to household needs rather than adoption of technologies. This agrees with the findings of Massresha et al. (2021a), who pointed out that as the number of family members increases in a household, the rate of adoption of modern technologies declines. Also, in Ethiopia, Zegeye, Fikire et al. (2022) reported a negative effect of family size on technology adoption, attributed to food purchase. This, however, disagrees with the findings of Lemma and Degefa (2023), who reported that family size had a positive but insignificant influence on the adoption of improved agricultural technologies in Nigeria.

Most farmers with large land sizes are mainly commercial farmers, hence they mainly produce maize for sale. These farmers are driven by profit maximization. As such, they seek ways to increase their farm income. This involves adoption of SAPs in order to maximize their farm income. Therefore, the adoption rate is significantly higher among farmers who have large portions of land than their counterparts who have small land acreage. This is consistent with the findings of Kwawu et al. (2021), who reported a 3% higher probability of technology adoption among farmers with large portions of land than those with small acreage in Ghana. In the United Kingdom, Feliciano (2022) noted that having large portions of land increases the rate of adoption of agricultural technologies. This was also reported in the studies conducted by Wordofa et al. (2021). Contrary to this, Anang (2019), in his study on adoption of technologies using Probit model, reported that farm size has a negative effect on adoption of agricultural technologies in Ghana. They illustrated that farmers with large portions of land tend to incur high cost of adoption of the SAPs practices.

There was a positive and significant ($P < 0.05$) effect of ICT use on the adoption of the SAPs considered in this study. Farmers who used ICT in farming, such as smartphones and computers, had a 17% higher probability of adopting SAPs than their counterparts who did not use ICTfor maize production. This may have been attributed to easy access to farming information (Perosa et al., 2021), including the SAPs available to them, as reported by Awuor and Rambim (2022). A similar observation was reported in the relationship between access to market information and the adoption of SAPs. It is easier for farmers with access to market information to adopt SAPs than their counterparts. Perosa et al. (2021) assessed the effect of market information on the adoption of agricultural technologies in Brazil and reported that ICT use and market information access indeed increase the adoption of agricultural technologies. In Ghana, Kwawu et al. (2021) assessed the covariates responsible for the adoption of SAPs, and their findings depicted that the use of smartphones as an ICT tool increases the adoption of technologies by 8%. Roztocki et al. (2019) also illustrated that one of the roles of ICT in socio-economic development is helping farmers to access information on the existence of new agricultural technologies for adoption. As such, there is a higher adoption rate among farmers who use ICT in farming than their counterparts.

Similarly, extension visits ($P < 0.05$) and credit access ($P < 0.10$) had positive and significant effect on the adoption of SAPs by 5% and 10%, respectively. Extension access serves as a training and mentorship avenue to smallholder farmers, while credit access increases the purchasing power of farmers, resulting in higher adoption of SAPs such as pesticides, hybrid seeds, and inorganic fertilizers. Unlike recommended spacing, cover cropping, crop rotation, and mulching, these practices (hybrid seeds, fertilizers, and inorganic fertilizers) require capital to purchase. As a result, the adoption of SAPs is highly evident among farmers who have access to credit than those who do not have access to credit. These results agree with the findings of Makate et al. (2019), who reported a positive effect of credit access on the adoption of climate smart agriculture in Africa. Similarly, Makate et al. (2019) reported that access to agricultural extension significantly improves technology adoption. Danso-Abbeam et al. (2017) analyzed the factors responsible for the adoption of improved and local varieties of maize in Ghana. Their findings reveal that extension visits and credit increase the probability of adopting both the improved and local maize varieties in Ghana. Similarly results were also reported in a study conducted in Ethiopia by Feyisa (2020). From her results, it is evident that extension visits and credit access increase adoption of SAPs by 23% and 13%, respectively.

6. Conclusion

The growing population, especially in SSA, signals future food crisis. However, such foods are sourced from agricultural production. Maize is dependent on by many households as a major source of calorie. It also generates income for most smallholder farmers as well as boosting the GPD of SSA economies. However, its declining productivity, which is closely attributed to the low adoption of agricultural technologies, signals food insecurity and poor living standards among smallholder farmers. It is estimated that if farmers continue to report sub-optimal maize yields, there will be many cases of malnutrition and poor living standards among farmers by the year 2030. The study therefore aimed at developing relevant policy recommendations that would help increase the adoption of sustainable agricultural practices, which, in the long run, would increase maize yield. To achieve this, the study's first objective was to determine the current level of adoption of SAPs. The results indicate that the mean adoption intensity was 70%. This implies that, even though the rate is above average, many interventions are still needed to boost it to full adoption level. From this objective, the study concluded that adoption of SAPs is above average but still needs to be improved to reach full adoption. The second objective was to assess the determinants of SAPs adoption. Based on the results, the study concluded that education, farm size, ICT use, market information access, extension visits, and credit access increase the rate of adoption of SAPs, while household size reduces the rate of adoption of SAPs. In general, the study concluded that the adoption of sustainable agricultural practices is much above average and that different covariates affect the adoption positively and negatively as shown in the results section.

6.1. Policy recommendations

(1) Strengthening adult literacy programs will help increase reasoning levels among farmers and result in the increased adoption of SAPs. This is a result of the positive influence of education on SAPs adoption.

(2) Extension agents should advise farmers to purchase ICT-related gargets such as smartphones and use them to obtain agricultural information such as the adoption of agricultural practices, weather, and market information, among others. This ensures that the majority of the farmers are aware of where they can access SAPs easily.

(3) Extension visits reported a significant effect on the adoption of SAPs, which is based on the finding that extension workers should increase the rate of their visits to farmers. Similarly, farmers should supplement this by watching agricultural shows on television and radio that offer extension programs.

(4) Farmers should target financial institutions offering agricultural loans at low interest rates. They need to apportion such loans to purchase of pesticides, fertilizers, and hybrid seeds. This will increase the adoption rate of agricultural technologies and increase the maize yield.

(5) Subsidizing farm inputs such as fertilizers, hybrid seeds, and agro-chemicals would increase the rate of adoption of these practices.

(6) Sub-Saharan African countries should employ more extension officers to reach even those farmers who are located deep in the villages, train them on the adoption of SAPs, and follow up continuously.

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