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Adoption of sustainable agricultural intensification practices: assessing the role of institutional and socio-economic factors amongst smallholder farmers

Enos Katya Kule[a], David Agole[b], Alfred Obia[c], Daniel Micheal Okello[d] and Walter Odongo[a,e]

[a]Department of Rural Development and Agribusiness, Faculty of Agriculture and Environment, Gulu University, Gulu, Uganda; [b]Department of Agricultural Extension and Community Engagement, Faculty of Agriculture and Environmental Sciences, Mountains of the Moon University, Fort-Portal, Uganda; [c]Department of Agronomy, Faculty of Agriculture and Environment, Gulu University, Gulu, Uganda; [d]Department of Agri-Business and Natural Resource Economics, Faculty of Agricultural Sciences, Kabale University, Kabale, Uganda; [e]Nabuin Zonal Agricultural Research and Development Institute, National Agricultural Research Organisation, Moroto, Uganda

ABSTRACT

Sustainable agricultural intensification practices (SAIPs) are highly recommended for smallholder farmers due to their positive impact on farm production and productivity. However, farmers remain reluctant to adopt SAIPs resulting in low agricultural productivity in Uganda. This study assessed the institutional and socio-economic factors affecting the adoption and adoption intensity of SAIPs amongst smallholder maize farmers in Eastern Uganda. Primary data were collected from 320 maize farmers in Kamuli and Jinja districts using a pretested questionnaire. The binomial logistic and generalized Poisson regression models were used to compute the predictor variables of adoption and adoption intensity of SAIPs respectively. Results showed that improved maize varieties, conservation tillage, legume intercrop, integrated soil fertility management (ISFM), and integrated pest management (IPM) were adopted by 58, 36, 44, 52, and 56% of the farmers. Institutional factors i.e., group membership, access to all-weather roads, credit, and extension information were the significant predictors of the adoption and the adoption intensity of SAIPs. Socio-economic factors i.e., market-oriented farming influenced both the adoption and adoption intensity of SAIPs, age of family head, family labour use, household size, and dependence ratio, only positively influenced the adoption intensity of adoption of SAIPs. The policy implications of this study include the need to strengthen agricultural extension institutions and streamline extension information disseminated to farmers to enhance the adoption of SAIPs. Farmers should be advised to utilize cheap credit services such as village savings and loan associations to facilitate the adoption of SAIPs.

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Introduction

Low agricultural productivity has been reported as the main cause of food insecurity amongst smallholder farmers in Sub-Saharan Africa (SSA) (Binswanger-Mkhize & Mccalla, 2008; Djoumessi, 2021). The declining agricultural productivity has been compounded by the use of inferior agriculture technologies, and land degradation due to the limited application of soil amendments, as well as the effects of climate change (Atube et al., 2021; Liu, 2023; Mucheru-Muna et al., 2014). Low agricultural productivity is further exacerbated by the rapidly increasing population that catalyzes a steady decline in farm sizes rendering smallholder farmers incapable of producing sufficient food to meet their household needs (Pretty, 2019). Analysis of the extent of land gradation in SSA shows that it affects 65% of the total arable land (Lakew

CONTACT Enos Katya Kule enosk78@gmail.com Department of Rural Development and Agribusiness, Faculty of Agriculture and Environment, Gulu University, Gulu, Uganda.

et al., 2024). Hence, swift action should be taken to mitigate low agricultural productivity due to land degradation.

Erisman et al. (2008) argue that SAIPs could quickly reverse agricultural productivity shortfalls if widely adopted by farmers. This is because SAIPs such as conservation tillage preserve the natural environment (Adolph et al., 2021; Mahama et al., 2020; Pretty, 2019). Additionally, most SAIPs are generated from locally available materials or by combining local and synthetic materials, which makes them more affordable than most synthetic inputs (Woelcke, 2006). SAIPs such as crop residues, intercropping, agroforestry, improved crop varieties, crop rotation, cover crops, intercropping, and integrated pest management (Kule et al., 2023), can sustainably conserve water and soils on farms, reduce pests and disease prevalence, and ensure sustained agricultural productivity (FAO, 2005; Sanchez, 2015; Tittonell, 2014; Zhao et al., 2008).

Therefore, the adoption of SAIPs is critical for agricultural productivity improvement (Ghimire et al., 2015; Jayne et al., 2019; Xie et al., 2019). According to Kuyah et al. (2021), cases of positive impact of SAIPs on crop production and productivity have been reported in Kenya, involving intercropping maize with pigeon peas which generated higher yields 2.67 tons/ha) compared to maize monocrops (2.46 tons/ha). Also in Burkina Faso, Niger, and Mali, on-farm experiments involving the use of fertilizer-manure micro dosing have reported higher grain yield of millet and sorghum (44–120%) compared with other farm soil fertility replenishing practices (FAdepoju, 2022). Additionally, positive experiences with the uptake of organic fertilizers have been reported among Southeast Asian countries including preventing soil degradation, conserving farm biodiversity, and enhancing farmers' livelihoods (Chang et al., 2024).

Despite the benefits associated with the adoption of SAIPs, such as enhancing crop productivity, and smallholder farmers' earnings (Piñeiro et al., 2020; Pretty, 2019; Pretty et al., 2011), the rate and intensity of their adoption in the smallholder farmer context in Uganda has been under-researched (Ngongalah et al., 2018). Limited studies conducted in Uganda on the extent of adoption of SAIPs by smallholder farmers indicate that their adoption is low, culminating in low crop productivity. For instance, Ekepu and Tirivanhu (2016) Ochago (2018). Ekepu and Tirivanhu (2016) conducted a study in the Soroti district, eastern Uganda, on the adoption of legume intercropping in sorghum production and found that only 8.3% of the respondents had intercropped sorghum with legumes. Ochago (2018) researched the uptake of IPM practices in the control of the Coffee Stem Borer pest on Mount Elgon, Uganda, and found that only 36% of the coffee farmers had adopted the practice. However, these studies were narrow in scope. They did not address the extent of adoption of multiple SAIPs as has been addressed in this research.

Existing empirical studies conducted in developing countries suggest that institutional and socio-economic factors are the major drivers of agricultural technology adoption (Fikirie, 2021; Mutyasira et al., 2018; Ochago, 2018; Omara et al., 2021; Sebatta et al., 2019; Tadesse et al., 2020; Tiamiyu et al., 2009; Urgessa Waktola & Fekadu, 2021). However, results on predictors of adoption are inconsistent across different countries and regions (Anang et al., 2020; Mahama et al., 2020; Nankya et al., 2017). For instance, a meta-analysis of the factors affecting the uptake of agricultural intensification techniques in Africa by Tey and Brindal (2024) revealed that socio-economic factors including gender, and level of education were the key determinates of technology adoption. A review of factors affecting the uptake of sustainable agricultural practices used in rice production in Southeast Asia countries by Chang et al. (2024) revealed that socio-economic factors (age, level of education, farm size, and land ownership) and institutional factors(access to credit, extension services) positively affected the uptake of agricultural practices. From the two studies, it can be observed that the determinants of adoption and adoption intensity vary across different regions. Hence the need to assess area-specific determinants of adoption (Anang et al., 2020).

Additionally, most studies on agricultural technology adoption have centered on adoption per se, with very few focusing on the adoption intensity (Awuni, 2018; Misango et al., 2022; Oyetunde-Usman et al., 2021). To boost agricultural production and productivity in Uganda, it is imperative to discern the extent, and the socio-economic and institutional drivers of adoption and adoption intensity of SAIPs. This article assessed the role of institutional and socio-economic factors on the adoption and adoption intensity of SAIPs amongst smallholder maize farmers. Specifically, this research answered the understated questions: (i) What are the institutional factors influencing the adoption and adoption intensity of SAIPs among smallholder maize farmers? (ii) What are the socio-economic factors affecting adoption and adoption intensity of SAIPs? This research contributes to the understanding of the role of institutional and socio-economic factors in influencing the adoption and adoption intensity of SAIPs among smallholder farmers. Information in this article can assist the government and development partners in putting in place appropriate institutions that can be used to facilitate the adoption of SAIPs by smallholder farmers to improve agricultural productivity. Additionally, information in this article can be used by policymakers to develop agricultural policies that are pro-smallholder farmers.

The subsequent sections of this article are structured as follows; the succeeding section describes the theoretical framework on which the research is anchored, the conceptual framework, followed by the methodology, results presentation, discussions, conclusion, policy implications, and recommendations for future research.

Theoretical perspectives

To understand the role of institutional and socio-economic factors on the adoption and adoption intensity of SAIPs, we anchor this article on the utility maximization theory (UMT). The UMT suggests that an individual will embrace technology if there is a perceived increase in utility arising from using such a technology, amidst a set of socioeconomic, and institutional factors (Alvino et al., 2018; Ghimire et al., 2015; Mugonola et al., 2013). Consequently, a smallholder farmer's adoption of SAIPs is realized if the perceived utility outweighs the alternatives. In practice, it is not possible to directly measure the perceived utility. Hence perceived utility is presumed to be directly associated with the socio-economic and institutional drivers under investigation (Rebecca et al., 2018). In this article, institutional and socio-economic factors are seen as the constraints to the adoption and adoption intensity of SAIPs. The UMT is therefore appropriate for this study since it explains farmers' choice for adoption and adoption intensity of SAIPs from the institutional and socio-economic perspectives.

Adoption, defined as the decision to take up an agricultural practice (Feder et al., 1985), is an essential prerequisite for economic development in less developed countries (Burhanuddin et al., 2009). According to Feder et al. (1985), Massresha et al. (2021), and Simtowe et al. (2016), the decision to embrace or reject an agricultural practice is not an instant occurrence. Adoption is a process that begins with potential adopters becoming aware that a particular practice exists. This phase is followed by a critical analysis of the agricultural practice's attributes by the potential adopter including but not limited to ease of use, cost, and benefits. Thirdly, a trial or experimentation with the new agricultural practice is done by the potential adopter. Depending on the actual benefits that the adopter experiences with the practice, after taking it up, a decision to embrace or reject the agricultural practice can then be taken (Feder et al., 1985).

Scholars have classified determinants of adoption and adoption intensity into different themes. For example, Polar et al. (2017) categorized drivers of adoption as; internal drivers such as age and experience; external drivers such as farmers' access to credit, insurance, and extension advisory services; and technological attributes such as cost, benefits, and risk. Omara et al. (2021) grouped drivers of adoption into; farmers' perceptions, institutional and socioeconomic. Scholars (Atube et al., 2021; Fikirie, 2021; Mogaka et al., 2021; Urgessa Waktola & Fekadu, 2021) argue that the adoption of agricultural practices is strongly influenced by the socio-economic properties of smallholder farmers. Similarly, Alexis et al. (2021), Mahama et al. (2020), Okello et al. (2022) and Sheikh et al. (2022) assert that institutional factors such as access to extension services, market, credit, and group membership influence the adoption and adoption intensity of agricultural practices by smallholder farmers. Consequently, this study categorizes the factors affecting adoption and adoption intensity into institutional and socio-economic as illustrated in the conceptual framework (Figure 1).

Conceptual framework

The conceptual framework portrays the association between the outcome variables (adoption, and adoption intensity of SAIPs), and the predictor variables (institutional and socio-economic factors). Consequently, this study categorizes the factors affecting adoption and adoption intensity into institutional and socio-economic as illustrated in the conceptual framework (Figure 1). Particularly, the research assessed socio-economic factors (land ownership, land tenure system, size of land owned by the household, size of land allocated to maize production, labour use, household size, age, gender, household size, number of

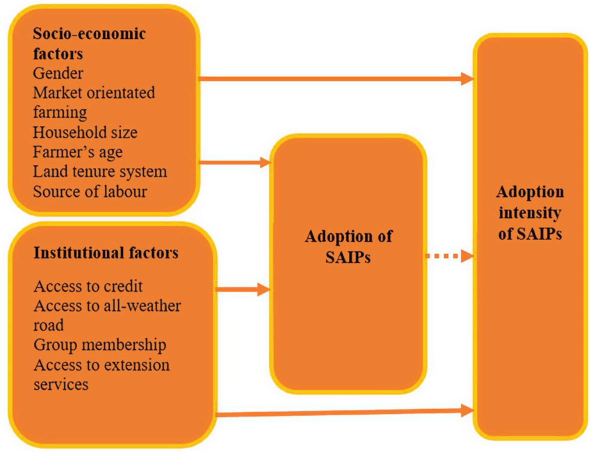

Figure 1. Conceptual framework: Modified from Alvino et al. (2018) and Atube et al. (2021).

dependents in the household, and market-orientated maize farming), and institutional factors (access to extension services, credit, group membership, and distance to all-weather road). The predictor variables are assumed to affect the resultant variables. Hence, the outcome variables are adoption and adoption intensity of SAIPs. The predictor variables are the socio-economic (land ownership, land tenure system, size of land owned by the household, size of land allocated to maize production, labour use, household size, age, gender, household size, number of dependents in the household, and market-orientated farming) and institutional factors (access to extension services, credit, group membership, and distance to the all-weather road).

Methodology

Study context

This study was conducted in the districts of Jinja and Kamuli in eastern, Uganda. Agriculture is the main source of livelihood in the two districts, with smallholders forming the largest majority of farmers. Crop yields in the area have declined to below a third of the yields at the national research stations mainly due to land degradation (Pender & Ehui, 2006). Land degradation has been exacerbated by land fragmentation and continuous cultivation, resulting in low crop productivity (Midamba et al., 2024). For example, maize productivity in Jinja and Kamuli districts stands at 2.5 metric tons per hectare contrary to the potential yield of 8 million metric tons at the national agricultural research centers in Uganda (Jjagwe et al., 2020).

To improve crop productivity in the area, One Acre Fund (1AF), a Non-Governmental Organization (NGO has promoted SAIPs using maize as a pilot crop for over a decade. The choice of maize as a pilot crop for productivity enhancement was because, it is a staple and source of income for close to 78% of farmers in the country (Epule et al., 2021). The 1AF maize project involved the promotion of numerous SAIPs including; legume intercrop, ISFM, conservation tillage, IPM, improved maize seeds, agroforestry, etc., as independent practices. A maize farmer had the leverage to decide on what SAIP to take up or reject depending on the farm's needs and the farmer's socio-economic situation (Kule et al., 2023). Farmers were trained by 1AF extension agents on the specific details of each SAIP. Aspects of the training included; SAIPs 'cost, benefits, and risk if any, and how and when to apply the practice on the farm. This enabled a farmer to scrutinize each SAIP independently and make an informed decision on whether to embrace or reject it. In this research, a farmer's adoption of a SAIP is treated as an independent binary decision. This is because every farm has unique challenges that require different solutions at the various stages of maize production (Mahama et al., 2020; Okello et al., 2022).

Sampling design

This study employed a cross-sectional survey research design (Ishtiaq, 2019; Kule et al., 2023) to gather information from 320 smallholder maize farmers on SAIPs adoption and their adoption intensity. A multi-stage sampling technique was employed to arrive at the study respondents. In the first step, Jinja and Kamuli districts were purposively selected for the study. The two districts were selected for the research because maize was the dominant crop grown in the area. In addition, the two districts have benefitted from 1AF intervention in improving maize productivity among smallholder maize farmers. For instance, 1AF has provided inputs, trained farmers, and established demonstration gardens. In the second step, Butansi and Kitayunjwa out of 14 sub-counties in Kamuli district, and Buwenge and Butayaga out of 11 sub-counties in Jinja district were purposively chosen for the research. These four sub-counties were selected for the research because they produce more maize than other sub-counties in the two districts. In addition, IAF had actively promoted the adoption of SAIPs in these sub-counties.

To avert bias in the research participants' responses, we utilized simple random sampling to obtain a sample of 320 maize farmers. For easy traceability, lists of maize farmers participating in the 1AF project were obtained from the sub-county extension offices. From the lists, it was found that IAF was working with 1600 maize farmers who constituted the study population. The study population was broken down into sub-counties; Kitayunjwa (417), Butansi (412), Butayaga (392), and Buwenge (379). The determination of sample size was done by using Yamane's 1967 formula for sample size estimation, as used by Uakarn (2021). The sample size was calculated using the following formula in Equation (1).

$$s = \frac{T}{1 + T\left(e^2\right)} \tag{1}$$

s is the sample size required for the study, T is the total number of maize farming households (study population) affiliated with 1AF in the four sub-counties (of the two districts) and e is the error margin (5%).

$$s = \frac{1600}{1 + 1600\left(0.5^2\right)}$$

$$s = 320$$

The sub-sample size (ss) per sub-county, was computed as a ratio of the number of 1AF-affiliated maize growers in a particular sub-county (Ts) to the total number of maize farmers from all sub-counties (study population) (T) multiplied by the sample size in Equation (1). Thus, the sub-sample follows from Equation (2).

$$ss = \frac{Ts}{T} * s \tag{2}$$

Hence 82, 83, 77, and 78 maize farmers were the sub-samples from Butansi, Kitayunjwa, Buwenge, and Butayaga sub-counties respectively giving a total of 320 respondents. Respondents were chosen by selecting every 5th member of 1AF affiliated maize growers in a particular Sub-County.

Informed consent and ethical approval

This study got approval from the Uganda National Council for Science and Technology (UNCST). In addition, researchers obtained clearance from the Gulu University Research and Ethics Committee, and Gulu University, Faculty of Agriculture and Environment, Graduate Research Committee, to conduct the study. The Dean of, the Faculty of Agriculture and Environment, at Gulu University, introduced researchers to the authorities in the districts of Jinja and Kamuli. Specifically, to the District Agricultural Officers (DAOs) through a formal letter that explained the purpose of the study. The DAOs of the two districts gave the green light for the study to be conducted in their areas of jurisdiction, with the smallholder maize farmers affiliated with 1AF as the target population. Before conducting research, interviewers explained to the respondents the purpose of the study and how the research output would be used for study purposes. Also, interviewers informed respondents that their identity, and the information provided, would be treated as confidential throughout the research process. At the start of each interview, a researcher verbally requested a respondent's consent to participate in the research, which was recorded as yes or no on the questionnaire. Only respondents who voluntarily consented to participate in the study were interviewed.

Collection of data

Data collection was preceded by the development of a questionnaire. The questionnaire was developed by the researchers through a literature review and consulting agricultural experts in the Faculty of Agriculture and Environment, Gulu University. Before real data collection, the questionnaire was pretested on 20 maize farmers in Nambale Sub County, Iganga district of eastern Uganda. Questions not easily understood by the respondents were fine-tuned with the help of agricultural experts in the Faculty of Agriculture and Environment, Gulu University. This was done to ensure questions were reliable, clear, relevant, and appropriately aligned with the study objectives. Primary data collection was conducted by trained research assistants through face-to-face interviews with the respondents using a structured questionnaire. The questionnaire comprised closed and open-ended questions that were used to gather the appropriate information required to respond to the research questions. The questionnaire comprised three sections. The first section was a brief introduction of the interviewer, the purpose of the research, usage of research output, confidentiality, and respondent informed consent. The second section was on the type and number of SAIPs adopted by maize farmers (legume intercrop, ISFM, conservation tillage, IPM, improved maize seeds, etc.). The third section was on socio-economic factors (land ownership, age, marital status, level of education, land size, household size, gender, land tenure, etc.) and institutional factors (access to markets, credit, extension services, group membership, etc.). Data were collected from the sampled smallholder maize farmers between June and July 2020.

Data analysis

The gathered data were entered into Stata (version 14) statistical package, and subjected to cleaning to find out if outliers existed. The first activity in cleaning data was to run a descriptive statistical analysis. A few irregularities identified in the dataset were rectified by reverting to the hard copies of the questionnaires of the collected data and completing the data set. All the questionnaires of the collected data (320) were used in data analysis because they possessed complete responses. The characteristics of respondents were analyzed using descriptive statistics including percentages and frequencies. Suitable models were used to compute inferential statistics.

Analysis of predictors of adoption of SAIPs

Farmers adopted each of the SAIPs independently based on the needs of the farm and their ability to procure them at any given time of the maize production cycle. Due to the binary orientation of dependent variables, it was possible to use any of the two models, i.e. the probit and logistic regression models to analyze data. However, in this research, we used the logistic model rather than the probit model, due to its robustness in handling outliers, and capacity to easily process categorical, discrete, and continuous variables to estimate binary outcomes (Kimbi et al., 2024; Wooldridge, 2015). Thus, the binary logistic regression model (BLRM) was used to compute independently, the socio-economic and institutional factors affecting uptake of each of the five major SAIPs identified among the maize growers. These major SAIPs included; improved maize varieties, IPM, conservation tillage, legume intercrop, and ISFM. Taking y_{ij} to denote an outcome variable for taking up a specific SAIP, would be defined as in Equation (3).

$$y_{ij} = \begin{cases} 1\, if\ the\ i^{th}\ farmers\ takes\ up\ the\ j^{th}\ SAIP,\ and\ 0\ otherwise \\ \end{cases} \tag{3}$$

In this instance, y_{ij} is a hypothetical construct with chances r of y_{ij} *= 1 (adoption) and 1−r for z_{ij} *= 0 (non-adoption). By regressing the binary outcome variable in Equation (3) against independent variables represented by x, we generated Equation (4).

$$y_{ij} = x'_{ij}\beta_{ij} + \varepsilon_{ij} \tag{4}$$

where x'_{ij} represents a collection of independent variables (socio-economic and institutional factors) that may potentially affect the adoption of a particular SAIP. ε_{ij} is the random error. The independent variables used in this research were chosen in line with empirical studies (Abera, 2016; Amare & Simane, 2017; Atube et al., 2021; Awotide et al., 2016; Bedeke et al., 2019; Gailhard et al., 2015; Gupta et al., 2017; Mazvimavi & Twomlow, 2009; Mogaka et al., 2021; Mwaura et al., 2021; Ndiritu et al., 2014; Nigussie et al., 2017; Ntshangase et al., 2018; Okello et al., 2020; Omara et al., 2021; Oyetunde-Usman et al., 2021; Pagliacci et al., 2020; Simtowe et al., 2016) whose focus has been on the effect of socio-economic and institutional factors on the utilization of agricultural technologies. The socio-economic variables incorporated are land ownership, the land tenure system, size of land owned by the household, size of land allocated to maize production, labor use, household size, age, gender, household size, number of dependents in the household, and market-orientated maize farming. The institutional variables include; access to extension services, credit, group membership, and distance to all-weather roads (see, Table 1). β_{ij} denotes parameters and their specifications for each of the independent variables.

Analysis of predictors of adoption intensity of SAIPs

Smallholder farmers in SSA usually use few sustainable agricultural practices that can be counted as one, two, three, etc. due to resource constraints (Jambo et al., 2019). Therefore, adoption intensity was measured by counting the sum of SAIPs taken up by individual smallholder maize farmers out of all SAIPs promoted by 1AF. Count data of this nature follows the Poisson distribution (Mahama et al., 2020; Wooldridge, 2015). As a result, to examine the drivers for adoption intensity of SAIPs, we utilized the Poisson regression model due to its robustness in handling minor deviations from the Poisson distribution (PRM) (Okello et al., 2022; Wooldridge, 2015). The PRM model was specified as in Equation (5).

Table 1. Binomial logistic regression model predictor variables.

Variable	Unit	Description /measurement	Sign	Source
Land ownership	Dummy	1 if the farmer owns the land, and 0 if otherwise	+	Nigussie et al. (2017)
Land tenure system	Categorical	1 for Customary, 2 for Freehold, 3 for Communal, and 4 for Mailo land.	+	Nigussie et al. (2017)
Size of land owned by the household	Continuous	Lands owned by the household (acres)	±	Pagliacci et al. (2020)
Size of land allocated to maize production	Continuous	Land allocated to maize production in acres	±	Ndiritu et al. (2014)
Labour used	Categorical	1 for Family labour, 2 for hired labour, and 3 for both hired and family labour	±	Mazvimavi and Twomlow (2009)
Household size	Continuous	Number of persons in the family	+	Awotide et al. (2016)
Age of household head	Continuous	Number of years	+	Gailhard et al. (2015)
Gender of household	Dummy	1 for male, 0 for otherwise	±	Simtowe et al. (2016)
Number of dependents in the household	Continuous	Number of non-working family members in the household	+	Bedeke et al. (2019)
Market-orientated farming	Dummy	1 for the farmer who grows maize purposely for sale, and 0 for otherwise	+	Gupta et al. (2017)
Access to extension services	Dummy	(1 for a farmer who accesses information from an extension worker, and 0 for otherwise)	+	Amare and Simane (2017)
Access to credit	Dummy	1 for the farmer who accesses credit for use in maize farming, and 0 for otherwise)	+	Okello et al. (2020)
Group membership	Dummy	1 for a farmer who is a member of a farmer's group, and 0 for otherwise	+	(Mazvimavi and Twomlow (2009)
Distance to all-weather road	Continuous	Distance traveled by a farmer from the farm to access an all-weather road measured in kilometers	–	Abera (2016)

Note: 1 is the event, and 0 is the reference category

$$\Pr\left[z = y_i \mid x_i\right] = \frac{e^{-} y\left(x\right)^{z_i}}{z_i\,!}, z = 0,1,2,3,\ldots\ldots, K \tag{5}$$

where: Pr is the likelihood of an outcome z_i occurring based on a previous come x_i in similar situations of the ith smallholder maize grower; y stands for a parameter that is characterized by equip-dispersion; z stands for the count outcome variable, in this case, the adoption intensity of SAIPs used by the ith smallholder maize farmer.

The PRM is generated by interpolating parameters in the association between y and the regressors x, resulting in Equation (6).

$$\mathrm{E}(z_i x_1, x_2, \ldots\ldots x_3) = Var(z_1 x_1, x_2, \ldots\ldots x_k) = Y_i = \mathrm{esp}\left(q + x'w + e\right) \tag{6}$$

Whereby, w stands for a collection of parameters to be approximated; q stands for regression constant; e is the random error term presumed to possess zero mean and is normally distributed. x' denotes a collection of independent variables that affect the intensity of SAIPs adopted by smallholder maize farmers. The predictor variables used in this study, their priori expectations, description, and measurements are shown in Table 1. Using the assumption of independent conditional probability, the log-likelihood function (L) is estimated as shown in Equation (7):

$$\mathrm{L}\left(\mathrm{w}\right) = \sum_{i=1}^{n} 1\left(\mathrm{w}\right) = \sum_{i=1}^{n} \{z_i x'\mathrm{w} - \mathrm{esp}(x'\mathrm{w} - \ln z_i\,!\} \tag{7}$$

In estimating the L, $\ln z_i\,!$ is removed from the equation because it is independent of w. Hence, the final L is shown in Equation (8).

$$\mathrm{L}\left(\mathrm{w}\right) = \sum_{i=1}^{n} 1\left(\mathrm{w}\right) = \sum_{i=1}^{n} \{z_i x'\mathrm{w} - \mathrm{esp}(x'\mathrm{w}\} \tag{8}$$

When $\mathrm{w} = 0$, the mean and the variance are presumed to be equal which may account for equi-dispersion, when $\mathrm{w} > 0$, the variance is thought to be bigger than the mean. In this scenario, count data represented by PRM is characterized by over-dispersion. Where $\mathrm{w} < 0$, the mean is presumed to be greater than the variance, and count data represented by PRM is characterized by under-dispersion. According to Liu (2008), equi-dispersion in real life is almost nonexistent. Data are usually characterized by under-dispersion, excess zeros, and over-dispersion.

According to Harris et al. (2012) and Rao (2015), there are many forms of the PRM model including the zero-inflated Poisson regression model that is applied when that data has very many zeros. The negative binomial regression model is applied when the data is over-dispersed. The zero-inflated negative binomial regression model is used when data is over-dispersed. The standard Poisson regression model (SPR) is used when there is equi-dispersion. The generalized Poisson regression model (GPR) is used to compute both overdispersion and under-dispersion. Considering the different data scenarios, we settled on the GPR and the SPR to analyze the possible dispersion scenarios by matching the outcome variables with the data. It was found that the outcome variables and data set were matching. We computed for dispersion, and a dispersion of −0.687 was found (Table 7), affirming the existence of under-dispersion, implying that the GPR was suitable for the data. Also, a comparison of the two models in terms of log-likelihood was done, and the GPR was found to possess a larger log-likelihood than the SPR. The GPR model which had a larger log-likelihood value than the SPR model was found suitable for computing drivers of SAIPs uptake than the SPR (Table 7). In addition, computing the Akaike Information Criterion (AIC) is the second point of reference for choosing which model to use in computing drivers of SAIPs' uptake. This is because the log-likelihood for degrees of freedom is modified by the AIC by increasing the variables and consequently enlarging the log-likelihood (Equation 9).

$$\mathrm{AC} = -2\ln \mathrm{Y}(\alpha) + 2\mathrm{n} \tag{9}$$

Whereby, n denotes the count of parameters applied in the approximation, Y(α) denotes the value of the log-likelihood. When the results of the GPR and SPR were closely scrutinized (Table 7), the GPR model had a smaller AIC than the SPR model which provided additional justification for applying the GPR model over the SPR to compute drivers of the intensity of adoption of SAIPs the GPR model had a smaller AIC than the SPR model which provided additional justification for applying GPR model over the SPR to compute drivers of intensity of adoption of SAIPs (Harris et al., 2012).

Results

Institutional and socio-economic characteristics

The institutional and socio-economic characteristics of farmers are presented in Table 2. Institutionally, most households had access to extension advisory services (63%) that were provided by different partners like 1AF and local and Central Government extension personnel. This implies that the majority of farmers were accessed by extension workers. Less than half (45%) of farmers belonged to a farmer group (45%), implying that many farmers lacked sensitization on the importance of groups or trust in groups. Few farmers (36%) had acquired credit, implying that most farmers struggled to find resources to invest in farming. Most households were located 2.3 kilometers from accessible roads. This implies that most farmers would easily access roads to deliver their farm produce to the market.

Socio-economically, the study findings indicate that most households (84%) were male-headed, implying that most farms were male-owned. The mean age of respondents was 47 years, implying that most farmers were falling within the active age bracket and therefore energetic to engage in labor-intensive farming activities. The average household size was 8 people of which 42% were dependents. This implies that most households had substantial human resources that could be utilized to provide farm labor. Most households (89%) owned farmland on the customary land tenure system (64%), implying that their access to land was secure. The average land size for most households is 3.3 acres, with 1.6 acres of the land apportioned to maize production. This implies that most farmers were small landholders and required the utilization of SAIPs to optimize maize production. It also implies that many farmers were engaged in enterprises other than maize. The majority (82%) of farmers were growing maize for sale (market-oriented). This implies that maize was being grown as a commercial crop to raise income for most households. Most households were using family labor (73%), implying that most households had readily available labor.

Adoption of SAIPS and their determinant factors

Adoption of SAIPs

The SAIPs adopted by maize farmers are presented in Table 3. The research identified five SAIPs that are most important in achieving higher maize yields. The most adopted SAIP was improved maize varieties (58%). This was probably due to extension efforts provided by IAF that promoted the crop quite aggressively. This is followed by IPM (56%), which was more likely to take up due to extension efforts and the need to control pests that affect maize yield. ISFM (52%) was also fairly well adopted, possibly due to the need to improve soil fertility to increase maize yields since the land in the Jinja and Kamuli districts is degraded. Legume intercrop (44%) and conservation tillage (36%) were less adopted by farmers possibly due to limited promotion efforts, as extension workers were promoting growing maize on the pure stand and limited use of agrochemicals in weeding.

Correlation of the outcome variables (SAIPs)

Following Kassie et al. (2013), We assessed the correlation among binary outcome variables (SAIPs) before running the logistic model. We intended to know if we were required to use the binary models or the multivariate probit model. The findings in Table 4 reveal no significant correlation among the SAIPs assessed in this research. The binary models are utilized in handling a single (independent) practice i.e.

Table 2. Institutional and socio-economic characteristics (N = 320).

Institutional characteristics	Mean	SD
Credit acquisition (1 = yes)	0.36	0.48
Access to extension services (1 = yes)	0.63	0.48
Group membership (1 = yes)	0.45	0.50
Distance to all-weather roads (km)	2.28	3.23
Socio-economic characteristics		
Sex of family head (1 = male)	0.84	0.37
Age of family head	46.58	16.10
Family size	7.52	3.73
Proportion of dependents in the family	0.42	0.22
Study location/district (1 = Kamuli)	0.50	0.50
Owns farmland (1 = yes)	0.89	0.31
Land is customary (1 = yes)	0.64	0.48
Total land size (acres)	3.27	4.22
Land allocated to maize (acres)	1.55	4.32
Market-orientated farming (1 = yes)	0.82	0.39
The main source of labor is family (1 = yes)	0.72	0.45

SD: Standard Deviation, and N: Number of research participants.
Source: Analysed from field Survey, 2020.

Table 3. Adoption of SAIPs.

SAIPs	Frequency	Percentage
Improved maize seeds	187	58.44
Conservation Tillage	114	35.63
Legume intercrop	142	44.38
ISFM	166	51.88
IPM	180	56.25

ISFM: Integrated soil fertility management, and IPM: Integrated pest management.
Source: Analysed from field data, 2020.

logistic and probit (Atube et al., 2021). We used the logistic regression model in this research because of its ability to estimate probabilities which are more intuitive than the latent probabilities assessed by probit models (Kimbi et al., 2024).

Model goodness of fit for socio-economic and institutional factors affecting adoption

The binomial logistic regression model results (Table 6) on the model goodness of fit reveal that the pseudoR-squared values were 40.1, 27.4, 15.0, 44.5, and 21.7% with corresponding log-likelihood ratios of −129.514, −149.842, −185.766, -122.167, and −170.849 for predictors of adoption of improved maize varieties, conservation tillage, legume intercrop, ISFM, and IPM respectively. Following Mbachu et al. (2012), all the loglikelihood ratios fit within acceptable limits. Also, across all the SAIPs, the confidence level of the model was 1%, demonstrating that the model coefficients are unequal to zero. Accordingly, the research indicated that the binomial logistic regression model was fit to showcase results on predictors of SAIPs' adoption.

Pre-estimation test for socio-economic and institutional factors affecting adoption

Before logistic regression for the socio-economic and institutional factors affecting the adoption of SAIPs, we carried out pre-estimation tests (Table 5) to verify whether predictor variables embodied in the assessment would not experience multicollinearity, omissions, and heteroscedasticity. We used the variance inflation factors (VIF) to verify the existence of multicollinearity, omissions, and heteroscedasticity within the predictor variables. According to Akinwande et al. (2015), the threshold VIF must be at least 1, as the upper limit should not exceed 10. Results in Table 5 of the VIF assessment, revealed that the mean VIF was 1.62, while the threshold and upper limit of the VIF were 2.22 and 1.05, respectively. This was achieved after dropping variables that possessed higher multicollinearity coefficients, for instance, study location, and marital status were dropped. Hence, the VIF of the research fits into the permissible bounds, revealing the absence of multicollinearity amongst predictor variables.

Additional pre-estimation assessments comprised the omitted variable and the Cook-Weisberg test of heteroscedasticity. Results of the Cook-Weisberg test revealed a heteroscedasticity value of 0.763 and the

Table 4. Correlation of the binary outcome variables (SAIPs).

SAIPs	Improved maize varieties	Conservation tillage	Legume Intercrop	ISFM	IPM
Improved maize varieties	1				
Conservation tillage	0.047	1			
Legume Intercrop	0.039	−0.091	1		
ISFM	0.018	0.048	−0.073	1	
IPM	0.043	0.056	0.051	0.019	1

ISFM: Integrated soil fertility management, and IPM: Integrated pest management.
Source: Analysed from field survey, 2020.

Table 5. Findings of pre-estimation test predictor variables.

Predictor variables	VIF	1/VIF
Age	2.22	0.442
Extension services	2.20	0.452
Land allocated to maize growing	1.87	0.535
Market-oriented farming	1.74	0.558
Labour use	1.71	0.658
Distance to all-weather road	1.52	0.670
Gender	1.40	0.676
Extension services	1.33	0.769
Credit	1.16	0.855
Group membership	1.05	0.935
Mean VIF		1.62
Additional assessments		
Omitted Variable test		0.294
Cook-Weisberg test of heteroscedasticity		0.763

VIF: Variance inflation factor.
Source: Analysed from field survey, 2020.

omitted variable test showed the omitted variable value of 0.294 which were both inconsequential. This confirms the non-presence of heteroscedasticity and omitted variables (Alela et al., 2024; Kimbi et al., 2024). Hence, we used the BLRM to assess the relationship between predictor and outcome variables.

Socio-economic and institutional factors influencing the adoption of SAIPs

Logistic regression results (Table 6) show that institutional factors affecting the uptake of SAIPs were; access to extension services, credit, membership to farmer groups, and nearness to all-weather roads. Access to extension services increases the chances of farmers taking up three SAIPs, i.e. improved maize varieties (36.4%), ISFM (55.4), and IPM (37.0%). Access to extension information improved farmers' knowledge of the importance of using SAIPs. On the other hand, access to extension services decreased the possibility of taking up conservation tillage (12.7%) and maize-legume intercrop (20.9%). This was because extension workers promoted growing maize on pure stands and discouraged the use of agrochemicals in weeding gardens.

Access to credit by farmers raised the probability of adopting all the five SAIPs, i.e, improved maize seeds (40%), conservation tillage (16.4%), ISFM (39.7%), legume intercrop (28.9%), and IPM (21.8%). Credit improved farmers' ability to purchase farm inputs. Similarly, membership in groups increased the chances of taking up improved maize seeds (31.6%), conservation tillage (28.3%), ISFM (19.2%), legume intercrop (36.5%), and IPM (27.3%). This implies that membership in groups improved social networking and access to information on SAIPs.

Also, distance to the all-weather affected the adoption of SAIPs positively and significantly. It improved the chances of adopting SAIPs i.e. improved maize varieties (25.9%), conservation tillage (8.8%), ISFM (27.6%), and IPM (15.3%). This implies that farm families that are situated close to all-weather roads experience a low cost of transporting maize to the market compared to their counterparts that are located far away from all-weather roads.

The socio-economic factors that affected the adoption of SAIPs were; customary land ownership, sex of household head, and market-orientated farming. Customary land ownership increased the chances of taking up IPM by 13.8%. This means for every unit increase (acreage) of customary land owned by

Table 6. Logistic results of institutional and socio-economic factors affecting the adoption of SAIPs.

	Improved maize varieties	Conservation tillage	Legume Inter cropping	ISFM	IPM
Explanatory variables	Coeff. (S.E)	Coeff. (S.E)	Coeff. (S.E)	Coeff. (S.E)	Coeff. (S.E)
Institutional factors					
Extension	0.364***	−0.127*	−0.209***	0.554***	0.370***
	(0.074)	(0.074)	(0.071)	(0.063)	(0.069)
Credit	0.400***	0.164**	0.289***	0.397***	0.218***
	(0.068)	(0.081)	(0.071)	(0.088)	(0.077)
Group membership	0.316***	0.283***	0.365***	0.192***	0.273***
	(0.064)	(0.012)	(0.057)	(0.032)	(0.053)
Distance to all-weather road	0.259***	0.088*	0.010	0.276***	0.153***
	(0.058)	(0.039)	(0.048)	(0.071)	(0.053)
Socio-economic factors					
Sex of family head	−0.010	−0.155*	0.069	0.221	−0.051
	(0.095)	(0.098)	(0.088)	(0.115)	(0.086)
Age of family head	0.123	0.043	0.049	0.126	−0.107
	(0.096)	(0.180)	(0.168)	(0.112)	(0.093)
Land allocated to maize	0.069	−0.049	−0.018	0.070	0.044
	(0.051)	(0.041)	(0.044)	(0.054)	(0.044)
Family labour	0.067	0.037	0.019	−0.030	−0.031
	(0.072)	(0.068)	(0.078)	(0.100)	(0.081)
Customarily owned land	0.054	0.061	0.073	0.110	0.138*
	(0.076)	(0.053)	(0.073)	(0.098)	(0.074)
Market orientated farming	0.203*	0.192*	0.039	0.214*	0.080
	(0.121)	(0.065)	(0.094)	(0.110)	(0.098)
Constant	−4.237	−2.043	4.042	−5.855	0.350
Wald chi^2 (14)	91.12	78.97	48.66	108.03	70.72
Prob > chi^2	0.000	0.000	0.000	0.000	0.000
Pseudo R^2	0.401	0.274	0.1502	0.4454	0.2168
Log-likelihood	−129.514	−149.842	−185.766	−122.167	−170.849
GOF Pearson chi^2(303)	304.89	317.33	325.81	302.75	321.45
Prob > chi^2	0.4588	0.2742	0.1759	0.4933	0.2232

ISFM: Integrated soil fertility management, IPM: Integrated pest management, ***, *, and **: Level of significance at 1%, 10%, and 5%, respectively.
Source: Analysed from field survey, 2020.

farmers, the probability of adopting IPM increased by 13.8%. Customary land ownership ensured secure tenure systems that enabled maize farmers to invest in more sustainable pest control practices to improve maize production than their counterparts who rent or borrow land.

Conversely, the sex of the household head had no effect on the adoption of four SAIPs except for conservation whose chances of adoption were reduced by 15.5% among male-headed households. Males controlled household labor and were less likely to spend money on buying agrochemicals for use in conservation tillage. Lastly, market-orientated farming increased the probability of adopting improved maize varieties (20.3%), conservation tillage (19.2%), ISFM (21.4%), and IPM (8.0%). Market-oriented farmers were growing maize mainly for sale. They are therefore more likely to invest in many SAIPs than food security-oriented farmers.

Adoption intensity of SAIPs and its determinant factors

Adoption intensity of SAIPs

Maize farmers (35%) had taken up at least three of the promoted SAIPs, while 22% adopted two SAIPs. Also, 21% of the maize farmers had adopted four SAIPs, whereas 20% had taken up one SAIP. Only 3% of the maize farmers had taken up all the five SAIPs.

Institutional and socio-economic factors affecting the adoption intensity of SAIPs

The PRM models most applied in computing socio-economic and institutional drivers of adoption intensity involving count data are the GPR and SPR (Harris et al., 2012; Rao, 2015). A comparison of the two models (Table 7) in terms of log-likelihood was done and the GPR was found to possess a larger log-likelihood (−414.265) than the SPR (−482.005) which makes the GPR more suitable for determining the socio-economic and institutional factors affecting SAIPs adoption intensity. In addition, the dispersion value of −0.687 for the GPR, indicates that the variance is less than the mean, which is under dispersion,

Table 7. Institutional and socio-economic factors affecting the intensity of adoption of SAIPs.

	Standard Poisson		Generalized Poisson	
Explanatory variable	Coefficient	SE	Coefficient	SE
Institutional factors				
Extension access	0.393***	0.059	0.336***	0.049
Credit access	0.173***	0.055	0.180***	0.046
Group membership	0.099***	0.051	0.078*	0.043
Distance to all-weather road	0.113***	0.043	0.143***	0.034
Socio-economic factors				
Sex of family head	−0.130**	0.063	−0.161***	0.059
Age of family head	0.173***	0.029	0.151***	0.026
Household size	0.043	0.034	0.065**	0.028
Land allocated to maize	0.137	0.051	0.136	0.043
Land ownership	0.139	0.046	0.155	0.039
Family labour	0.162***	0.053	0.151***	0.044
Customary land tenure	0.134	0.144	0.252**	0.127
Household dependency ratio	0.200**	0.091	0.112*	0.062
Market orientation	0.563**	0.226	0.797***	0.209
Constant	0.393***	0.059	0.336***	0.049
Observations	320		320	
LR chi^2 (15)	329.89		271.43	
Prob > chi^2	0.000		0.000	
Pseudo R^2	0.0980		0.194	
Log-likelihood	−482.005		−414.265	
AIC	996.01		862.530	
BIC	1056.203		926.485	
Dispersion	NA		−0.687***	

Note. SE: Standard error, AIC: Akaike Information criterion, BIC: BIC: Bayesian Information Criterion, NA: Not applicable, ***, *, and **, respectively stand for significance level at 1%, 10% and 5%.
Source: Analysed from field survey, 2020.

augmenting its suitability for the study. Based on the research results, the institutional factors affecting the adoption intensity of SAIPs were; access to extension services, credit, membership to farmer groups, and distance to all-weather roads.

Farmers' access to extension services on SAIPs used in maize production had a positive and significant effect on adoption intensity. That shows the role extension agents play in the diffusion of modern agricultural practices. Likewise, farmers' access to credit had a positive and significant effect on the adoption intensity of SAIPs. Various inputs are used to constitute SAIPs, for example, constituting ISFM involves combining inorganic fertilizers that are bought from input dealers, with organic fertilizers that are made by farmers on their farms. Some of the ingredients that are used in constituting SAIPs require capital. That is why access to credit was key to the adoption of SAIPs.

Furthermore, group membership positively and significantly affected the adoption intensity of SAIPs. Farmers who are members of groups can access information from fellow farmers on the utilization of SAIPs in maize production than their counterparts who are not group members. Last but not least, distance to all-weather roads had a positive and significant effect on the adoption intensity of SAIPs. This implies that maize farmers near all-weather roads had higher chances of taking up multiple SAIPs to improve maize production than their counterparts who are adrift from the all-weather roads.

The study reveals that the socio-economic factors affecting adoption intensity of SAIPs were; family size, gender, age, use of family labor, dependency ratio, market orientation, and customary land ownership. In light of the research findings, the sex of the household head affected the adoption intensity of SAIPs negatively. The sex of the family head decreased farmers' chances of taking up additional SAIPs by 16.1%. This was probably because male farmers were more focused on producing more maize for sale to generate high income. As a result, men were less likely to embrace practices like conservation tillage and legume intercrop that would attract spending. Instead, they opted for mechanical tillage and growing maize on pure stand respectively which required the use of family labor at no cost.

Similarly, the age of the household head increased the adoption intensity of SAIPs by 15.1%. This was because old farmers had more experience in farming and understood the value of using more SAIPs in maize production than young farmers.

Results also showed that there was a positive relationship between household size and adoption intensity of SAIPs. Households with more people had higher chances of taking up more SAIPs due to the availability of more labor than their counterparts in households with fewer people. Family labor increased the chances of taking up additional SAIPs by 15.1%. Farmers using family labor were more likely to take up more SAIPs compared to farmers who hired labor because they were not spending money on the payment of laborers. The household dependency ratio improved the adoption intensity of SAIPs by 11.2%. Farm families that had more dependents were motivated to produce additional food for home consumption leading to more diversification in the maize cropping system.

Discussion

Embracing SAIPs is vital to producing sufficient food to feed an increasingly resource-constrained global population (Pretty et al., 2011). This article examined the factors affecting the adoption and adoption intensity of SAIPs amongst maize farmers in eastern Uganda. The article finds that five SAIPs had been adopted by maize farmers including improved maize varieties, conservation tillage, legume intercrop, ISFM, and IPM. In addition, the article finds that institutional factors positively affected both adoption and adoption intensity while socioeconomic factors mainly impacted the adoption intensity of SAIPs.

Effect of institutional factors on adoption and adoption intensity of SAIPs

Farmers' access to extension services played a key role in enhancing the adoption and adoption intensity of SAIPs. Extension officers build the capacity of farmers through group training, triggering farmer mindset change. The increment in adoption and adoption intensity of SAIPs due to access to extension services could be due to well-packaged extension messages that promoted SAIPs as enhancers of agricultural productivity. For instance, information that farmers will get higher maize yields upon taking up SAIPs compared to conventional maize production practices may trigger higher adoption. Another message like, that embracing IPM reduces chemical use, protects the environment, and improves maize yields than using only pesticides. Through these messages, farmers were convinced to embrace SAIPs.

The research results are in concordance with previous studies (Adolwa et al., 2017; Oyetunde-Usman et al., 2021; Swami & Parthasarathy, 2024), who found access to agricultural extension services a key determinant of the uptake of agricultural technologies. These research findings also align with studies by Chaudhary et al. (2022), Danso-Abbeam et al. (2017), and Nkomoki et al. (2018) who argue that farmers' contact with extension agents positively impacts agricultural technologies adoption intensity. On the contrary, the influence of extension service access negatively affected the uptake of conservation tillage and legume intercrops, these findings rhyme with the message extension workers passed regarding these two practices. Farmers in the study areas largely use herbicides in the control of weeds. The use of herbicides was discouraged by extension workers promoting the adoption of SAIPs because it was associated with environmental pollution. Legume intercrop was also being discouraged by extension workers because it reduces the population of maize in the field consequently reducing harvestable maize. This therefore explains the negative relationships observed with conservation tillage and legume intercrop. The study finding is in agreement with Omara et al. (2021) who disclosed that access to agricultural extension services negatively affected the chances of taking up rocket barn technology in northern Uganda. This shows that access to agricultural information does not always lead to technology adoption. Hence to establish technology-focused and well-designed intension services that foster technology adoption and intensity of use.

Another key determinant of the adoption and adoption intensity of SAIPs was access to credit. Smallholder farmers in the study context are resource constrained, and cannot fully self-finance their farming operations. Therefore, access to credit makes it easy for maize framers to buy the necessary agri-inputs from the market that can be integrated with locally available materials to generate some of the SAIPs. This explains the significance of credit access to farmers in increasing the adoption and intensity of SAIPs. This research finding is in line with Mujeyi et al. (2020), Omara et al. (2021) and Sheikh et al. (2022) who revealed that credit access was positively linked to the uptake of improved agricultural technologies. Access to credit relaxes the liquidity constraint, as well as boosts the risk-bearing ability of the farmers (Mwangi & Kariuki, 2015), and consequently enables farmers to invest in SAIPs to increase their crop yields. This research result is further reinforced by Rayhan et al. (2023), who found that access to credit increased the adoption and intensity of technology used in rice farming in the rural areas of

Bangladesh. This insight provides further evidence of the necessity to link farmers to reliable credit service providers to increase farmers' affordability and uptake of SAIPs.

Furthermore, distance to all-weather roads had a positive influence on the adoption and adoption intensity of SAIPs. Farmers' proximity to all-weather roads makes it easy to access markets to acquire agricultural inputs and marketing of farm output. The study finding aligns with Bekele et al. (2021), Morgan et al. (2019), and Ogisi and Begho (2023) farmer's proximity to all-weather roads and markets necessary for timely agricultural input delivery and output marketing which leads to low transport costs and improved income. This finding is further supported by Abera (2016) research in Ethiopia which discovered that farmers' proximity to all-weather roads increased adoption of the improved beans. In addition, farmers whose farm families are close to all-weather roads can easily be accessed by extension workers and provided with information on SAIPs application in maize production. This observation provides additional insight into the need to increase road connectivity to most rural areas to enhance technology adoption and intensity of use.

Group membership had a positive and significant effect on the adoption and adoption intensity of SAIPs. Implying that the chances of farmers taking and intensifying SAIPs increase as farmers join groups. Farmers who belong to groups can easily get information on SAIPs from other group members who have already adopted the SAIPs or through collective training by extension workers since most rural training programs tend to target groups rather than individuals (Okello et al., 2020).

Likewise, groups enhance collective access to farm inputs and extension services at relatively lower costs than usual market prices. Additionally, farmers in groups can arrange for collective marketing of the farm produce and bargain for better prices than individuals. This is in agreement with (Nkomoki et al., 2018) who deduced that farmer group membership enables smallholder farmers to get advice from extension officers and receive better market prices for their agricultural produce. Membership to groups therefore influenced the adoption and intensity of SAIPs because it shapes the actions of members to strive for collective action. This finding also aligns with Neves et al. (2021), who revealed that membership in cooperatives increased the adoption of agricultural technologies, enhanced agricultural production, and reduced production costs in Brazil. This augments the need to encourage farmers to join groups so that they benefit from group members.

In a nutshell, institutional factors create an enabling environment that drives and facilitates smallholder maize to adopt and intensify the adoption of SAIPs through farmer training, credit access, market, and group influence. Therefore, institutional structures essential to the adoption process should be strengthened to facilitate the adoption and adoption intensity of SAIPs.

Effect of socio-economic factors on adoption and intensity of SAIPs

The study finds that socio-economic factors including the sex of the household head, land ownership, family labor, market-orientated farming, and age mainly affected the adoption intensity of SAIPs amongst smallholder farmers. The sex of the household negatively affected the intensity of the adoption intensity of the SAIPs, and the adoption of conservation tillage. This is because most males' interests in the research area are centered on income generation, and less focused on providing food for households. Consequently, male-headed households tend to adopt maize mono-cropping to maximize marketable output. The study finding conforms with Kunzekweguta et al. (2017), Nigussie et al. (2017) and Singaña Tapia and Satama Bermeo (2022) who reported a negative effect of male family headship on the uptake of improved farm technologies in Ethiopia. Males are less likely to take up conservation tillage because some of the technologies used in the practice like herbicides require spending money to acquire them. Male household heads are unwilling to venture into a practice that would increase spending on maize farming because they control family labor which they can deploy to replace conservation tillage. The study finding agrees with Farnworth et al. (2016), Nyanga et al. (2012), Brown et al. (2017) and Ouma et al. (2014) who reported that conservation tillage was more popular in female-headed families than male-headed families because it freed females from overworking and provided them with the opportunity to participate in other income generating activities. This illustrates the need for gender analysis before promoting technologies to match males and females with appropriate technologies.

Additionally, farmers using family labour had higher chances of taking up multiple SAIPs compared to their counterparts who were using alternative sources of labour. This implies that family labor would easily be deployed to apply SAIPs on the farm rather than hired labor because of the costs involved in hiring labor. The research findings also corroborate Kiconco et al. (2022), Mwangi and Kariuki (2015), and Olaniyi (2010), who argue that using family labor determines the adoption process of agricultural technologies because larger households can meet the required labor needed to take up diverse SAIPs. This research finding further agrees with Kassie (2018), who found that family labour facilitated the adoption of agroforestry in Ethiopia. This demonstrates the need for family members to participate actively in farming activities for adoption and the intensity of adoption of agricultural practices to be enhanced.

Likewise, household size positively and significantly affected the adoption intensity of SAIPs, because multiple practices were required to generate higher maize yields to meet the various needs of larger families including finance and food security compared to small families. This finding aligns with Lugamara et al. (2019) research results that linked household size to adopting improved common bean varieties in Tanzania. However, the research finding contradicts (Awotide et al., 2016) who found that household size negatively affected the adoption of multiple agricultural technologies among rice farmers in Nigeria.

Similarly, the household dependency ratio affected the adoption intensity of SAIPs positively and significantly because households having more dependents are motivated to produce more food for home consumption leading to more diversification in the maize cropping system. Households with few dependents will more likely focus on producing maize for commercial purposes and therefore limit the diversification of SAIPs. This research results conform with Kebede et al. (2017) who revealed that technologies used in wheat production in Ethiopia were associated with a large household dependency ratio.

Also, results revealed that the age of a family head affected the adoption intensity of SAIPs positively and significantly compared to young farmers. This was probably because old maize farmers possess divergent farm needs and interests including income and food security than young farmers who mainly engage in farming to generate income. Likewise, old farmers are more experienced and could easily understand the need for additional SAIPs to improve maize production. The research output is in agreement with Bekele et al. (2021), Oyetunde-Usman et al. (2021) and Rotich et al. (2024), who deduced that old farmers have higher chances to invest in diverse farm technology adoption compared to young ones because they can easily comprehend many benefits that accrue from investing in multiple technologies that are realized over time. However, this research finding contradicts Milkias (2020) who found old farmers were less likely to embrace multiple high-yielding teff varieties in Ethiopia. This illustrates the need to consider a farmer's age as a critical determinant of the adoption intensity of agricultural technologies in technology promotion programs.

Market orientation positively influenced the adoption and adoption intensity of SAIPs. Market-oriented smallholder maize growers had more chances of adopting and intensifying SAIPs than non-market-oriented farmers because their actions are income and profit-driven. They will adopt several SAIPs that are deemed economically viable to break even (Awotide et al., 2016; Mazvimavi & Twomlow, 2009). Martey et al. (2017) reported that market orientation triggers the commercialization of agricultural enterprises, consequently influencing the adoption and adoption intensity of technologies. This research finding is in line with (Ye et al., 2023), This research is in line with Ye et al. (2023), who found that China market-oriented farming positively affected the uptake of new wheat and rice varieties in China. Therefore, market orientation influences farmers to adopt multiple SAIPs to facilitate the commercialization of maize, to get higher income than peasants.

Lastly, the results showed that farmers with customary land ownership had significantly higher adoption intensities of SAIPs than counterparts under other arrangements. Land ownership guarantees ownership, access to land, and long-term security of investing in multiple technologies. Farmers that rent, borrow, or squatter on land are less likely to engage in diverse SAIPs because, at any time their access to land can be terminated by the land owners. This research finding agrees with Ndiritu et al. (2014), Oyetunde-Usman et al. (2021) and Gebremedhin and Swinton (2003) who found that long-term use of improved farm technologies was linked to secure land tenure systems such as customary land ownership, as it ensures sustainable gains to smallholder farmers. Also, Kassie et al. (2013), found that customary land ownership was positively associated with sustainable agricultural practices in Tanzania. This shows that secure land tenure systems are a prerequisite for multiple technologies on the farm.

In summary, socio-economic factors mainly affected the adoption intensity of SAIPs and had limited effect on their adoption. This suggests that outside the enabling external environment for adoption and adoption intensity that is provided by the institutional factors, individual farmers/households must possess appropriate attributes and capacities that are compatible with each of the SAIPs to be able to intensify adoption and hence benefit from it.

Conclusions

Agriculture is the main source of livelihood for smallholder farmers in Uganda. Despite its importance, the agricultural sector in the country is faced with the challenge of low agricultural production and productivity mainly due to land degradation. Hence, SAIPs are a viable remedy to low production and productivity. Strikingly, farmers tend to be reluctant to adopt the SAIPs that boost agricultural productivity in Uganda. Understanding the institutional and socio-economic factors associated with farmers' adoption and adoption intensity of the SAIPs is therefore essential to finding remedies to low agricultural productivity. The purpose of the research was to assess the effect of institutional and socio-economic factors on the adoption and adoption intensity of SAIPs amongst smallholder maize farmers in Eastern Uganda. The binomial logistic regression and generalized Poisson regression models were used to analyze the determinants of adoption and adoption intensity of SAIPs respectively. The results showed a moderate adoption of the SAIPs. The econometric findings also revealed that institutional factors such as group membership, access to all-weather roads, and credit were the significant predictors affecting the adoption and adoption intensity of all five major SAIPs among farmers. Access to extension information affected the adoption of SAIPs in a mixed way. It positively affected the adoption of three SAIPs (improved maize varieties, IPM, and ISFM), affected adoption intensity positively, and negatively affected the adoption of two SAIPs (conservation tillage, and legume intercrop). Socio-economic factors including market-oriented farming positively affected the adoption of three SAIPs (improved maize varieties, conservation tillage, and ISFM) and the adoption intensity of SAIPs. Other socio-economic factors such as, the age of the family head, use of family labor, household size, and household dependence ratio only influenced the adoption intensity of SAIPs positively and not their adoption. On the contrary, the sex of household heads affected the adoption of one SAIP (conservation tillage) and the adoption intensity of SAIPs negatively. Therefore, the research concludes that these are the determinants of adoption and adoption intensity of SAIPs among smallholder farmers in Eastern Uganda.

Policy recommendations

Based on the study findings, the following recommendations can be drawn to inform policy and practice. There is a need to strengthen the agricultural extension institutions to enhance farmers' extension outreach. Such strengthening should streamline extension information delivered by all extension workers to farmers to achieve uniformity in the extension messages. Farmers need to be advised on affordable credit sources such as Village Savings and Loans Associations, where they can borrow from and pay back after harvesting. This will enhance SAIP adoption due to increased farmers' access to capital required for buying ingredients such as inorganic fertilizers that are used in constituting SAIPs on farms.

Limitations of the study

A few limitations of this study are worth noting. The article did not examine the effect of bio-physical factors on the adoption and adoption intensity of SAIPs; did not assess the impact of SAIPs on maize productivity and only looked at 5 SAIPs, although there could be more parameters. Future studies could therefore consider an analysis of the effects of bio-physical factors on the adoption and adoption intensity of SAIPs and assess the impact of SAIPs on maize productivity.

Authors' Contributions

In producing this article, Enos Katya Kule, Alfred Obia, David Agole, and Walter Odongo designed the research; Enos Katya Kule spearheaded the data collection exercise; and data analysis was executed by Daniel Michael Okello and Enos Katya Kule. Enos Katya Kule wrote the initial draft of the manuscript. All five writers participated in reading and reviewing subsequent drafts and final article approval.

Disclosure statement

The writers of this article proclaim no conflict-of-interest possession.

About the authors

Enos Katya Kule is PhD fellow in Agriculture and Applied Bio-sciences – Agricultural Extension from the Faculty of Agriculture and Environment, Gulu University. Research interest is in the areas of soil agricultural extension, rural innovation, gender, climate change adaption, and sustainable agriculture.

David Agole holds a PhD in Agricultural and Extension Education, Pennsylvania State University, USA. Research interest is in the areas of rural sociology, extension education, and qualitative research.

Alfred Obia holds PhD Soil Science, Norwegian University of Life Sciences, Norway. Research interest is in the areas of soil science and sustainable agricultural practices.

Daniel Micheal Okello holds a PhD in Agriculture and Applied Bio-sciences – Agricultural Economics from the Faculty of Agriculture and Environment, Gulu University. Research interest is in the areas of resource economics and policy analysis.

Walter Odongo holds a PhD in Applied Bio-Sciences (Agricultural Economics), Ghent University. Primary research interest is in the areas of Agricultural Economics, rural development, agri-entrepreneurship, consumer behaviour, and supply chain management, and climate change adaptation.

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ORCID

Enos Katya Kule http://orcid.org/0000-0003-1798-6710
Daniel Micheal Okello http://orcid.org/0000-0003-2967-2428

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