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Adoption Intensity of Bundled Sustainable Agricultural Practices among Small-Scale Maize Growers in Morogoro Region, Tanzania

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Abstract*:* The study examined the adoption rate and intensity of bundled sustainable agricultural practices (SAPs) among smallholder maize farmers in Tanzania. The SAPs considered include crop rotation, intercropping, manure, improved seeds and crop residual. Using descriptive techniques and ordered probit model, data was collected from 470 farming households from Kilosa and Mvomero Districts through a multi-stage sampling procedure. The results show that education level, occupation, farming experience, sex of the household head, farm size, plot ownership, geographical location, membership in farmers' organization and production diversity had significant impacts on the adoption intensity of multiple SAPs. In addition, there were greater disparities in the adoption intensity than in the adoption rates; the awareness and recognition of SAPs did not necessarily translate into increased usage. The study recommends that the interdependence nature of agricultural innovations should be considered in designing strategies dissemination of SAPs to provide farmers with a choice among different sets of practices that possess desirable traits. Given that diverse factors influence the usage of different combinations of SAPs, it is important that policymakers should take into consideration the significant factors to ensure that farmers can maximize the benefits of SAPs through provision of training programs to enlighten farmers on the benefits of SAPs.

Keywords: Sustainable agricultural practices; rate and intensity; adoption; ordered probit model; small-scale maize growers.

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Introduction

Agriculture contributes considerably to the economies of the majority of developing nations (Addison *et al*., 2022) and supports people's livelihoods (Pawlak & Kołodziejczak, 2020). In Sub-Saharan Africa, a substantial proportion of the population is directly dependent on the agricultural sector (Misango *et al*., 2022). Agriculture remains a vital sector of Tanzania's economy and contributes significantly to economic expansion (Bank of Tanzania, 2021). Faced with a growing global population, there is a need to increase the agricultural production to attain food security, employment opportunities and foreign currency. Moreover, the burden on agricultural production systems to achieve global food security in the context of rising demands and depletion of natural resources necessitates a rethinking of current production systems in the direction of more sustainable models from economic and resource management perspectives (Piñeiro *et al*., 2020).

FAO (2022) estimates that agricultural production must increase by 60% by 2050 to satisfy the global rising demand for food. In Tanzania, it is projected that by 2050 the population will exceed 129 million. The implication is that there is a need for a corresponding increase in agricultural output, notably for food crops such as maize, which is the most important cereal in Tanzania, accounting for about 70% of annual cereal production (URT, 2017).

Notwithstanding, Tanzania's agricultural sector, like in most East African countries, remains predominantly subsistent (Selejio &Lasway, 2019). Crop production is dominated by small-scale farmers who largely rely on climatic conditions for production. The use of basic farming techniques and a limited number of farming practices, on top of such challenges as declining soil fertility and drought conditions contributes to the low productivity of major staple crops like maize (Lyimo *et al*., 2014). It is critical to note that along with paddy, maize is regarded as a staple and cash crop (USAID, 2022). In addition, maize consumption increased from 5,162 metric tons in the 2020/2021 season to 5,325 metric tons in the 2021/2022 season. This necessitates an increase in maize production (USAID, 2022).

Globally, smallholder farmers administer 85% of all farms, with 75% of this population residing in Africa (FAO, 2022). Consequently, there are approximately 33 million smallholder farmers in Sub-Saharan Africa, who account for 80% of all farmers in the region. This signifies the contribution of smallholder farmers to the overall production of cereal commodities in the region.

In recognition of the food and commercial values of maize and its importance as a food security crop, the government and other development agencies have made concerted efforts to improve production and productivity. One of the focus areas has been testing, promoting and disseminating sustainable agricultural practices (SAPs). Available evidence shows that the use of improved maize varieties, crop rotation, manure, intercropping and crop residuals can significantly increase maize productivity (Gunton *et al*., 2016; Kansiime *et al*., 2022; Lyimo *et al.,* 2014; Selejio *et al*., 2018).

Statistics show that in Tanzania, domestic maize production steadily decreased from 6,540 metric tons to 6,148 metric tons per year, while demand increased from 6,072 metric tons to 6,186 metric tons per year in the year 2020 (National Bureau of Statistics, 2020). Moreover, while domestic consumption exceeds domestic production, reported actual yield increase results from land expansion rather than from intensification, even though intensification has been branded as the best method to increase crop yields on existing croplands.

In light of diminishing availability of land caused by a burgeoning population, SAPs intensification remains pivotal in addressing inefficiencies within the food production system. Therefore, to be able to intensify domestic maize production, identifying and resolving the socio-economic policy and institutional factors that contribute to the low uptake of the relevant technologies need to be empirically done.

In this regard, several attempts have been made and some empirical research on determinants of the adoption of agricultural technologies in Tanzania and elsewhere have been done (Ghimire *et al*., 2015; Lyimo *et al*., 2014; Mwalupaso *et al*., 2019; Nchinda *et al*., 2020; Simtowe *et al*., 2016;Selejio &Lasway, 2019). It is unfortunate that only a handful account of research (Bongole, 2021; Kassie *et al*., 2013) focused on the extent of adoption of the same. Increasing the intensity of adopting existing practices can significantly enhance productivity. This approach often proves more beneficial than introducing complex and challenging new agricultural technologies.

Leveraging and maximizing the potential of current agricultural practices through increased usage and optimized application can bring about tangible and immediate improvements in productivity while minimizing the complexity and challenges associated with adopting entirely new agricultural technologies (Ruzzante *et al*., 2021).

Due to a lack of rigorous research evidence, context heterogeneity and the risk of bias in the limited sample of existing research, it is difficult to formulate evidence-based policies to increase the intensity of the adoption of sustainable agricultural practices. This study seeks to address this study gap.

Furthermore, utility theory was used to establish the study's hypotheses on the association between the adoption intensity of multiple SAPs and socio economic, institutional and farm related variables. The null hypothesis (H_0) posits that there is no significant association between the adoption intensity of multiple SAPs, socio economic, institutional and farm related variables among smallholder maize farmers in the Morogoro Region.

Literature Review

Sustainable Agriculture and Sustainable Agricultural Practice

According to FAO, resource-conserving, environmentally benign, technically appropriate, economically acceptable and socially justifiable are the salient characteristics of sustainable agriculture practices. The concept of sustainable agriculture (SA) gives economic, social and environmental concerns that the agricultural sector must address with equal weight. Today, most societal issues are interconnected, global and swiftly evolving; therefore, SA provides effective solutions to establish and strengthen a secure agriculture, food system and safe energy for a healthy and sustainable future (Aslihan *et al*., 2020).

Table 1: Studies on Adoption Intensity of Sustainable Agriculture

Authors	Country	Practice	Theory/ Assumption	Statistical Model
Kiconco et al. (2022)	Uganda	IMP (Banana)	Utility	Ordered probity model
Pedzisa et al. (2015)	Zimbabwe	GAP	Utility	Poisson regression
Kolady et al. (2021)	USA	Precision Agriculture	Utility	Poisson regression
Wang et al. (2016)	Canada	Improved sirrigation technologies	Utility	Ordinary least squares (OLS)
Kabir & Ruslan (2013)	India	IPM	Utility	Linear regression
Mwaura et al. (2021)	Kenya	Soil management practices	Utility	Tobit regression
Arslan et al. (2014)	Zambia	CA	Utility	Random effects Tobit, pooled fractional Probit
Ghimire et al. (2015)	Taiwan	IMV	Utility	Crag's double-hurdle model
Misango et al. (2022)	Rwanda	IMP	Utility	Fractional Logit approach
Thompson et al. (2023).	USA	CA	Utility	Lognormal hurdle model
Addison et al. (2022)	Ghana	IPM	Utility	Univariate theory
Bongole (2021)	Tanzania	CSAPs	Utility	Ordered probit model

CA = Conservation Agriculture, IPM = Integrated pest management, IMV = Improved Maize varieties
GAP = Good Agricultural Practices. CSAPs= Climate Smart Agricultural Practices

Empirical studies on the Adoption Intensity of Sustainable Agricultural Practices

The status of the intensity of the adoption of agricultural technologies in the literature is summarized in Table 1. Most studies have focused on the adoption intensity of individual practices rather than on multiple practices. The few, which did, were either not based in Tanzania or did not focus on maize. This means there is limited empirical information on the rate and intensity of adoption of bundled SAPs among small-scale maize growers in Tanzania.

Theoretical Framework

The previous adoption studies have primarily employed correlational technique to explain adoption behavior as a function of multiple variables. Consequently, estimating a function of:

$$\text{Adoption} = f(\mathrm{X})$$

Where 'adoption' is the observed adoption behavior towards SAPs and $\mathbf{X} = \{x_1, x_2, \dots x_n\}$ represents a matrix encompassing a diverse array of socio economic, farm-related, environmental, institutional, and other pertinent factors (as described in Table 2, outlining the specific variables utilized in this study).

The fundamental foundation within this theoretical framework posits that farmers are rational agents who endeavor to optimize an unobservable expected utility function (Adesina & Zinnah, 1993). In the context of this study, utility is operationalized as enhanced maize production, leading to increased profits and subsequently amplifying the potential income derived from the application of multiple SAPs (crop rotation, intercropping, manure, improved seeds, and crop residual).

Furthermore, these SAPs may exert an indirect influence on expected utility, chiefly through their interaction with risk factors at the farm level. To illustrate, factors such as larger farm plots, increased production diversity and higher levels of education may mitigate risk aversion, thereby incentivizing more educated smallholder farmers to embrace SAPs and innovations, such as improved maize varieties, which offer the prospect of heightened income with reduced associated risks (Knight *et al*., 2003).

Consequently, it is posited that the degree of adoption corresponds to the realized value of an unobserved latent utility function, denoted as U^*. This estimate, U^*, is typically assumed to take the form of a linear function of X (Marenya & Barrett, 2007).

$$U^* = \mathbf{X}\beta + \varepsilon$$

In this context, β represents a vector comprising estimated parameters while ε denotes a random error term. It is postulated that the ith farmer will adopt (utilize) a greater number of practices when the anticipated utility gained from an additional practice surpasses the utility derived from not adding a practice (i.e., greater than 0).

$$y_i = \begin{cases} 1, & \text{if } U_i^* \geqslant 0 \\ 0, & \text{otherwise} \end{cases}$$

The observed adoption behavior of the ith farmer is denoted as y_i. Various modifications of this foundational model can be found in the literature. For instance, studies conducted by Bongole (2021), Kiconco et al. (2022), Kolady *et al*. (2021), Mensah Bonsu *et al*., 2017), Misango *et al*. (2022), Mwaura *et al*. (2021) and Pedsiza *et al*. (2021) employed utility theory as a framework for assessing the intensity of adoption. This is typically achieved through a descriptive approach that quantifies the total number of practices employed by a farmer during a cropping season.

In the case of assessing the adoption intensity of SAPs, the outcome is often assumed to be a censored linear function of expected utility:

$$y(\text{ intensity })_i = \begin{cases} \gamma U_i^*, & \text{if } U^* \geqslant 0 \\ 0, & \text{otherwise} \end{cases}$$

Where γ is a scaling term.

Thus, despite the wide variety of dependent variable definitions and estimation techniques, all adoption studies rely on the underlying theory of utility maximization. This theoretical consistency is a necessary condition to make this study a valid exercise. Thus, the utility maximization theory provides a fundamental framework for identifying the determinants of adoption intensity of bundled SAPs among smallholder maize growers in Tanzania. It should be noted that in this study, the adoption rate is a binary decision measured by a dummy variable (1 = who has land under SAPs; 0 = who does not have land under SAPs), and the intensity of adoption as a total number of individual SAPs adopted.

Methodology

Data Source

This study utilized data from the Adoption Pathways project which was conducted during the 2017/2018 cropping season. The project worked with the Australian International Food Security Research Centre (AIFSRC) and was managed by the Australian Center for International Agricultural Research (ACIAR). The project was implemented and led by the International Maize and Wheat Improvement Center (CIMMYT) in collaboration with five African countries (Ethiopia, Kenya, Tanzania, Malawi and Mozambique), Sokoine University of Agriculture and Tanzania Agricultural Research Institute (TARI).

Population and Sampling

Two districts in the Morogoro Region, Mvomero and Kilosa, were selected in the first phase of the sampling procedure (Multistage) based on their potential for maize-legume cultivation. Each district received an identical number of sample households. The distribution of households within each district was proportional to the number of households in that district (proportional sampling). An entirely proportional random sampling technique was used to select 5 to 13 wards in each district, 1 to 4 villages in each ward and 2 to 30 farm households in each village from each district. Although the sample might not be a representative of Tanzania as a whole, it is representative of the main maize-legume farming systems in the country. Thus, data was collected from 470 farming households.

Research Tools

A survey was conducted through one-on-one interviews using a well-designed and pre-tested structured questionnaire administered by enumerators familiar with the local agricultural system and language. The questionnaire was utilized to collect detailed household, plot and village information on the demographic and infrastructure, household production activities and plot-specific characteristics. For each allotment, the respondent detailed the SAPs implemented during the sample year, including intercropping, crop rotation, crop residue, improved seed varieties and manure. Observations and casual conversations provided space for probing and clarifications. This yielded additional data on farmers' concerns and experience, which helped to interpret the quantitative data.

Validity and Reliability

Similar to Hair et al. (2019), the development and validation for the measurement of rate and intensity were carried through three distinct stages. First, a literature review was conducted to gain an understanding of how to measure the rate and intensity and its operationalization in this study. Thereafter, variables were constructed. Second, face validation was performed through consultation with agriculture experts to determine the relevance of constructed items in-terms of the relationship with adoption of sustainable agriculture practices, readability, clarity, conciseness, omission and adequacy.

This procedure ruled out the possibility of measure contamination which according to Nenty (2009) occurs when items unrelated to the construct or variable are included in the instruments. The comments from the experts were evaluated and accommodated accordingly. Thereafter, sematic validation was done by conducting a pilot study which involved 20 respondents, to gauge the effectiveness of the tool. The tool's reliability was statistically validated by computing the composite reliability, which was 0.961205. The composite reliability test was preferred because, it is more reliable than the Cronbach alpha, and does not rely on the number of items on the scale. Furthermore, whereas Cronbach's alpha considers all variables to be equally weighted, composite reliability weights individual indicators. Convergent test was also conducted with results of 0.67036. The coefficient values obtained for composite reliability and convergent validity were higher than the recommended minimum value of 0.7 (for composite reliability) and 0.5 (for convergent validity), cementing satisfactory levels of reliability and validity respectively.

Statistical treatment of Data

This study used quantitative data. Distinct analytical techniques were employed for each objective. The assessment of adoption rate and intensity involved descriptive analysis to derive average scores values for the adopters of SAPs, whereas the investigation into the factors influencing adoption intensity utilized an ordered probit model.

Econometric Framework

Adoption intensity is a count variable that may be analyzed with Poisson regression or Binomial negative. The Poisson regression and binomial negative assume that the occurrence of all events has the same probability. However, the adoption intensity of SAPs doesn't have the same chances of happening. The likelihood of adopting the first SAP may differ from the likelihood of adopting subsequent SAPs (second through fifth) because smallholder farmers acquire experience upon adopting the first SAP. Smallholder farmers could have realized a greater return by adopting the first practice, and they may be willing to adopt a combination of practices to maximize their utility. Notably, the adoption intensity of SAPs may vary based on their specific characteristics, such as labor requirements, practical knowledge requirements, initial investments and whether short-term or long-term benefits are anticipated. In addition, smallholder maize farmers are hypothesized to use multiple SAPs to achieve greater utility than those who employ none or a single practice.

Adoption intensity (number of SAPs adopted by the i^{th} farmer) was regarded as an ordinal variable that could be examined with the ordered probit model. The model permits estimation of the determinants of count variables (intensity of adoption of 1, 2, 3, 4, and 5 SAPs). The ordered outcome could be evaluated as a latent variable Y, where Y is an unobservable measure of the SAPs adoption intensity among smallholder maize farmers and is specified as follows:

The adoption intensity of bundled SAPs was determined using the ordered probit model:

$$\boldsymbol{y^* = x'\beta + \varepsilon}$$

Where y * is unobserved and is given by:

$$\begin{cases} \boldsymbol{y = 0 \text{ if } y^* \leq 0} \\ \boldsymbol{= 1 \text{ if } 0 < y^* \leq \alpha_1} \\ \boldsymbol{= 2 \text{ if } \alpha_1 < y^* \leq \alpha_2,} \\ \\ \boldsymbol{= J \text{ if } \alpha_{j-1} \leq y^*} \end{cases}$$

Where values of y are observed $\boldsymbol{\alpha}$ and are unknown parameters to be estimated. We assume that $\boldsymbol{\varepsilon}$ follows a normal distribution with zero mean and unit variance. Then the probabilities of each outcome can be expressed as:

$$\boldsymbol{\Pr(y = 0 \mid x) = \Phi(-x'\beta)}$$
$$\boldsymbol{\Pr(y = 1 \mid x) = \Phi(\alpha_1 - x'\beta) - \Phi(-x'\beta)}$$
$$\boldsymbol{\Pr(y = 2 \mid x) = \Phi(\alpha_2 - x'\beta) - \Phi(\alpha_1 - x'\beta)}$$

$$\boldsymbol{\Pr(y = J \mid x) = 1 - \Phi\left(\alpha_{J-1} - x'\beta\right)}$$

As per Greene (2007), the researchers further measured the intensity of adoption by taking the number of technologies adopted by the households as the dependent variable. It was assumed that: (i) provided a household derives greater utility from the last adopted technology, there is a limit of five practices; (ii) the adoption decision of the farming household to one agricultural technology/practice does not rule out the adoption of the another available technology since the effects of certain technologies could be complementary; and (iii) the adoption of agricultural practices/technologies elements could be independent due to the variable needs and conditions of producers. Smallholder maize farmers were categorized as follows: Those who didn’t practice any SAP were referred to as non-adopters, while those who practiced 1 to 3 were referred to as partial adopters, and lastly those who used 4 to 5 practices were categorized as full adopters.

Table 2: Description of Variable used in the study

Variables	Measure	Expected Sign	Justification
Crop rotation	If a farmer practised crop rotation 1, 0 if not	N/A	Helps improve soil health, decrease the occurrence of pests and diseases, improve crop diversification and preventing soil erosion (Teixeira *et al*., 2018).
Improved maize varieties	If a farmer used improved maize 1, 0 if not	N/A	Superior cultivars, with tolerance to disease and environmental shocks like drought and floods, can further help farmers adapt to climate change, ensure food security and improve livelihoods (Masuka *et al*., 2017).
Intercropping	If a farmer practised intercropping 1, 0 if not	N/A	Improves productivity, hence promoting sustainable utilization of resources such as land and water; diversifies income sources (Teklewold et al. 2019).s
Crop residual	If a farmer practised crop residual 1, 0 if not	N/A	Enhances soil moisture and fertility and reduces soil erosion (Chalise *et al*., 2019).
Manure	If a farmer used manure 1, 0 if not	N/A	Improves soil structure and its water-holding capacity with minimum leaching (Khaitov *et al.,* 2019).
Age of the household head	Years	+/-	Older farmers with better farm experience are more likely to practise SAPs (Mazvimavi and Twomlow, 2009; Ngwira *et al*., 2014; Ng'ombe *et al*., 2017).
Education of the household head	Level of education attained by household head-1= primary, 2= secondary 3= university, 4=technical	+	Increases the speed with which SAPs information is processed and may likely lead to SAP adoption (Kotu *et al*., 2017; Ng'ombe *et al*., 2017; Khonje *et al*., 2018).
Sex of the household head	1= Male, 0 = Female	+/-	Agricultural technologies/practices are deeply gendered, from its inception in research and development to its diffusion, access, and adoption. (Mazvimavi & Twomlow, 2009; Congress *et al*., 2010; Ngwira *et al*., 2014; Ng'ombe *et al*., 2017).
Farming experience	Number of years of farming (years)	+	Useful in the early stages of adoption of a given technology when farmers are still testing its potential benefits (John &Mugisha, 2014).
Household Size	Number of members in the household	+	Household size is a quite notable proxy of labour supply that can as well influence the usage of certain technology or practice (Usman *et al.,* 2022).
Farm size	Available land for production (measured in Acre)	+/-	Allow flexibility in using SAPs alongside other GAPs to spread risks. The expected effect is mixed depending on the technology under consideration (Mazvimavi&Twomlow, 2009; Ngwira et al., 2014; Ngoma *et al*., 2021).
Soil fertility	1 (if the plot has fertile soil)[2], 0= if otherwise	+	Increases the quality and quantity of crop yields over the long term because it keeps topsoil in its place and preserves the long-term productivity of the soil (Mwaura et al., 2017).

Geographical location	1= Kilosa District 0 = Mvomero District	+/-	Accounts for agro-ecological differences that may have mixed effects on the adoption of SAPs (Mazvimavi & Twomlow, 2009; Arslan et al., 2014; Pedzisa et al., 2015).
Group membership	1= Yes, 0 =No	+	Increases farmer access to key services such as credit and extension services which are critical for SAPs uptake (Kansiime *et al.,* 2022).
Access to extension services	Number of extension contacts per agricultural season	+	Extension services increase information on SAPs awareness and subsequent uptake and application of SAPs principles (Mazvimavi & Twomlow, 2009; Wossen *et al*., 2017; Fisher *et al*., 2018; Ngoma *et al*., 2021).
Distance to the market place	Kilometers (Kms)	-	Increases transaction costs and thus limits access to inputs/ technologies (Kotu *et al*., 2017; Wossen *et al*., 2017).
Land ownership	1 If the farmer is the owner of the land, 0 = otherwise	+/-	Reflects tenure security status and reduces the likelihood of investing in SAPs due to the limited time horizon because of the lack of land tenure security rights (Arslan, 2014).
Access to credit	1=If the farmer has access to credit, 0= otherwise	+	Provide incentives for farmers to practice SAPs (Kansiime *et al.,* 2022).
Livestock ownership	Total tropical Livestock Unit	-	May conflict with SAPs principles (such as mulching) uptake due to competition over crop residues for feed (Ngwira *et al*., 2014; Ng'ombe *et al*., 2017).
Occupation	Number of occupations of the household head	+	Having a job outside agriculture provides additional income and financial stability. This means the farmer may have more resources available to invest in agricultural technology. Purchasing and adopting new technologies can be costly, so having an additional source of income increases the farmer's capacity to afford and implement these innovations (Tefera *et al.,*2018).
Production diversity	Number of crops cultivated	+/-	Production diversity can help reduce the vulnerability of farmers to market fluctuations, pests, diseases, and climate-related risks (Bongole, 2021). Also, managing diverse production systems can be more challenging and time-consuming. Farmers may be hesitant to adopt new technologies due to the complexity of integrating them into their diverse farming operations (Gatti *et al*., 2023).

Soil fertility is somewhat subjective and region- dependent. Unfortunately details about how fertility was measured and what constitutes fertile soil are infrequently reported.

Results and Discussion

Adoption Rate of Sustainable Agriculture Practices

It is evident from Table 3 that crop rotation, manure and improved seeds were the most widely used SAPs, with adoption rates of 55%, 43% and 60% respectively. Among the five SAPs addressed by the study, crop residual and intercropping were the least popular. Table 3 illustrates that the total average of the adoption rate of SAPs by smallholder maize farmers exceeded 45%, implying a moderate usage of these practices.

Table 3: Adoption Rates of SAPs

Type of SAPs	Adoption rate (%)
Intercropping	40
Crop rotation	55
Manure	43
Crop residual	30
Improved seed varieties	60

The adoption intensity of SAPs

The findings in Table 4 reveals the intensity of SAPs adoption among smallholder maize farmers, specifically in terms of the quantity of SAPs embraced. The results underscore that the degree of SAPs adoption were notably elevated when one to three SAPs (improved seed varieties, crop rotation and manure) are implemented. These empirical findings corroborate with earlier scholarly investigations, which have consistently asserted that agricultural technologies are commonly embraced by producers in composite arrangements, as evidenced by Bongole (2021), Kassie et al. (2013) and Usman (2022).

Table 4: Adoption intensity

Number	Frequency
1	201
2	150
3	80
4	25
5	14

Note: Combination between SAPs exhibits a multitude of variations

Determinants to the Adoption Intensity of Multiple SAPs

The results in Table 5 demonstrate that a farmer with high farming experience had a probability of using three, four, and five practices by 4.12, 4.06, and 5.40 per cent points, respectively, than the inexperienced ones. These findings corroborate with the findings of Yang et al. (2021) who argued that as farmers acquire more experience, they can evaluate the benefits of using innovation and as a result, intensity increases. This is contrary to Gatti et al. (2023) who reported that experiences had heighten farmers' perception of risks and uncertainties associated with adopting agricultural technologies. It is argued that farmers' encounters with unexpected challenges, crop failures, or negative consequences in the past may heighten their views on technology adoption as a risky endeavor. The perception of risk can discourage them from embracing new technologies such as improved seed varieties. Consequently, this perspective implies that individual coping mechanisms, technology maturity could significantly shape farmers' perceptions on the adoption of SAPs.

The results in Table 5 indicate that households headed by farmers with higher levels of formal education exhibited a high adoption intensity of multiple SAPs. The findings show that the adoption intensity increased by 3.01, 2.51, and 4.90 per cent points for the two, three, and four practices, respectively. The findings confirm those of studies by Ali et al. (2020) and Emmanuel et al. (2021) which showed that more educated farmers had higher rate of adoption of improved maize varieties. This implies that most of the respondents in the study area were capable of effectively following and using instructions or guidance for the application of SAPs. Results are consistent with those by Paltasingh (2016), Paltasingh and Goyari (2018) which reported that education helped farmers in making informed decisions including adopting modern agricultural technologies in India.

Households with higher production diversity had higher probability of using three, four and five practices by 3.12, 6.10 and 4.03 per cent points, respectively, compared to those with less production diversity. This is consistent with Teklewold et al. (2019) who found that farming household in Ethiopia diversified their production system to mitigate the risks of production shocks. Similarly, Bongole (2021) reported comparable observations in Tanzania.

Table 5: Coefficients for the ordered Probit model for the adoption intensity of bundled SAPs.

Variables	Coef.	Std. Err.	Pr (Y = 0|X)	Std. Err.	Pr (Y = 1|X)	Std. Err.	Pr (Y = 2|X)	Std. Err.	Pr (Y = 3|X)
Sex of the household head	0.1901	0.1322	0.005	0.00143	-0.02534	0.0278	0.0340*	0.00128	0.0205**
Age of the household head	0.0108	0.0021	0.001	0.00030	-0.00061	0.0011	-0.0007	0.00051	0.0017
Farm experience	-0.0310	0.0031	0.000	0.00021	0.00053	0.0007	0.0003	0.00149	0.0412**
Production Diversity	0.1127	0.0291	0.0051	0.00127	0.0201	0.0046	0.0102	0.00420	0.0312***
Occupation	0.1109	0.0454	0.0076	0.00225	0.0316	0.0084	0.0290	0.00781	0.0211***
Level of Education	0.0150	0.0101	-0.001	0.00051	-0.00262	0.0021	0.0301***	0.00171	0.0251**
Household size	0.0021	0.0236	-0.001	0.00061	-0.00308	0.0035	0.0045	0.00217	0.0398
Tropical Livestock Unit	0.0066	0.0094	0.000	0.00041	-0.001	0.0017	-0.0009	0.00156	0.0005
Farm size	0.0000	0.0022	0.000	0.00033	2.61E-06	0.0006	0.0000	0.00054	0.0302**
Geographical location	-0.1076	0.0615	0.0042	0.00260	-0.0134	0.0114	0.0215	0.01042	0.0406**
Soil fertility	-0.0099	0.0560	0.000	0.00246	0.01595	0.0102	0.0015	0.00932	-0.0008
Membership	0.2010	0.0552	0.0065	0.00165	-0.0354	0.0117	0.0291	0.01007	0.0277***
Extension services	-0.0412	0.0769	0.002	0.00359	0.007573	0.0143	0.007	0.01245	-0.0039
Access to market	-0.0001	0.0001	0.010	0.00123	1.41E-05	0.0000	0.001	0.00002	0.0000
Plot ownership	0.1489	0.0810	-0.0051	0.00367	-0.02525	0.0108	0.0201*	0.01325	0.0311**

Variables	Pr (Y = 4|X)	Std. Err.	Pr (Y = 5|X)	Std. Err.
Sex of the head of the household	0.0125*	0.0361	0.0161	0.0081
Age of the household head	0.0011	0.004	0.0010	0.0013
Farm experience	0.0406**	0.011	0.0540**	0.0085
Production diversity	0.0610***	0.009	0.0403***	0.0040
Occupation	0.0366***	0.016	0.0191***	0.0038
Level of education	0.0490**	0.001	0.0013	0.0010
Household size	0.0233	0.003	0.0302	0.0010
Tropical Livestock Unit	0.0041	0.002	0.0005	0.0008
Farm size	0.0411***	0.003	-0.0001	0.0003
Geographical location	0.0211***	0.019	0.0206**	0.0081
Soil fertility	-0.0018	0.011	-0.0008	0.0050
Membership	0.0408***	0.020	0.0190	0.0056
Extension services	-0.0084	0.016	-0.0036	0.0065
Access to market	0.0001	0.002	0.0011	0.0001
Plot ownership	0.0275***	0.025	0.0223	0.0062
/cut1	1.498165	0.319682		
/cut2	2.509412	0.380126		
/cut3	3.406715	0.322087		
/cut4	4.339516	0.327751		
/cut5	5.308471	0.390562		

*, **, and *** indicate statistical significance at $p < 0.1$, $p < 0.05$ and $p < 0.01$ respectively.

The findings in Table 5 further show that having multiple jobs significantly influenced the adoption intensity of multiple SAPs. It was found that the probability of using three, four and five practices were 2.11, 3.66 and 1.91 per cent points, respectively, higher among farming households with multiple jobs compared to those with fewer occupations. These findings concur with those by Bongole (2021) in Tanzania but contradict those by Tuda et al. (2019) who found that multiple occupations decreased the intensity of using more than two practices in Malawi.

Male-headed households were more likely to use two, three and four practices by 3.40, 2.05, and 1.25 per cent points, respectively, higher than female-headed households. The findings support previous results by Asante et al. (2021) who reported that males are less preoccupied with daily family management duties, giving them more time to interact with extension workers. Additionally, male-headed households tend to have a better financial status partly due to their ability to work in multiple jobs. Similarly, Kapoor (2019) reported that male-headed households had greater access to cash as an asset compared to female-headed households, which was attributed to the higher hourly earnings of males in various occupational groups in Ghana.

Membership in farmer organizations had a significant impact to the intensity of SAPs usage. The findings indicate that the likelihoods of using two, three, and four practices were 2.77 and 4.08 per cent points, respectively, higher for members of farmer's organization. This can be attributed to the knowledge sharing platform provided by such settings, which played a critical role in increasing knowledge about SAPs and sharing success testimonies. The group pressure within the organization could serve as a push factor for intensifying the adoption of SAPs. These findings are consistent with findings of previous research by Teklewold et al. (2019) and Bongole (2021) who reported that membership in farmer organizations increased the intensity use of Good Agricultural Practices (GAPs) and Climate Smart Agricultural Practises (CSAPs) among farming households in Ethiopia and Tanzania respectively.

The results in Table 5 show a significant positive relationship between farm size and the number of SAPs used. This implies that farmers with larger farm sizes were 3.02 and 4.11 per cent points more likely to use three and four practices, respectively, compared to those with smaller farm sizes. This is consistent with Akter et al. (2021) who found that land size positively influenced the number of agriculture-based technologies used by a farmer in rice-maize systems in Bangladesh. A plausible reason for this could be that a larger farm size serves as a security against the risk of crop failure.

Agricultural households in Kilosa district showed higher probability of using three, four and five practices by 1.02, 2.11, and 2.06 per cent points, respectively, compared to agricultural households in Mvomero district. The difference in the intensity of adoption of SAPs can be attributed to varying climatic conditions such as rainfall within their respective locations. This is consistent with Arslan et al. (2017) Bongole (2021) and Kassie et al. (2013) who concluded that farming households in developing countries such as Tanzania exhibit differentiation in their agricultural output due to varying climatic conditions and soil characteristics of their locations.

The likelihoods of using two, three and four practices were 2.01, 3.11, and 2.75 per cent points, respectively, higher on farms/plots that were owned versus rented farms/plots for agricultural production. Farmers who lease or rent plots of land may be hesitant to invest in agricultural technologies, particularly if the lease term is short or uncertain. The temporary nature of their access to the land limits their willingness to invest in technologies that may not yield immediate returns or that require long-term commitments. Moreover, lack of long-term control over land can discourage the adoption of technologies that require substantial investments or alterations to the plot. The findings are corroborated by Teklewold et al. (2019) who found comparable results in their Ethiopian study.

The study found that tropical livestock unit, household size, soil fertility, access to market and access to extension services were not significantly related to the adoption intensity of SAPs in the study areas. These findings are consistent with the previous research by Tuda *et al*. (2019 on Tropical livestock units in Ghana, Wainaina *et al*. (2016) on household size in Kenya, Mwaura *et al*. (2021) on soil fertility in Kenya, Kotu *et al*. (2017 on market access in Ghana and Wossen *et al*. (2017 on access to extension services in Nigeria.

Conclusions and Recommendations

The study concludes that the rate of SAPs adoption among the surveyed population was average, indicative of a moderate level of uptake. Furthermore, education level, occupation, farming experience, sex of the household head, farm size, plot ownership, geographical location, membership in farmers' organization and production diversity had significant impacts on the adoption intensity of multiple SAPs. Hence, the authors failed to accept the H_0, implying that the adoption intensity can significantly be influenced by the socio economic, institutional and farm related factors.

There were greater disparities in the adoption intensity than in the adoption rates; the awareness and recognition of SAPs did not necessarily translate into increased usage while the socio-economic factors, institutional and farm related factors had significant influences on the adoption intensity of multiple SAPs. Thus, the study recommends that the interdependence nature of agricultural innovations should be considered in designing effective strategies for the development and dissemination of agricultural SAPs. Such an intervention should provide farmers with a choice among different sets of practices that possess desirable traits such as high yields, cost effectiveness, and suitability to local climatic conditions.

Given that diverse factors influence the different combination of SAPs, it is important that in designing incentives that smallholder farmers should use multiple SAPs; policymakers should take into consideration farm managerial, socio-economic and plot-specific factors to ensure that farmers can maximize the benefits of SAPs. Examples of such incentives include provision of training programs designed to enlightening farmers on the benefits of SAPs as well as on first-hand information on weather conditions. Furthermore, shock management strength of farmers should be well examined and considered when designing and executing dissemination schemes for different SAPs. Lastly, it remains a subject for further exploration to discern the potential impacts of adopting multiple SAPs on the production outcomes and overall welfare of smallholder maize farmers such as yield, household incomes and food security. Addressing this gap in adoption is crucial to unlock the full potential of these practices.

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