Unlocking the drivers of smallholder farmers' adoption of improved seed varieties in Kilosa District, Tanzania

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ABSTRACT

This study examines the determinants affecting the adoption of improved seed varieties of maize, rice, and sunflower among smallholder farmers in Kilosa District, Tanzania. Data were collected from a cross-sectional household survey of 243 farmers, who were randomly selected. Descriptive statistics and multivariate probit analysis were employed for data analysis. The findings revealed a significant negative association between the adoption of improved maize and improved rice varieties, indicating that the adoption-enhancing factors of either improved maize or improved rice varieties would negatively impact adoption in the other. Conversely, the adoption of improved sunflower varieties was not interdependent. However, the adoption of improved maize varieties was positively influenced by farm size and the level of education and extension contact. Nevertheless, extension contact and household size positively influenced the uptake of improved rice varieties, while the effect of education was marginally positive. Regarding sunflower varieties, education was the significant factor, and the availability of credit was marginally significant. The study recommends that improving agricultural extension services and enhancing the accessibility and provision of information to farmers would greatly impact the uptake of improved seed varieties and the increased agricultural output of smallholder farmers in Tanzania.

Keywords: Adoption, Improved Seed Varieties, Multivariate Probit, Tanzania, Smallholder Farmers

I. INTRODUCTION

Agriculture remains the backbone of most Sub-Saharan African economies, contributing significantly to employment, rural livelihoods, and national food security, particularly among smallholder farmers who dominate agricultural production systems (FAO, 2021; IFAD, 2019). Despite its importance, agricultural productivity in the region remains low, largely due to limited adoption of improved agricultural technologies, including certified and high-yielding seed varieties (Suri and Udry, 2022). In Tanzania, the agricultural sector continues to be characterized by small-scale, subsistence-oriented farming systems with weak integration into input and output markets (URT, 2021).

Improved seed varieties are widely recognized as a key driver of agricultural productivity growth and food system transformation in developing countries (Assaye et al., 2022; Khonje et al., 2015). However, despite their potential benefits, adoption rates of improved seed varieties remain relatively low and uneven across Sub-Saharan Africa, including Tanzania, where farmers often continue to rely on recycled or local seed varieties with lower productivity potential (Wossen et al., 2018; Ragasa and Mazunda, 2018). Empirical studies reported that factors such as exposure to sex, farm size, education level, and extension visits are important determinants of improved seed adoption (Kebede., 2020; Okonji and Awolu., 2020). More broadly, adoption can be conceptualized as a process that unfolds over time, in which factors such as social networks and expectations regarding support during crop failure may affect the speed of adoption (Abebe and Kassie, 2015).

In Tanzania, and particularly in Kilosa District, agriculture is predominantly rain-fed and characterized by smallholder farmers cultivating limited land sizes under constrained access to modern inputs and financial services (Mwatawala et al., 2019). Previous studies conducted in Kilosa and similar districts indicate that adoption of improved seed varieties is influenced by factors such as extension contact, access to credit, market proximity, and household socio-economic characteristics (Kaliba et al., 2018; Mugula et al., 2023). However, most of these studies focus on single specific crops and do not provide a consolidated understanding of adoption behavior across broader contexts.

Moreover, existing evidence in Tanzania is largely fragmented, with many studies relying on case-specific econometric approaches such as logit, probit, and multinomial models (Mmbando and Baiyegunh, 2016; Lasway et al., 2020; Kimbi et al., 2021). As a result, there remains limited integrated empirical evidence on the determinants of improved seed adoption in specific high-potential agricultural districts such as Kilosa, despite its importance in national food production systems. Therefore, this study examines the determinants of smallholder farmers' adoption of improved seed varieties in Kilosa District, Tanzania. Specifically, it analyzes how socio-economic, institutional, and farm-level factors influence the probability of adopting improved seeds using a multivariate probit model. The study contributes to the literature by providing localized empirical evidence from an important crop-producing district and by integrating multiple explanatory factors within a unified analytical framework. The rest of the paper is organized as follows: Section 2 presents a literature review, Section 3 presents the methodology, Section 4 presents the results and discussion of the results, and Section 5 provides a conclusion and recommendations.

1.2 Research Objective

The objective of the study was to examine the drivers of smallholder farmers' adoption of improved seed varieties in Kilosa District, Tanzania.

II. LITERATURE REVIEW

2.1 Theoretical Framework

2.1.1 Random Utility Theory

This study is grounded in Random Utility Theory (RUT), which provides a microeconomic foundation for modeling discrete choice decisions under uncertainty (McFadden, 1981). RUT assumes that when faced with a set of alternatives, a rational decision-maker selects the option that yields the highest utility. In this study, smallholder farmers in Kilosa District decide whether to adopt improved maize, rice, and sunflower seed varieties based on the expected benefits and costs of each option. Let U_1 represent the utility derived from adopting an improved seed variety, and U_0 represent the utility derived from non-adoption. A farmer will choose to adopt if:

$$U_1 > U_0$$

Utility is not directly observable but can be expressed as a function of observable and unobservable components:

$$U_{ij} = V_{ij} + \varepsilon_{ij}$$

where V_{ij} is the deterministic (observable) component of utility associated with farmer i choosing alternative j, and ε_{ij} is the random component capturing unobservable factors. The deterministic component V_{ij} is specified as a linear function of observable farmer, household, farm, and institutional characteristics:

$$V_{ij} = \beta_j X_i$$

where X_i is a vector of explanatory variables such as age, sex, education, household size, farm size, farming experience, access to credit, extension services, membership in farmer groups, and distance to input markets, while β_j represents parameters to be estimated.

The probability that farmer i adopts an improved seed variety can therefore be expressed as:

$$P(\text{Adopt}) = P(\varepsilon_i < V_1 - V_0)$$

The probability that farmer i adopts an improved seed variety equals the probability that the unobserved random factor (ε_i) is less than the observable net benefit derived from adoption ($V_1 - V_0$). In this study, farmers may adopt improved maize, rice, and sunflower seed varieties simultaneously. The adoption decisions are likely to be interrelated because unobserved factors influencing the adoption of one seed variety may also influence the adoption of another. Therefore, Random Utility Theory provides the theoretical foundation for employing a Multivariate Probit (MVP) model, which simultaneously estimates the adoption decisions for improved maize, rice, and sunflower seed varieties while accounting for potential correlations among these decisions.

2.2 Empirical Review

Empirical literature on the adoption of improved seed varieties in developing countries consistently shows that adoption decisions are influenced by a combination of socio-economic characteristics, institutional access, and resource endowments. Early theoretical and empirical work by Feder et al., (1985) establishes that agricultural technology adoption is determined by farmers' human capital, risk preferences, farm resources, and access to information. This framework is widely supported by subsequent empirical studies, which emphasize that imperfect information, liquidity constraints, and heterogeneous farmer characteristics constrain adoption.

Nevertheless, evidence from Sub-Saharan Africa supports this theoretical work. Across the region, adoption of improved seed varieties is consistently influenced by education, farm size, extension access, and social capital. In Ethiopia, Siyum et al. (2022) reported that adoption of improved wheat technologies is significantly influenced by the number of oxen, education level, mobile phone ownership, household age, and access to extension services, highlighting

the combined role of asset ownership and information access. Similarly, Kebede (2020) reports that farm size, livestock ownership, extension contact, and access to credit positively influence the adoption of improved wheat technologies, while age, distance to markets, and distance to training centers reduce adoption likelihood in Ethiopa. In Ethiopia, Teshome et al. (2019) also revealed that adoption of improved potato varieties is positively associated with income diversification, extension services, training participation, and membership in cooperatives, while the age of the household head negatively affects adoption. In Nigeria, Adebayo et al., (2018) and Okonji and Owolu (2020) also confirm that education, extension contact, farming experience, input use practices, and social participation significantly enhance the adoption of improved crop technologies. Nevertheless, in Tanzania, Kimbi et al. (2021) find that adoption of improved sorghum technologies is significantly influenced by education level, household characteristics, and extension services, while institutional support plays a key enabling role. Overall, these studies suggest that adoption in Sub-Saharan Africa is strongly driven by both human capital and institutional access, while resource constraints and weak market access continue to limit uptake.

III. METHODOLOGY

3.1 Research Design

In this study, a cross-sectional research design was employed. This design involves collecting data from a sample of respondents at a single point in time, allowing the researcher to obtain a snapshot of the variables of interest across different groups simultaneously. It is also advantageous because it enables the researcher to capture diverse perspectives within a relatively short period. Moreover, the design is economical in terms of both time and financial resources, making it suitable for studies with limited budgets.

3.2 Study Area

The research was conducted in Kilosa District, Tanzania. Kilosa District is an important agricultural district of Morogoro region, known for having a high number of smallholder farmers and various agricultural practices. Kilosa District is a fertile agricultural district with suitable climate that facilitates cultivation of food and cash crops such as maize, rice, sunflower and other food crops that play a critical role in contributing to the economic livelihoods of households and regional food security. The reason behind choosing Kilosa District for the research is the high agricultural potential and prevalence of smallholder farmers who derive their economic survival from agriculture.

3.3 Target Population

The target population for this study comprised smallholder farmers in Kilosa District, Tanzania. Specifically, it included households engaged in crop production who have the potential to adopt or have already adopted improved seed varieties. These farmers were selected because they are directly involved in agricultural production decisions, including seed selection and adoption of improved agricultural technologies. Therefore, they possess relevant and reliable information on the factors influencing the adoption of improved seed varieties, which is central to the objectives of the study.

3.4 Sampling and Sample size

Kilosa District was purposively selected because it is a prominent crop-producing area in Tanzania. A sample size of 243 farmers was determined using Cochran's (1977) formula. Subsequently, a simple random sampling technique was employed to select 243 households engaged in crop farming for participation in the study.

3.5 Data Collection Instruments and Procedures

A structured questionnaires were adopted as an instrument for data collection from respondents involved in crop farming. Questionnaires were structured in accordance with the objective of the study. Moreover, a permission was acquired from local authorities before starting the data collection.

3.6 Data Analysis

The collected data were analyzed using both descriptive and inferential statistical techniques to address the study objective. Descriptive statistics were employed to summarize and present the dataset's basic characteristics. Specifically, measures such as means, and standard deviations. Inferential statistics enabled the estimation of the factors influencing the adoption of improved seed varieties.

3.6.1 Model Selection

In this study, a Multivariate Probit (MVP) model was used to analyze factors influencing farmers' adoption of improved seed varieties. The MVP model is appropriate because farmers may adopt more than one improved seed

variety simultaneously, and these adoption decisions may be interrelated. The model therefore, allows the estimation of multiple binary adoption decisions while accounting for possible correlations among them (Greene, 2018; Cappellari and Jenkins, 2003).

The latent adoption decision for improved seed varieties *j* by farmer *i* is specified as:

$$Y_{ij}^{*} = X_j'\beta_i + \varepsilon_{ij}$$

The observed adoption outcome is defined as:

$$Y_{ij} = \begin{cases} 1, if\ Yij * > 0 \\ 0, if\ \text{oherwise} \end{cases}$$

Where:

Y_{ij}^{*} is the latent (unobserved) utility associated with the adoption of improved seed variety *j* by farmer *i.*

Y_{ij} is the observed adoption decision for improved seed variety $_j$ by farmer $_i$.

Y_{ij} = 1 if the farmer adopts the improved seed variety and Y_{ij} = 0 otherwise

X_i is a vector of explanatory variables influencing adoption decisions

β_i is a vector of parameters to be estimated

ε_{ij} is the error term

i =1, 2, 3$_i$ n denotes the farmers (observations)**.**

j = 1, 2, 3,,...,n denotes the improved seed varieties (maize, rice, and sunflower)

The Descriptions of variables, and their expected signs are shown in **Table 1.**

Table 1

Descriptions of variables and expected signs

Variables	Variables Descriptions	Expected sign
Age	Number of years	-
Sex	1 if male; 0 if otherwise	+/-
Education	Number of years in school	+/-
Farm size	Continuous(acres)	+
Land tenure	1 if owned; 0 if otherwise	+
Credit access	1 if farmer accessed credit; 0 if otherwise	+
Extension contacts	Continuous (number of contacts)	+
Group membership	1 if member of farmer group; 0 if otherwise	+
Distance to market	Continuous(km)	+/-
Household size	Number of adults in the household	+
Off-farm income	1 if farmer engaged in off-farm activities; 0 if otherwise	+/-

3.7 Ethical Considerations

This study ensured that all ethical principles were strictly observed during the research process. On the other hand, prior to the administration of the questionnaire, consent was sought from all the respondents. Participation in this research was purely on a voluntary basis. The respondents were guaranteed anonymity and confidentiality. Moreover, no names or any other personal identifiers have been collected by the respondents in the questionnaire.

IV. FINDINGS & DISCUSSION

4.1 Descriptive Statistics of the Dependent and Independent Variables Used in the Model

Table 2 presents the descriptive statistics of the dependent and independent variables included in the analysis. The results indicate that 52.0% of the sampled farmers adopted improved maize varieties, while 48.0% and 45.0% adopted improved rice and sunflower varieties, respectively. These figures suggest a relatively moderate level of adoption of improved seed varieties among smallholder farmers in Kilosa District.

Moreover, the average age of household heads was 43.7 years (SD = 15.25), indicating that most respondents were within the economically active age group. The mean value for sex was 0.543, implying that approximately 54.3% of the sampled households were male-headed. Respondents had an average of 8.3 years of formal education (SD = 5.11), suggesting that most farmers had attained at least primary education. The average farm size was 5.33 acres (SD = 2.62), indicating considerable variation in landholding among households. Likewise, about 67.1% of respondents owned the land they cultivated, as reflected by the mean value of land tenure (0.671). Furthermore, only 37.9% of farmers reported having access to credit services, suggesting limited access to financial resources that could facilitate agricultural investment.

On the other hand, on average, farmers had approximately three extension contacts per year (mean = 3.04, SD = 1.62), highlighting the presence of extension support, although the frequency varied across households. The mean

value for group membership was 0.519, signifying that about 51.9% of respondents belonged to farmer groups or associations. The average distance to the nearest market was 16.74 kilometers (SD = 8.25), suggesting that some farmers faced substantial market access challenges. Also, household size averaged 4.36 members (SD = 2.28), which is consistent with the typical rural household structure in Tanzania. Additionally, about 42.8% of households participated in off-farm income-generating activities, implying that a considerable proportion of farmers relied on supplementary income sources besides farming.

Table 2

Descriptive statistics of the dependent and independent variables used in the model

Variable	Mean	SD
Maize variety	0.520	0.500
Rice variety	0.480	0.500
Sunflower variety	0.450	0.500
Age	43.700	15.246
Sex	0.543	0.499
Education	8.313	5.110
Farm size	5.333	2.619
Land tenure	0.671	0.471
Access to credit	0.379	0.486
Extension contacts	3.037	1.617
Group membership	0.519	0.501
Distance to market	16.741	8.254
Household size	4.362	2.282
Off-farm income	0.428	0.496

4.2 Determinants of Farmers' Adoption of Improved Seed Varieties

The results of the multivariate probit model presented in Table 3 indicates the socio-economic determinants of farmers' adoption of improved maize, rice, and sunflower seed varieties. The model further accounts for potential correlations among unobserved factors influencing the adoption decisions. The estimated results show that only the correlation between maize and rice adoption ($\rho_{(21)} = -0.483$, $p = 0.004$) is statistically significant and negative, suggesting that unobserved factors increasing the likelihood of adopting improved maize varieties are associated with a reduced likelihood of adopting improved rice varieties. In contrast, the correlations between sunflower adoption and maize adoption (ρ_{31}) and between sunflower and rice adoption (ρ_{31}) are statistically insignificant, indicating that sunflower adoption decisions are independent of the other two crop choices in terms of unobserved influences. Furthermore, the joint likelihood ratio test of the correlation coefficients ($\chi^2 = 7.41$, $p = 0.06$) provides marginal evidence of overall dependence among the adoption decisions, suggesting weak but not strongly conclusive interdependence across the three equations.

For the adoption of improved maize varieties, factors such as age, education, land size, contact with extension services, and distance to market have a significant impact. The explanatory variable age has a negative and significant effect ($p = 0.016$), demonstrating that the likelihood of adopting improved maize varieties decreases as farmers' age increases. Old farmers usually stick to traditional agriculture methods and are not ready to experiment with new methods. The inverse relationship between age and adoption supports Teshome et al. (2019), who found that younger farmers are more willing to take risks and adopt improved technologies than older farmers'.

Also, an explanatory variable education level has a positive and highly significant impact ($p = 0.01$) on adoption of improved maize varieties. This is consistent with prior study by Okonji and Owolu (2020) who found that education is significantly associated with the adoption of improved maize varieties. The strong positive effect of education aligns with the argument that human capital enhances farmers' ability to process and utilize agricultural information effectively. Nevertheless, farm size is positively and significantly related to seed adoption ($p = 0.01$). This indicates that farmers with large farms have a high chance of using improved maize seeds due to their abundant resources to experiment with improved technologies. The role of farm size aligns with the findings by Kebede (2020), who emphasized that larger landholdings reduce risk aversion and allow experimentation. Moreover, the number of contacts a farmer makes with an extension officer positively and significantly affects seed adoption ($p = 0.01$). When a farmer frequently interacts with an extension officer, he/she learns more about the availability of improved seeds and how to use them, thus increasing the chances of adopting improved seeds. Furthermore, the significance of extension services is consistent with findings by Adebayo et al., (2018), Teshome et al., (2019), Siyum et al., (2022), who highlighted the importance of information dissemination in technology uptake. Likewise, the distance of a farmer to a market location negatively

and significantly influences seed adoption (p = 0.006). This shows that the further away a farmer is from a market, the lower the probability that the farmer adopts improved maize seeds.

Regarding the adoption of improved rice varieties, extension contacts and the number of people in households are significant determinants of adoption. The coefficient of extension contact is positive and statistically significant at (p = 0.009), and therefore, farmers who interact with extension workers often tend to adopt improved rice varieties because they gain more agricultural knowledge through such interactions. The positive and significant effect of extension contact strongly supports Okonji and Owolu (2020) views, who found that access to extension services is a key driver of improved seed adoption in Bangladesh. Nevertheless, the number of people in the households is positive and statistically significant at (p = 0.017), and hence larger households adopt improved rice varieties. This may mean that large households have sufficient labor for growing their crops.

Concerning the adoption of improved sunflower varieties, the independent variable, education, has an important effect on the adoption of new varieties (p = 0.017). From the results, it is evident that farmers with high levels of education are likely to adopt new varieties of sunflower seeds since they can obtain knowledge regarding new agricultural techniques. The positive influence of education is consistent with broader adoption literature, including Adebayo et al., (2018), which emphasizes the role of knowledge in facilitating innovation uptake. Moreover, access to credit facilities is positively but marginally significantly associated with the adoption of new sunflower seeds (p = 0.079). This demonstrates that farmers with access to funds are likely to adopt the seeds, as they will have enough money to buy the improved seeds.

Table 3

Multivariate probit results on the factors influencing adoption of improved seed varieties

Variables	Improved seed varieties								
	Maize variety			Rice variety			Sunflower variety		
	Coef.	Std. Err	P-value	Coef.	Std. Err	P-value	Coef.	Std. Err	P-value
Age	-0.021**	0.009	0.016	0.003	0.009	0.724	0.005	0.009	0.614
Sex	0.098	0.245	0.688	-0.385	0.289	0.184	0.329	0.289	0.255
Education	0.143***	0.029	0.000	0.054*	0.028	0.056	0.077**	0.032	0.017
Farm size	0.258***	0.054	0.000	0.085	0.054	0.113	0.069	0.055	0.213
Land tenure	-0.190	0.268	0.479	0.278	0.303	0.359	0.406	0.293	0.165
Credit access	0.078	0.245	0.751	-0.116	0.279	0.678	0.594*	0.338	0.079
Extension contacts	0.289***	0.083	0.000	0.258***	0.099	0.009	0.003	0.091	0.978
Group membership	0.153	0.239	0.521	-0.143	0.280	0.611	0.353	0.290	0.224
Distance to market	-0.045***	0.016	0.006	0.007	0.016	0.681	-0.019	0.018	0.279
Household size	-0.027	0.052	0.610	0.159**	0.067	0.017	0.065	0.062	0.296
Off-farm income	0.284	0.252	0.259	0.219	0.300	0.465	0.507	0.337	0.132
_cons	-0.323	0.672	0.631	-0.820	0.764	0.283	-0.435	0.773	0.574

Notes: ***, ***, and * indicate significance levels at 1, 5, and 10 percent, respectively.

V. CONCLUSION & RECOMMENDATIONS

5.1 Conclusion

This study aimed to analyze the factors that influence the adoption of improved seed varieties by smallholder farmers in the Kilosa District of Tanzania, specifically for maize, rice, and sunflower crops. Using a multivariate probit model, this study found that adoption decisions across the three crops are not wholly independent. This was particularly true for maize and rice, where an inverse and significant correlation was found. This shows that the same unobserved factors that encourage the adoption of maize may also inhibit the adoption of rice. On the other hand, adoption decisions with respect to sunflowers appeared to be independent. In addition, this study indicated that smallholder farmers' adoption decisions were significantly impacted by the integration of social, economic, and institutional factors. For the improved maize varieties, adoption was influenced positively by the farmer's education, size of the farm, extension services, and proximity to market. For the rice farmers, the positive influence of extension services was significant, and education was positively correlated with rice adoption. For sunflower varieties, education was a major factor, and the access to credit, which was positive and marginally significant.

5.2 Recommendations

Based on the findings of this study, several recommendations are proposed to enhance the adoption of improved seed varieties among smallholder farmers in Tanzania. First, the government and other agricultural stakeholders should strengthen farmer education and training programs to improve farmers' knowledge and capacity to utilize improved seed varieties effectively. Adult education programs, farmer field schools, and targeted training initiatives should be

expanded to increase awareness of the benefits and proper management of improved agricultural technologies. Second, agricultural extension services should be strengthened by increasing the number of extension officers, improving their working conditions, and promoting regular interactions between farmers and extension personnel. Enhanced extension support will facilitate the timely dissemination of information and technical guidance on improved seed varieties. Third, efforts should be made to improve rural market infrastructure and accessibility. Nevertheless, investments in rural roads, input distribution networks, and market facilities will reduce transaction costs and improve farmers' access to both agricultural inputs and output markets, thereby encouraging greater adoption of improved seed technologies. Fourth, policies and programs aimed at improving smallholder farmers' access to productive resources should be enhanced. Moreover, access to agricultural credit, quality inputs, and adequate farmland should be promoted through inclusive financing schemes, input support programs, and farmer-friendly lending mechanisms. Although access to credit was not found to be marginally significant determinant of sunflower seed adoption, its positive association suggests that improved financial services may contribute to increased technology uptake. Last but not least, policymakers should adopt crop-specific intervention strategies that recognize the differing factors influencing the adoption of maize, rice, and sunflower seed varieties. Tailored approaches are likely to be more effective in promoting widespread adoption and improving agricultural productivity among smallholder farmers.

Declaration of Interest

The authors declare that they do not have any known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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