Farmer Perceptions on Appropriate Agricultural Mechanization and their Influence on Technology Use: Evidence from Smallholder Maize and Rice Farmers in Uganda

Fred Ssajakambwe[1*] Fredrick Bagamba[1] Bernard Bashaasha[1] Rosemary Emegu Isoto[1]

1. School of Agricultural Sciences, Makerere University, PO box 7062, Kampala, Uganda

* E-mail of the corresponding author: jakambwe.fred@gmail.com

This study was privately sponsored under the College of Agricultural and Environmental Sciences Research Ethics Committee grant number CAES-REC-2025-113.

Abstract

Despite the availability of a number of appropriate agricultural mechanization developed by various players in the sector, their use remains low especially among smallholder farmers. This results into low production, productivity and quality of the produce. This study seeks to show whether the low use of these technologies is explained by farmers' perceptions on appropriate agricultural mechanization and the factors that influence farmers' use of the different appropriate agricultural mechanization technologies. Utilizing cross-sectional data from users and non-users of five appropriate agricultural mechanization technologies in the production of maize and rice, an appropriate sample was determined and interviewed. Assessment of farmers' perceptions on appropriate agricultural mechanization was achieved using factor analysis. Factors influencing farmers' use of the different appropriate agricultural mechanization technologies were determined using binary probit model on each of the appropriate agricultural mechanization technology. The results show that maize shellers were most used, followed by rice threshers and walking tractors while the least used were motorized tillers and motorized sprayers. The results further show that the farmers find the available appropriate agricultural mechanization technologies beneficial and user-friendly. Factors that influence farmers' use of appropriate agricultural mechanization technologies show that farmers characteristics such as household size, level of education, location, possession of a communication asset, being married, being female, and land ownership influence farmers' use of appropriate agricultural mechanization technologies. There is need to increase farmers' exposure to different appropriate agricultural mechanization. On-site trainings, knowledge sharing and exchange visits should be encouraged. Programs that offer subsidized and free agricultural mechanization should target scattered distribution so as to reach as many farmers as possible as opposed to giving many farmers in a given location.

Keywords: Farmer perceptions, Appropriate Agricultural Mechanization, Technologies, use, Factor Analysis, Binary Probit Model

DOI: 10.7176/DCS/16-1-04

Publication date: February 28th 2026

1. Introduction

Maize and rice production in Uganda is dominated by smallholder farmers that produce 90% of both commodities in the market (UBOS, 2023: Hong *et al*., 2021). The crops have continued to increase in importance as rural cash crops and urban food commodities replacing traditional staple foods (UBOS, 2023: Kavuma & Kisaame, 2023: Hong *et al*., 2021). However, their increased production and productivity are limited by limited use of time and labor-saving technologies (Hong *et al*., 2021). To achieve meaningful development and competitiveness of agricultural enterprises, there is need to foster increased use of appropriate agricultural technologies and innovations especially among smallholder farmers (Nkonya *et al*., 2020).

There are a number of appropriate agricultural mechanization that have been promoted to solve the problem including; Animal drawn light weight plough, Power tiller drawn moldboard plough, Animal drawn ripper planter, Animal drawn inter-row weeder, Motorized rice thresher, Motorized, maize sheller, Wind powered pump system for water delivery, Low head hydraulic ram pump, Two-wheel tractors, Low-cost multipurpose tractor and the four-wheel tractors (Wanyama *et al*., 2016). These machines are designed with low-cost durable materials which makes them cheaper, easy to operate and use, easy access to spare parts and highly compatible with local conditions especially soils and topography (Epule *et al*., 2017; Wanyama *et al*., 2016). However, most smallholder farmers are still using human muscle to perform activities along the agricultural value chains. This results into a need to evaluate whether limited use of these machines is due to their unsuitability in view of farmers and factors that influence farmers' use of such technologies so as to inform efforts to increase suitability and use of these machines by smallholder farmers.

Use of the different appropriate agricultural mechanization by smallholder farmers is explained by the Diffusion of Innovations Theory (Rogers, 2003) which shows that farmers limited use of appropriate agricultural mechanization can be explained by factors such as perceived benefits, complexity, and compatibility with existing practices. The Technology Acceptance Model (TAM) (Davis, 1989) also shows that use of appropriate agricultural mechanization among smallholder farmers is explained by perceived usefulness and ease of use. And the Sustainable Livelihoods Approach (Chambers & Conway, 1992) also shows that farmers' use of appropriate agricultural mechanization is influenced by their evaluation of the impact of the technology on their impact on livelihoods.

Therefore, understanding farmer perceptions on the different appropriate agricultural mechanization technologies using the factor analysis and factors that influence use of the different appropriate agricultural mechanization technologies among smallholder maize and rice farmers in Uganda is crucial. This information is important for artisans, government and development partners to ensure that machines with suitable attributes are designed to suit farmer's needs. This would go further in increasing acceptability and use of the availed mechanization.

The findings of the study offer agricultural stakeholders including researchers, policymakers, and extension agents' necessary information to ensure that promoted appropriate agricultural technologies align with farmers' needs, are able to address farmers concerns, and offer visible benefits or perceived benefits such as labor savings and increased production so as to attract farmers to use these technologies for increased incomes. If the promoted appropriate agricultural technologies are compatible with existing practices, their acceptance levels would be high which would reduce the challenges associated with low agricultural production in developing countries.

This study is sectioned as follows: Section 1 provides the introduction followed by section 2 that provides an empirical analysis of related literature; section 3 shows the methodology used while section 4 provides the results and discussions. Finally, section 5 provides the conclusion and policy recommendations.

2. Empirical Analysis of Related Literature

Smallholder farmers' evaluation of sustainable intensification technologies highlights that farmers' knowledge and perceptions often outweigh economic incentives in determining technology adoption (Glover *et al*., 2019). However, studies on farmers' evaluation of appropriate agricultural mechanization in Uganda remain limited. Evidence shows that socioeconomic and demographic characteristics, alongside institutional factors, significantly influence farmers' evaluation and eventual use of mechanization (Feder *et al*., 1985; Doss, 2006; Guerin, 2001; Glover *et al*., 2019). Agricultural technologies perceived to be beneficial, culturally compatible, low-risk, and institutionally supported are more likely to be embraced by smallholder farmers (Keo & Roth, 2023).

Socioeconomic factors such as education, income, farm size, and access to credit shape adoption decisions (Feder et al., 1985). Institutional factors such as access to extension services, farmer group membership, and access to input markets also play a role (Guerin, 2001) in modifying farmers' perceptions on benefits and risks, such as yield improvement, labor savings, and climate resilience, further improving technology evaluation (Doss, 2006). For instance, Adesina & Zinnah (1993) demonstrated that farmers' perceptions determine whether technologies are adopted, modified, or rejected, with decisions shaped by social, economic, and environmental contexts.

Participatory approaches such as Farmer Field Schools (Braun & Duveskog, 2008) and Participatory Rural Appraisal (Chambers, 1994) enhance farmers' positive assessment of technologies through experiential learning. Farmers tend to adopt technologies perceived as beneficial, timely, and labor-efficient, while costly innovations like precision agriculture tools face limited uptake (Meijer *et al*., 2015). Cultural alignment also matters: technologies compatible with traditions and indigenous knowledge are more readily adopted, while those requiring major shifts in beliefs face resistance (Keo & Roth, 2023; Glover *et al*., 2019). For example, walking tractors in Asia are preferred due to their compatibility with low-input systems (Keo & Roth, 2023). Recent Ugandan evidence highlights that awareness gaps and limited digital literacy constrain adoption of climate-smart mechanization practices (Mafumo, 2024). In addition, weak extension systems in Uganda and limited market linkages have been identified as key constraints to appropriate agricultural mechanization uptake (Kinuthia & Mabaya, 2017).

Risk perception is another critical factor. Farmers avoid technologies associated with financial risks, environmental impacts, or performance uncertainties, such as water-intensive tools in drought-prone areas (Glover *et al*., 2019). Conversely, training, demonstrations, and peer influence increase adoption likelihood (Meijer *et al*., 2015). Digital platforms and social media now play a growing role in shaping perceptions by providing accessible information on technology use and benefits (Meijer *et al*., 2015; Glover *et al*., 2019; Keo & Roth, 2023). Yet, imported technologies often fail due to complexity and poor contextual fit (Nkonya *et al*., 2020). Recent studies in Uganda confirm these dynamics: smallholder farmers' perceptions of mechanization are shaped by affordability, accessibility, and institutional support, with adoption constrained by credit and information gaps (Ninsiima, 2021; Kinuthia & Mabaya, 2017). Climate-smart practices also show promise in improving yields but face similar barriers of awareness and resource limitations (Mafumo, 2024). Conversely, training, demonstrations, and peer influence increase adoption likelihood of appropriate agricultural mechanization (Meijer *et al*., 2015).

Access to credit remains a major barrier, limiting adoption despite perceived opportunities (Glover *et al*., 2019). Subsidized technologies or those linked to incentives are more widely accepted (Meijer *et al*., 2015; Glover *et al*., 2019). Similarly, lack of market access discourages investment in mechanization, as farmers see little benefit in boosting production without reliable outlets (Meijer *et al*., 2015). Recent Ugandan studies confirm that affordability and access to financial services are critical determinants of mechanization adoption (Ninsiima, 2021; Kinuthia & Mabaya, 2017). Farmers are more likely to adopt technologies they perceive as relevant and beneficial to their specific farming conditions. However, costly innovations such as precision agriculture tools face limited uptake compared to labor-efficient options (Meijer *et al*., 2015).

Cultural traditions and indigenous knowledge influence technology adoption. Farmers prefer technologies that align with existing practices and beliefs, while those requiring major shifts face resistance (Keo & Roth, 2023; Glover *et al*., 2019). For example, walking tractors in Asia are favored due to compatibility with low-input systems (Keo & Roth, 2023). In Uganda, mechanization options that integrate with traditional farming practices are more readily accepted (Ninsiima, 2021).

Digital platforms and social media increasingly shape farmers' perceptions by providing accessible information on technology use and benefits (Meijer *et al*., 2015; Glover *et al*., 2019; Keo & Roth, 2023). However, imported technologies often fail due to complexity and poor contextual fit (Nkonya *et al*., 2020). This study therefore investigates how Ugandan smallholder maize and rice farmers evaluate appropriate agricultural mechanization and how these evaluations influence adoption across the country's four regions.

To achieve the objectives of the study among smallholder maize and rice farmers, this study was conducted among 1088 smallholder farmers from all the four regions; Western, Central, Eastern and Northern. The study aimed at exploring farmers' perceptions about appropriate agricultural mechanization used in the production of maize and rice and their influence on use of such mechanization options.

3 Methodology

3.1 Description of the Study Areas

The study was conducted among districts leading in the production of rice and maize in the four regions of Uganda. The sample districts among regions were purposively selected to represent hubs for maize and rice production and commercialization with activities promoting mechanization along the two value chains. This resulted into Nwoya district for rice and Oyam district for maize in northern Uganda, Hoima district for rice and Masindi district for maize in Western Uganda, Mubende district for maize and Kyankwazi district for rice in central Uganda and finally Iganga district for maize and Pallisa district for rice in eastern Uganda. The districts are according to UBOS, (2023) the leading producers of the respective value chains in the respective regions.

3.2 Sampling Approaches

The sample size was determined using sampsi formula in Stata. The formula was used to determine power and sample size in clusters of the study since the outcome of using or not using the appropriate agricultural mechanization is binary in nature. The command requires the power for a given set of design parameters to calculate the sample size of a prespecified number of clusters or number of subjects per cluster for a given power (Batistatou *et al*., 2014). It is specified as follows;

clsampsi #1 #2, k1(#) k2(#) k(#) m1(#) m2(#) varm1(#) varm2(#) varm(#) rho1(#) rho2(#) cv1(#) cv2(#) ni(#)

alpha(#) power(#) onesided ratio(#) rangek1(#)rangek2(#) (#) minimum(#) maxm1(#) maxm2(#) maxm(#) sampsisampnctiarcsinlogodds) (1)

#1 #2 specifies to proportions of the two samples, according to UBOS, (2023), 0.61 is the proportion in the target population estimated to have characteristics being measured which is 0.61 for this study (61% of Uganda's population is engaged in agriculture), 0.50 is the alternative proportion (when a farmer is randomly selected, the probability that she/he uses an appropriate agricultural mechanization is 0.5) as a default.

k specifies number of clusters

m specifies to cluster sizes in samples

varm specifies to cluster size variations in samples

rho specifies to interclass correlation coefficient in samples

cv specifies to coefficient of variation of outcome in sample

ni(#) specifies the sample size for integrating the noncentral F distribution. The default is ni(10000).

Alpha (#) specifies the significance level of the test. The default is alpha (0.05).

power (#) specifies the power of the test. The default is power (0.90).

onesided indicates a one-sided test. The default is a two-sided test.

Ratio (#) specifies the allocation ratio between sample 2 and sample 1 (= N2/N1, where N1andN2 are the total sample sizes of sample 1 and sample 2, respectively).

rangek (#) adds (#−1) clusters to the prespecified k(#) number of clusters.

Minimum (#) determines the minimum sample size of subjects required to achieve the specified power (#) for given m1() and m2()

We estimated sample size for two-sample comparison of proportions at the effect size of 35, alpha of the desired level of precision (0.5%) and power desired for detecting a difference in the means of the sample units of 0.8. The estimated required sample size for the alternative proportion: n=264 per region

Our design generated a randomized sample of around 264 smallholder farmers using and not using any appropriate agricultural mechanization in each region of the study as shown in Table 1.

Table 1: Sample size per region

Region	Users	Non-users	Total
Western	132	132	264
Central	132	132	264
Eastern	132	132	264
Northern	132	132	264
Total	**528**	**528**	**1056**

The 132 farmers composed of users of the different appropriate agricultural mechanization and for comparison purposes, an equal number of 132 farmers that are non-users of appropriate agricultural mechanization were randomly selected and interviewed. This makes a total sample of 264 of farmers per region. A sampling frame was obtained from the Agricultural Engineering and Appropriate Technology Research Institute Namalere (AEATRI), Musabody and Sasakawa global together with their suppliers of the technologies. After obtaining the sampling frames of smallholder farmers using appropriate agricultural mechanization in maize and rice, a random sample of 132 users was selected with equal proportion from maize and rice farmers. Using propensity score matching by nearest neighbor, a smallholder farmer not using the technology was identified and interviewed in the neighborhood.

Therefore, the sample was drawn using a multistage sampling procedure involving communities that are leading producers of maize and rice. The primary sampling unit (PSU) was a sub-county for all the districts. A total number of 16 PSUs was selected, made up of two PSU per district culminating into four PSU per region.

The secondary sampling unit was the village. At the sub-county, two parishes were randomly selected for the survey. In each parish, one village (community) was drawn using a systematic random sampling criterion with a random start. The final sample comprised 32 villages for the whole survey. From each village, 17 households using any appropriate agricultural mechanization were randomly selected. For each household selected a neighboring household not using any appropriate agricultural mechanization was selected using propensity score matching nearest neighbor making a total of 1088 farming households. Out of the 1088 farming households, 544 were rice farmers and an equal number composed of maize farmers.

3.3 Data Collection

Cross-sectional primary data was collected in January and February 2025 through face-to-face interviews. Data were collected using a formal questionnaire pre-tested on both maize and rice farming communities. Twenty enumerators were hired and trained specifically for this study. Data for this objective included two different parts: farmer characteristics and farmer's evaluation of appropriate agricultural technologies that are available in their communities. Non-users of the technologies were asked in relation to the technology used by the neighbor so as to make a perfect match of the responses. Smallholder farmers were asked questions to assess their evaluation of technology attributes on the Likert scale from 1 to 5 with 1 for strongly disagree and 5strongly agree. The evaluation questions overlapped and could reflect more than one motivational concern toward access and use of appropriate agricultural technology in Uganda. Non-users were asked to evaluate technologies used by their matched neighbours, ensuring comparability of perceptions.

3.4 Data Analysis

Data were analyzed using descriptive statistics, factor analysis and a binary probit model for each technology. The results are hereafter presented using graphs and Tables. Factor analysis with Crawford-Ferguson rotation was performed to develop scales based on a linear combination of statement responses that have similar patterns of variation across the sample into an appropriate factor solution. Farmers were further categorized based on their socio-demographic characteristics and comparison made in relation with their appropriate agricultural technology evaluation scores.

To analyse the determinants of use of the different appropriate agricultural mechanization technologies, a binary probit model was used on each technology. The independent variables included residues for the factor analysis together with farmer characteristics and institutional characteristics of the farmer. The choice for the binary probit model was due to the fact that the dependent variable takes on a binary outcome with 1 for users and 0 for non-users (Gujarati, 2004). The model is specified as indicated in Equation 2 below.

$$y_i^* = x_i\beta + \varepsilon_i \qquad (2)$$

where;

y^* = latent variable that captures the farmers utility derived from using appropriate agricultural technologies for agricultural mechanization.

y = the farmers decision to use an appropriate agricultural mechanization which takes on 1 for users and 0 for non-users, β parameters to be estimated, x_i's are independent variables and ε is the error term under the assumption that ε ~N (0, 1). As a robustness check, robust standard errors were used to address heteroskedasticity.

4. Results and Discussions

4.1 Farmers' use of Appropriate Agricultural Mechanization in Uganda

Results indicate that the majority of farmers were using maize shellers, followed by rice threshers and walking tractors. Among the least used technologies were motorized tillers and motorized sprayers. Results imply that walking tractors, rice threshers and maize shellers are more popular. Figure 1 presents proportions of farmers using the different appropriate agricultural mechanization in the study areas.

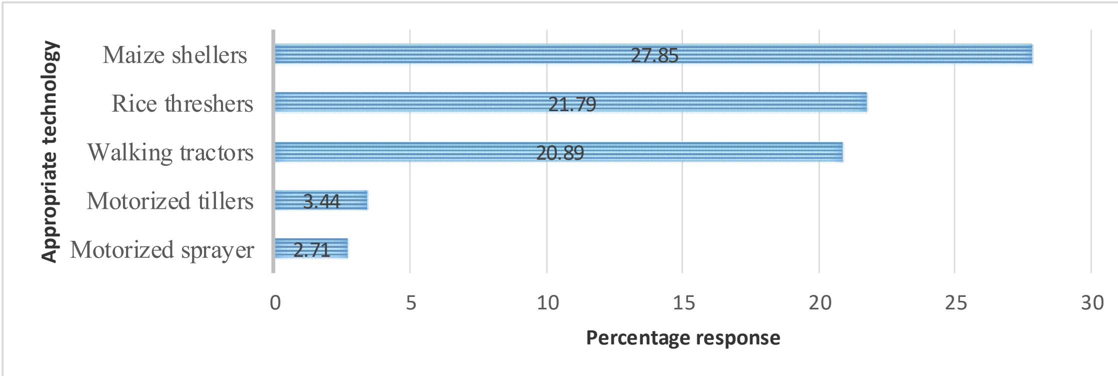

Figure 1. Appropriate Agricultural Mechanization Technologies Used by Farmers

The high use of maize shellers and rice threshers can be explained by the increased importance of maize and rice among smallholder farmers as sources of income and food. Rice and maize are replacing traditional food crops in Uganda with increased consumption and use in animal feeds especially among urban areas (UBOS, 2023). The increased importance has necessitated increased production thus calling for more use of appropriate agricultural mechanization in the production of these crops. This shows that appropriate agricultural mechanization is faced with derived demand making technologies that are used in the production of the most demanded enterprises to be more demanded. This therefore implies that the different appropriate agricultural mechanization technologies need to be developed and promoted in relation to the most popular enterprises in addition to the labor requirements of the respective enterprises in which the mechanization should be used.

Farmers were taken through 21 statements that evaluate use of appropriate agricultural mechanization technologies. The responses to the questions varied on the Likert scale ranging from 1 to 5 with appropriate coding where 1 showed strongly disagree and 5 showed strongly agree. The evaluation statements concerning appropriate agricultural mechanization technologies overlap and can reflect more than one motivational reason for use of the technology.

Principal factor analysis with Crawford-Ferguson rotation was performed to develop scales based on linear combination of statement responses that have similar patterns of variation across the sample into an appropriate factor solution. The results of this analysis indicate that the most appropriate solution involved two factors (Table 2). The criteria for acceptability of a factor solution were based on: (1) minimum factor membership of four items (Fabrigar *et al*., 1999); (2) exclusion of items with factor loadings less than 0.30 (Birol *et al*. 2007; Kontoleon 2003); and (3) minimum factor eigenvalues of 1.0.

A comparison analysis revealed that the extraction of two factors was in accordance with the standard evaluation criteria. The scree test and the number of eigenvalues greater than 1 support the decision to accept a two-factor solution. An orthogonal Crawford-Ferguson rotation specifying a two-factor solution accounted for 93 percent of the common variance with factor 1 accounting for 56 percent and factor 2, 44 percent; suggesting that each factor represents an important factor of farmers' evaluation of appropriate agricultural mechanization. Cronbach's alpha coefficients were computed to give an indication of the internal consistency of each factor. Values were found to be moderate to high, displaying the homogeneity of each factor. Factor naming was based on variables that factored together and the relative magnitude of the loadings in absolute terms. The first factor termed as "beneficial" (BEVA) had high loadings on questions related to technology use and potential benefits associated with use of appropriate agricultural mechanization. This category of BEVAs captures the tendency of farmers to get attracted to appropriate agricultural mechanization based on their various potential benefits (fast, easy to use, ensuring better quality, affordable, culturally accepted, and use of local resources).

The second factor labeled "user friendly EVA" (UFEVA) had high loadings on statements that reflected farmers concerns on using and quality of the product. The user-friendly EVA refers to concerns over the impact of the appropriate mechanization on use and quality of using the appropriate agricultural mechanization. For BEVA scores, higher positive values indicate a greater liking of appropriate agricultural technologies. While, higher positive values of UFEVA scores indicate higher levels of concern over use of the technology and quality of the product as a result of using appropriate agricultural mechanization.

Table 2: Factor Loadings for Evaluation of Appropriate Agricultural Mechanization

Evaluation statement (1. Strongly disagree 2. Disagree 3. Neutral 4. Agree, 5. Strongly agree)	Factor loading	
	Beneficial	**User-friendly**
The technology is faster	0.2968	0.0831
The technology is easier to use	**0.5896**	**0.3265**
The technology gives better results in terms of quality	**0.5671**	**0.3993**
The technology is friendly to the environment	**0.6224**	0.2946
The technology is culturally accepted	**0.6281**	**0.3678**
The technology is economic to community	**0.6815**	0.2298
The technology is simple to use	**0.6502**	0.1886
The technology is cost-effective	**0.6799**	**0.3439**
The technology is affordable	**0.6087**	**0.3488**
The technology is adaptable to local conditions and resources	**0.7256**	0.1835
The technology uses local materials thus promotes self-reliance within the community	**0.7315**	0.2616
The technology empowers farmers by providing means to reduce labor needs	**0.4492**	**0.4017**
The technology promotes self-sufficiency and independence	**0.6015**	0.1876
The technology can be replicated and implemented in different settings	**0.6167**	0.0601
The technology is designed to be low-maintenance and easy to repair	**0.6887**	**0.3349**
The technology is built to last and can be serviced using local resources and skills	**0.7366**	**0.3350**
The technology prioritizes the health and safety of users	**0.6708**	**0.3440**
The technology is designed to minimize risks and hazards during use	**0.7250**	0.2585
The technology takes into account the cultural norms and practices of the community	**0.5922**	**0.3873**
The technology fits local traditions and values, ensuring acceptance and sustainability	**0.5666**	**0.3132**
The technology meets basic needs in a manner that is practical	**0.6018**	0.2633

Loadings in bold are values of 0.3 and above

Factor scores for each factor were obtained for each household. The scores were then compared against farmer characteristics in their respective farmer characteristics. The significance of differences between the different regions and technologies was established using multiple-comparison tests (F-test) and two group mean-comparison tests (T-test) (at $\leqslant$ 10% significance level) are provided in Table 3. Results indicate that there were significant differences in mean scores by the different regions in Uganda. The North and East had the lowest scores followed by central and then west with the highest scores. These results show that farmers in west and central show higher and supportive evaluation of appropriate agricultural mechanization which further indicates favorable condition for promoting use of these technologies. North and east on the other hand show low scores that are an indication of limited appreciation of these technologies by farmers in these locations.

In terms of the technologies, the results show that motorized sprayers were scored highly followed by maize shellers and then walking tractors. The results show that rice shellers were scored lowest followed by motorized tillers. The interesting part of these results is that non-users scored appropriate agricultural mechanization higher than the scores that farmers gave to rice shellers and motorized tillers. This shows positive evaluations among non-users which offers an opportunity for promoting and popularization of these technologies among smallholder farmers for increased production, productivity and better incomes.

In addition, evaluation scores were statistically different between the different marital statuses. The evaluation scores for single respondents which make a big fraction of youth were also not the lowest which offers an opportunity for popularizing these appropriate agricultural mechanization technologies among youth for future use and sustainability. The results suggest that appropriate agricultural mechanization attract positive interest from smallholder farmers as cost-effective approach for increasing production and productivity leading to better incomes. The results on the determinants of use of the different appropriate agricultural mechanization technologies was obtained using a binary probit regression model on each technology. The independent variables included residues for the factor analysis together with farmer characteristics and institutional characteristics of the farmer as shown in Table 4.

Table 3: Comparison of Mechanization Appropriateness Scores with Farmer Characteristics

Variable	Description	Mean scores	F/T-value
Region	North	0.014 (1.136) a	5.08***
	West	0.178 (0.948) ab	
	Central	0.145 (0.949) ac	
	East	0.039 (0.827) ac	
Technology	Non-users	0.177(1.106) ae	18.73***
	Maize shellers	0.317(0.959) b	
	Rice thresher	0.071(0.745) ce	
	Walking tractor	0.257(0.929) de	
	Motorized tiller	0.103(0.694) e	
	Motorized sprayer	0.933(0.744) f	
Marital status	Married monogamous	0.062(0.942) a	2.94***
	Married polygamous	0.156(1.024) ab	
	Single	0.125(0.953) ac	
	Separated	0.048(1.057) a	
	Widowed	0.295(0.949) ad	
	Divorced	0.169(1.085) a	
	Cohabiting	0.261(1.048) a	
Sex of the farmer	Male	0.065(1.091) a	0.05
	Female	0.016(1.086) a	

Means scores for each variable with the same letter/s are not statistically different at 5%.

The results show that residuals from factor analysis are significantly associated with farmers' probability of using maize shellers, walking tractors, and motorized sprayers all at $(P \leq 0.1)$. From the results, smallholder rice and maize farmers' appreciation of these tools as appropriate mechanization with regard to their conditions influences positively and significantly the probability of using these technologies. Most appropriate agricultural mechanization technologies face a limitation of large-scale production mainly due to their ability to perform well on relatively large production. This is in agreement with Glover *et al*. (2019) who found that smallholder farmers prefer using appropriate agricultural mechanization technologies that are usually suitable for small scale production such as micro-tillers and walking tractors. Such technologies tend to make more sense when farmers are dealing with small scale production that they can handle easily and quickly.

Results from Table 4 also show that household size is positively related $(P < 0.01)$ with the probability of the farmer using a motorized sprayer and negatively related $(P \leq 0.05)$ with the probability of the farmer using a maize sheller. Large families were found to have a greater likelihood of using a motorized sprayer and lower likelihood of using a maize sheller compared to those with small families. This can be explained by the likelihood of large families to offer labor for maize shelling as opposed to spraying. Large households may use their labor to open up more land which may require greater effort to spray for both pest and wed control. This finding is in agreement with Keo & Roth, (2023) who found that large families tend to use mechanization in the production of food for both income and home consumption which motivates them to embrace technologies that can help in the enhancement of food production.

Table 4: Factors influencing Farmers' Use of Appropriate agricultural Mechanization

Variables	Maize sheller (dy/dx)	Rice thresher (dy/dx)	Walking tractor (dy/dx)	Motorized tiller/weeder (dy/dx)	Motorized sprayer (dy/dx)
Factor residuals	0.104*** (0.015)	-0.017 (0.012)	0.055*** (0.013)	-0.003 (0.003)	0.016*** (0.004)
Age of the farmer	0.002 (0.002)	-0.001 (0.002)	-0.001 (0.002)	-0.001 (0.001)	0.001 (0.001)
Household size	-0.012** (0.005)	-0.006** (0.002)	0.003 (0.004)	0.001 (0.001)	0.002*** (0.001)
Total land owned	-0.003 (0.002)	0.005*** (0.001)	0.001 (0.001)	-0.001 (0.003)	-0.001 (0.001)
Farming experience	0.002 (0.002)	0.001 (0.002)	0.001 (0.002)	-0.001 (0.001)	-0.001 (0.001)

Variables	Maize sheller (dy/dx)	Rice thresher (dy/dx)	Walking tractor (dy/dx)	Motorized tiller/weeder (dy/dx)	Motorized sprayer (dy/dx)
Level of education	0.004***	-0.003	0.002*	-0.001	0.001**
	(0.001)	(0.002)	(0.001)	(0.001)	(0.001)
Access Credit	0.009	-0.014	0.033	-0.007	0.003
	(0035)	(0.033)	(0.032)	(0.011)	(0.006)
Being married	0.079**	-0.018	0.032	-0.001	0.009*
	(0.035)	(0,034)	(0.033)	(0.011)	(0.005)
Being female	0.055	-0.011	0.042	-0.013	0.015**
	(0.038)	(0,032)	(0.035)	(0.009)	(0.009)
Northern	0.056	-0.079**	0.036	-0.026**	-0.002
	(0.051)	(0.039)	(0.047)	(0.012)	(0.007)
Central	-0.092**	-0.011	0.091**	0.024	0.005
	(0.041)	(0.039)	(0.046)	(0.021)	(0.009)
Eastern	-0.036	-0.012	0.098**	0.025**	0.003
	(0.044)	(0.042)	(0.047)	(0.018)	(0.008)
Radio ownership	0.112	0.086*	0.145**	0.031***	0.076***
	(0.079)	(0.052)	(0.072)	(0.009)	(0.028)
Phone ownership	0.142***	0.002	0.048*	0.026***	0.009**
	(0.031)	(0.027)	(0.026)	(0.009)	(0.005)
Number of observations	1068	1068	1068	1011	1011
Wald chi2(14)	105.51	29.13	45.80	55.07	73.16
Prob > chi2	0.0000	0.0100	0.0000	0.0000	0.0000
Pseudo R2	0.0872	0.0242	0.0406	0.1192	0.1948
Log pseudolikelihood	-580.56943	-546.6801	-528.82329	-142.65166	-108.76831

*, ** and *** Represents significance at 10%, 5% and 1% levels respectively

The results further show that farmers' level of education is positively and significantly associated with use of maize shellers, walking tractors and motorized sprayers at $(P \leq 0.01)$, $(P \leq 0.1)$ and $(P \leq 0.05)$ respectively. The positive relationship between education and the probability of using appropriate agricultural mechanization is explained by increased ability to appreciate the importance of using such machines to increase agricultural production. Educated farmers are in better position of appreciating the advantages associated with their use as is a case with Farmer Field Schools (Braun & Duveskog, 2008). Education empowers farmers with understanding that appropriate agricultural mechanization technologies are designed to suit usage in their small-scale production with regard to their circumstances especially limited resources.

Farmer demographic characteristics of being female and married were also found to be positively related with smallholder farmers' probability of using maize shellers and motorized sprayers as appropriate agricultural mechanization technologies. Female and married farmers tend to share information with their peers leading to greater appreciation of agricultural technologies for better performance. This is in agreement with Braun & Duveskog, 2008) and (Chambers, 1994) who both found that female and married farmers learn from their peers through groups and farmer field schools thus improving their appreciation of new technologies that are relevant to their environments such as appropriate agricultural technologies.

Location of the farmer was found to influence their choice and use of the different appropriate agricultural mechanization technologies in Uganda. The model results show that farmers from central region were less likely to use maize shellers while those from North were also less likely to use motorized weeders and rice shellers compared to their counterparts from western Uganda at$(P \leq 0.05)$. The results further show that farmers from Eastern Uganda were more likely to use motorized weeders. This can be explained by the low interest in agricultural production with east being dominated by subsistence farmers that do not see value in investing in the technologies while central Uganda concentrates more of the service and business such as transport and retail shops making them not attracted to agricultural technologies. This is in agreement with Doss, (2006) and Adesina & Zinnah (1993) who found out that farmers' use of appropriate agricultural mechanization technologies is influenced by the benefits associated with use of the technology and its relevance to the farmers' production activities.

Ownership of a radio and a phone significantly $(P \leq 0.05)$ increases the likelihood of farmers' use of maize shellers, rice threshers, motorized weeders, motorized sprayers and walking tractors in Uganda. Radios and phones are important sources of information through listening to radio programs and communicating with other farmers. A phone is a mode of communication through phone calls, messages, and the internet. Nonetheless, the farmer has control over information received via the phone. Therefore, the farmer is likely to search for information related to appropriate agricultural technologies in terms of availability and cost. Availability of such information to farmers influences their appreciation of the technologies for use in agriculture thus increasing the likelihood of scoring them high. These results are in agreement with Meijer *et al*. (2015), Glover *et al*. (2019) and Keo & Roth, (2023) who found out that access to information on the different digital platforms influence farmers' evaluation of technologies which may influence their use.

The results also show that land owned by the farmer is positively related ($P \leq 0.01$) with the probability of the farmer using rice threshers. Farmers with large land were found to have a greater likelihood of using rice threshers compared to those with small land holdings. This can be explained by the likelihood of farmers with large land holdings to require such appropriate agricultural mechanization technologies in rice production. This finding is in agreement with Keo & Roth, (2023) who found that farmers with large land holding tend to use mechanization in the production of crops for income generation which motivates them to embrace technologies that can help in the enhancement of production.

5. Conclusion, Policy Implications and Recommendation

The study reveals that Ugandan smallholder farmers hold mixed perceptions towards appropriate agricultural mechanization technologies. However, the five technologies examined were generally perceived as meeting farmers' needs in terms of speed, ease of use, quality improvement, affordability, cultural acceptance, and reliance on local resources. Farmers emphasized that these technologies are user-friendly and beneficial, though adoption varies depending on crop type, location, and farmer characteristics such as household size, education level, marital status, and land ownership. Exposure to mechanization through communication assets and peer influence also significantly shaped adoption decisions.

The findings underscore the importance of tailoring mechanization policies to farmers' socio-economic realities and cultural contexts through ensuring the following:

Accessibility and affordability by ensuring that technologies are financially attainable for smallholder farmers through subsidies, credit schemes, and flexible payment options.

Targeted promotion by aligning mechanization programs with specific crops and regions where technologies are most relevant, thereby maximizing impact.

Information dissemination by leveraging radio, mobile phones, and digital platforms to improve awareness and perceptions of mechanization technologies.

Capacity building through strengthening extension services and farmer training programs to enhance knowledge, reduce risk perceptions, and build confidence in technology use.

Equity considerations by addressing gender and youth inclusion in mechanization programs to ensure broad-based adoption and sustainability.

Based on the study findings, the following recommendations are proposed:

Promote user-friendly technologies and emphasizing mechanization options that are simple, labor-saving, and adaptable to smallholder conditions. Communication campaigns should highlight these attributes to improve farmer perceptions.

Expand awareness through ICTs and utilizing radio programs, mobile phone platforms, and social media to disseminate information on mechanization benefits, costs, and practical demonstrations. This will broaden exposure and reduce misinformation.

Strengthen extension and training services by provide hands-on demonstrations, farmer field schools, and peer learning opportunities to build confidence in appropriate agricultural mechanization use. Training should be localized and crop-specific.

Enhance access to finance by developing farmer-friendly credit schemes and promote partnerships with microfinance institutions to reduce financial barriers to appropriate agricultural mechanization adoption.

Government subsidies should be strategically targeted to high-potential farming communities.

Support inclusive appropriate agricultural mechanization policies by ensuring that women and youth farmers are actively included in appropriate agricultural mechanization programs through tailored training, incentives, and access to technologies that suit their farming contexts.

Promote market linkages by strengthening rural market infrastructure and value chain integration so that increased production from mechanization translates into higher incomes, thereby sustaining adoption.

Encourage decentralized distribution of appropriate agricultural mechanization programs to avoid concentrating technologies in single locations. Instead, scattered distribution across communities will maximize exposure and peer influence.

Integrate cultural compatibility by promoting technologies that align with indigenous practices and local knowledge systems to enhance acceptance and reduce resistance.

By focusing on affordability, accessibility, cultural compatibility, and institutional support, Uganda can accelerate appropriate agricultural mechanization adoption among smallholder farmers. Policies that combine financial incentives, training, and information dissemination will not only improve perceptions but also ensure sustainable use of appropriate agricultural mechanization technologies.

References

Adesina, A. A., & Zinnah, M. M. (1993). Technology Characteristics, Farmers' Perceptions, and Adoption Decisions: A Tobit Model Analysis in Sierra Leone. Agricultural Economics, 9(4), 297-311.

Batistatou, E., Roberts, C., and Roberts, S. (2014) Sample size and power calculations for trials and quasi-experimental studies with clustering, The Stata Journal 14, Number 1, pp. 159–175

Birol, E., Villalba Rayn, E., and Smale, M. (2007), 'Farmer preferences for *Milpa* diversity and genetically modified maize in Mexico: a latent class approach', IFPRI Discussion Paper No. 726, Washington, DC: International Food Policy Research Institute (IFPRI).

Braun, A. and Duveskog, D. 2008. The Farmer Field School Approach- history, global assessment and success stories, 3rd draft.

Chambers, R. (1994). Participatory Rural Appraisal (PRA): Analysis of Experience. World Development, 22(9), 1253-1268.

Chambers, R., & Conway, G. (1992). Sustainable rural livelihoods: practical concepts for the 21st century.

Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. MIS Quarterly, 13(3), 319–339. https://doi.org/10.2307/249008.

Doss, C. R. (2006). Analyzing Technology Adoption Using Micro studies: Limitations, Challenges, and Opportunities for Improvement. Agricultural Economics, 34(3), 207-219.

Fabrigar, L. R., Wegener, D. T., MacCallum, R. C., & Strahan, E. J. (1999). Evaluating the use of exploratory factor analysis in psychological research. *Psychological Methods, 4*(3), 272–299. https://doi.org/10.1037/1082-989X.4.3.272

Feder, G., Just, R. E., & Zilberman, D. (1985). Adoption of Agricultural Innovations in Developing Countries: A Survey. Economic Development and Cultural Change, 33(2), 255-298.

Glover, D., Sumberg, J., & Andersson, J. (2019). Rethinking Technological Change in Smallholder Agriculture. Outlook on Agriculture, 48(3), 169-180.

Guerin, T. F. (2001). Why sustainable innovations are not always adopted. *Resources, Conservation and Recycling*, *34*(1), 1-18.

Gujarati, D. (2004). Basic econometrics (4th ed.). New York: McGraw-Hill/Irwin.

Hong, S., Hwang, S., Lamo, J., Nampamya, D., & Park, T. S. (2021). The current status of opportunities for rice cultivation in Uganda. *J. Korean Soc. Int. Agric*, *33*(1).

Kavuma, S. N., & Kisaame, E. K. (2023). Factors influencing maize and cassava commercialization among smallholder farmers in Uganda. *International Fund for Agricultural Development (IFAD). [Online] https://www*, *50*(2030), 2023-07.

Keo, S., & Roth, V. (2023). Sources of Information Diffusion and Adoption of Agricultural Technologies:

Evidence from Cambodia.

Kinuthia, B. K., & Mabaya, E. (2017). The impact of agricultural technology adoption on farmer welfare in Uganda and Tanzania. Scientific Research Publishing. Retrieved from https://www.africaportal.org/publications/impact-agricultural-technology-adoption-farmer-welfare-uganda-and-tanzania

Kontoleon, A. (2003). *Essays on non-market valuation of environmental resources; policy and technical explorations*. University of London, University College London (United Kingdom).

Mafumo, H. R. (2024). Adoption of climate-smart agriculture technologies by smallholder maize farmers in Manafwa District, Eastern Uganda (Master's dissertation, Uganda Christian University).

Meijer, S. S., Catacutan, D., Ajayi, O. C., Sileshi, G. W., & Nieuwenhuis, M. (2015). The Role of Knowledge, Attitudes, and Perceptions in the Uptake of Agricultural and Agroforestry Innovations Among Smallholder Farmers in Sub-Saharan Africa. International Journal of Agricultural Sustainability, 13(1), 40-54.

Ninsiima, A. (2021). Small holder farmers' perception on agriculture mechanization: A case study in Rwakishaakizi Village, Nyakayojo Division, Mbarara District. Global Science Research Journals, 8(3), 1–10.

Nkonya, E., Bashaasha, B., Kato, E., Bagamba, F., & Danet, M. (2020). Impact of creative capacity building of local innovators and communities on income, welfare and attitudes in Uganda.

Rogers, E. M. (2003). Diffusion of Innovations (5th ed.). Free Press.

UBOS (2022). Uganda Bureau of Statistics: Statistical Abstract. *Kampala, Uganda and Calverton*

UBOS (2023). Uganda Bureau of Statistics. Statistical Abstract. *Kampala, Uganda and Calverton*.

Wanyama, J., N. Banadda, F. Kiyimba, S. Okurut, A. Zziwa, I. Kabenge, C. Mutumba, P. Tumutegyereize, A. J. Komakech, and N. Kiggundu. 2016. Profiling agricultural engineering technologies for mechanizing smallholder agriculture in Uganda. Agricultural Engineering International: CIGR Journal, 18(4):40-51

Institutional Review Board Statement: This study was approved by the College of Agricultural and Environmental Sciences Research Ethics Committee, Makerere University, Uganda, under protocol number CAES-REC-2025-113, dated September 15, 2024. Prior to data collection, the purpose and procedures of the study were explained to all participants, and informed verbal consent was obtained. Participation was voluntary, and participants were informed of their right to withdraw at any time without penalty. All data were anonymized during analysis to protect participant confidentiality, and no personally identifiable information is included in this publication.

Authors' Contributions: Fred Ssajakambwe designed the research methodology, developed data collection instruments, supervised field data collection, performed the statistical analysis, prepared figures and tables, and wrote the original draft manuscript. Fredrick Bagamba provided guidance on research design, supervised the analytical approach, and contributed to interpretation of results. Bernard Bashaasha provided conceptual framing, guided the literature review, and contributed critical revisions on policy implications. Rosemary Emegu Isoto contributed to sampling design, provided methodological guidance, and reviewed the econometric analysis. All authors reviewed, edited, and approved the final manuscript.

Acknowledgments: The authors gratefully acknowledge the cooperation of the 1,056-smallholder rice and maize farmers across Uganda who participated in this study. We thank the Agricultural Engineering and Appropriate Technology Research Institute Namalere (AEATRI) for providing sampling frames and technical support during data collection. We also acknowledge the enumerators who assisted with field data collection.