Gender and Mechanization in Small-Scale Irrigation Schemes: Analysis of Agricultural Machinery Access by Smallholder Rice Farmers in Mbarali District, Tanzania

Mwalyagile, N.*, J.N. Jeckoniah and R.J. Salanga

Department of Development and Strategic Studies, Sokoine University of Agriculture, Morogoro, Tanzania

*Corresponding author e-mail: *nmwalyagile@gmail.com*

Abstract

Given that women in Tanzania bear a disproportionate amount of the agricultural labour burden, it is anticipated that agricultural mechanization could help them substantially. However, the impact of agricultural mechanization is gendered, with women not receiving the same benefits as men, particularly in terms of access. Smallholder farmers use agricultural machinery inequitably. This paper explores the socio-economic factors linked to gender inequalities in agricultural machinery access for smallholder rice farmers. A cross-sectional research approach was used to collect data from 397 farmers randomly selected from small-scale irrigation schemes in Mbarali District. A structured questionnaire was used to collect the data. The data was analyzed using descriptive and inferential statistics. The study found the most used agricultural machinery are power tillers and combine harvesters, with a larger proportion of male farmers using combine harvesters (84.1%) compared to 59.7% of women. From the binary logistic regression analysis, agricultural machinery access for male farmers is positively associated with education, membership in scheme associations, and farming experience. Female farmers' access to agricultural machinery is significantly associated with land size cultivated, membership in the scheme association, and off-farm income activities ($p<0.05$). Male farmers had more access to agricultural machinery than female farmers. It is concluded that membership in a scheme association, education and training, off-farm income activities, and land area cultivated are potential determinants of agricultural machinery access. It is therefore recommended for enhancing land access, particularly for female farmers, and creating an enabling environment for gender equality in agricultural machinery access.

Keywords: Mechanization, Agricultural machinery, Access, Gender

Introduction

Mechanization in agriculture has altered farming techniques worldwide by increasing efficiency, productivity, and sustainability (Sims *et al.,* 2016; Van Loon *et al.,* 2020). It has also been acknowledged as an important component of initiatives aimed at improving livelihood outcomes and increasing gender inclusion in agri-food systems, particularly in developing countries (Takeshima & Diao, 2021). Clarke (2000), Daum and Birner (2020), and Singh and Singh (2023) describe mechanization as the distribution and use of tools, equipment, and machinery across diverse agricultural activities such as farm land management, planting, harvesting, and processing. This enables farmers to enhance crop yields and optimize resource utilization. According to studies by (Sims *et al.,* 2016; Daum & Birner, 2020; Paudel *et al.,* 2020; Zhou *et al.,* 2020; Takeshima & Diao, 2021; Zhou & Ma, 2022), mechanization empowers farmers, eliminating drudgery and inequity, increasing inclusiveness, and contributing to positive agricultural transformation, particularly in South Asia and some African countries. Additionally, the adoption of mechanized farming practices has the potential to feed more people compared to reliance on human and animal power alone (FAO, 2013).

Mechanization in rice farming has considerably improved rice farming technology in Asia and Africa (Estudillo *et al.,* 2022). Mechanization in rice farming has also been acknowledged for its ability to lessen women's drudgery, free up time for other income-generating activities, and contribute to women's empowerment (Castelein *et al.,* 2022). In this area, mechanization has demonstrated promising outcomes in increasing land and crop productivity, improving product quality by reducing labour requirements, and increasing overall efficiency benefits (Kirui, 2019; Daum & Birner, 2020). Agricultural machinery, such as power tillers or two-wheel tractors (2WTs), rice transplanters, and combine harvesters, have been shown to improve rice output (Fukai *et al.,* 2019; Magezi *et al.,* 2023). Adoption of mini-tillers by smallholders in Nepal, for example, resulted in a 27% increase in rice output (Paudel *et al.,* 2019). Meanwhile, women's access to power tillers in Bangladesh has improved their social standing, decision-making capacity, and community involvement (Malapit *et al.,* 2019). Power tillers (2WTs) have proven advantageous to smallholder rice farmers in Tanzania, leading to improved rice technology, greater paddy output, and the expansion of rice cultivation areas at the household level (Magezi *et al.,* 2021a; Daum *et al.,* 2022; Magezi *et al.,* 2023).

Despite the numerous benefits of mechanization in most developing countries, particularly in South Asia, parts of Latin America, and sub-Saharan Africa, smallholder farmers' access to agricultural machinery remains low (Mottaleb *et al.,* 2017; Van Loon *et al.,* 2020). Most sub-Saharan African countries continue to lag behind in terms of farm machinery and tractor power. Accessibility, high equipment costs, limited access to finance, land, and water, a lack of technical knowledge and training, and gender norms have all been identified as barriers to the widespread adoption and use of agricultural machinery (Achandi *et al.,* 2018; Theis *et al.,* 2019; Badstue *et al.,* 2020; Van Loon *et al.,* 2020; Bryan & Garner, 2022; Thakur, 2023). Gender roles in agriculture often perpetuate inequities in farm machinery utilization, with men predominantly operating machinery and controlling farm operations while women are allocated unmechanized labor-intensive duties (Sims *et al.,* 2016).

Gender divisions of labour exacerbate existing disparities, restricting women's capacity to engage in non-agricultural conventional roles. According to Afridi *et al.* (2022), the adoption of mechanized tilling in India has resulted in a drop of up to 5% of women's labour use in farms without an increase in non-farm sector employment. Kurniawan (2021) and Mohammed *et al.* (2023) in their studies further confirms that the adoption of agricultural technologies has gendered outcomes, with women often not enjoying the same benefits as men. The usage of agricultural machinery such as tractors and combine harvesters shifts more women to non-farm activities than men (Takeshima & Diao, 2021). As a result, increasing mechanization in land preparation in Tanzania has a relatively small direct impact on women's labour burden (Mrema *et al.,* 2020). Mechanization, if not approached with a gender-inclusive perspective, has the potential to reinforce these disparities and further marginalize women by displacing them from agricultural activities or confining them to lower-value tasks, causing women to rely disproportionately on men's tasks (Baudron *et al.,* 2019; Ahmad & Murtaza, 2021).

Gender and mechanization studies (Njuki *et al.,* 2014; Kuwornu *et al.,* 2017; Fischer *et al.,* 2018; Theis *et al.,* 2019; Kadir and Prasetyo, 2020; Afridi *et al.,* 2023) show that women have less access to and adoption of mechanized equipment than males. According to Achandi *et al.* (2018), institutional, agricultural input, technological, contextual, socio-cultural, and extension constraints limit women's access to agricultural technology in Ethiopia, Madagascar, and Tanzania. Women, on the other hand, do not constantly experience disadvantages. Women have benefited from agricultural mechanization, but not at the same rate as men, by reducing drudgery, freeing up time for non-income activities, improving decision-making capacity, increasing crop yield, and decreasing their reliance on male labour, allowing them to pursue "male" crops and activities (Fischer *et al.,* 2018; Kirui, 2019; Malapit *et al.,* 2019; Daum *et al.,* 2020; Castelein *et al.,* 2022; Zhou & Ma, 2022). However, Men remain dominant in both on-

farm mechanization and agricultural machinery (Baudron *et al.,* 2019; Ahmad & Murtaza, 2021). Factors associated with farmers' access to agricultural machinery are widely studied by (Akram *et al.,* 2020; Daum *et al.,* 2022; Hinnou *et al.,* 2022; Neway & Zegeye, 2022; Ngochembo *et al.,* 2022; Mohammed *et al.,* 2023) including education, farm cooperatives, land size, marital status, off-arm activities, saving, property rights, and access to credit. Babu (2017) and Magezi *et al.* (2021b) found that factors such as household age, technology availability, a high wage rate for hired labour, and the availability of four-wheeled tractors and power tiller rental markets are associated with the use of on-tilling technologies and machinery in the Mbarali district, Morogoro, and Mbeya regions. However, evidence from a comparative analysis of gender and agricultural machinery access remains inconclusive, particularly in the context of the small-scale irrigation scheme in the study area. This knowledge gap necessitates this study to investigate socioeconomic factors associated with agricultural machinery access by smallholder rice farmers across gender. Understanding these factors can help to enhance access to agricultural machinery among both male and female farmers and promote gender resource equity in small-scale irrigation systems. The objectives of this study were to determine gender patterns in agricultural machine use, gender disparities in agricultural machinery access, and determinants of agricultural machinery access for among both male and female smallholder farmers.

The study intends to contribute to the growing body of knowledge on agricultural mechanization in two ways. First, it provides evidence on the gender pattern in agricultural machinery usage and accessibility. Second, it presents evidence on the factors influencing agricultural machinery access across gender.

The remainder of the paper is organized as follows: The second section describes the methodology, which comprises the study area, sampling procedure, data collection, and data analysis. The third section discusses the results, while the fourth section contains the conclusion.

Methodology

Study Area, Sampling Procedure, and Data Collection

The study was conducted in the Mbarali District, Mbeya Region. The district is located in Tanzania's Southern Highlands. The Southern Highland is one of three agroecological zones for rice production in Tanzania; the others are the eastern and lake zones (Magezi *et al.,* 2023). The district was specifically chosen because of its prominence in agricultural mechanization, rice production, irrigation, and ideal irrigation ecosystems in Tanzania's rice production agroecological zones (URT, 2017; URT, 2018; Mrema *et al.,* 2020). The district is relatively highly mechanized in comparison to the rest of Tanzania (Mrema *et al.,* 2020). Rice is primarily cultivated by smallholder farmers under small-scale irrigation systems, and farm mechanization activities are a crucial driver of rice productivity (Ngailo *et al.,* 2016; Makoi, 2016). Rice plays an important role in food security and is a major source of revenue and household income in the district (Ngailo *et al.,* 2016; URT, 2017).

The study adopted a cross-sectional research approach, using data collected from 397 randomly selected smallholder rice farmers in three small-scale irrigation schemes: Majengo, Mbuyuni, and Mwendamtitu. The sample frame for this study consisted of smallholder rice farmers who are beneficiaries of small-scale irrigation schemes in the Mbarali District. The Yamane formula (Yamane, 1967) was used to estimate the sample from a specified study population of 42,592 with a 95 percent confidence level and a precision of 0.05. Farmers in the three schemes investigated were chosen using a stratified proportionate sample technique. The respondents for the study were selected using a simple random technique.

Face-to-face interviews with the chosen rice farmers were conducted using a pre-tested, standardized questionnaire. The questionnaire was developed to collect information about socioeconomic characteristics, agricultural machines used by farmers in rice production, and their accessibility. The data collection process assured participant privacy, confidentiality, and respect for their rights. Data was collected between May and June of 2022.

Data Analysis

The data were analyzed using both descriptive and inferential statistics. To describe the demographic and socioeconomic characteristics of male and female rice farmers, descriptive statistics such as frequencies, means, and percentages were employed. The t-test and chi-square test were employed to determine differences and relationships between the variables under consideration. The variables associated with farmers' access to agricultural machinery were estimated using a binary logistic regression model. To validate the data, the Statistical Package for Social Science software (IBM SPSS Statistics version 26) was utilized; any found abnormalities were addressed, followed by a descriptive analysis. The data was then imported to STATA 15 software, which was used to run the binary logistic regression model.

Model estimation

The binary logistic regression (logit model) was used to determine the likelihood (odds) of socioeconomic variables that had a significant association with smallholder rice farmers' access to agricultural machinery. The model was chosen due to the nature of the dependent variable, which follows the Bernoulli distribution (Evans *et al.,* 2000; Weisstein, 2002), which is suited for the logit and probit models. However, due to the extreme values in some of the independent variables, such as age, farming experience, household size, and land size cultivated, which are much higher than the median values as shown in Table 2(B), the logit model was chosen over the probit model for its superior performance in these situations. The regression model was estimated using 397 observations based on gender, with independent variables consisting of eight variables from farmers' socioeconomic characteristics versus the dichotomous dependent variable, agricultural machinery access (dummy). Agricultural machinery access is measured as a binary variable with a value of 1 if a farmer reported being able to easily access any of the agricultural machines used in rice production and 0 otherwise. At the study site, three machines were identified: tractors, power tillers, and combine harvesters. However, because 0.5% of farmers reported using tractors, they were left out of the analysis. The regression model was represented as follows:

$\text{Logit(P)} = \beta_0+\beta_1X_1 + \ldots +\beta_8X_8+ \varepsilon_i$

$\text{Logit(P)} = \beta_0+\beta_1\text{Age} + \beta_2\text{Marital Status} + \beta_3$ Educational attainment $+ \beta_4$Beneficiary Group $+ \beta_5$ Farming Experience $+ \beta_6$Household Size $+ \beta_7$Land Size Cultivated $+ \beta_8$Off-farm Income $+ \varepsilon_i$

Whereby:

Logit (P) represents the natural logarithm of the odds ratio of agricultural machinery access,

P represents the probability of the event for dependent variable to occurs, that is, agricultural machinery access ($0 \leq P \leq 1$)

β0 is the constant

β1-β8 are the coefficients associated for each independent variable

X_1-X_8 are vector contains independents variables that might have effects on interest on dependent variable and ε_i is error term

The description of the independent variables estimated in the model presented in Table 1.

The unit of analysis was an individual farmer who farmed rice under in small-scale irrigation schemes for the cropping season 2020–2021. Farmers are known as scheme beneficiaries in Mbarali District's small-scale irrigation schemes, and they are recognized and recorded as individuals as long as they manage to cultivate rice in the schemes, regardless of whether they own a piece of land or not.

Results and Discussion

Socio-economic characteristics of the respondents

The description of the farmer's socio-economic characteristics variables estimated in the model with their mean values, standard deviations, and percentages is presented in Table 2. The results showed that the mean age of farmers was 46.50 and 46.41 for males and females, respectively. However, the differences were not statistically significant ($p>0.05$). This indicates both male and female farmers were in a similar active working age group; therefore, their engagement in rice production suggests the potentiality of agricultural mechanization in small-scale irrigation schemes. This observation compares well with a study by Ngailo *et al.* (2016), who reported similar observations of

Table 1: Description of variables used in the binary regression model

Variables	Variable definition and description
Dependent variable	
Agricultural machinery access	1 if farmers access any agricultural machinery, i.e., power tillers or combine harvesters; 0 otherwise (dummy).
Independent variables	
Age	The age of a farmer in years (continuous)
Marital status	1 if married; 0 otherwise (dummy)
Educational status	1 if the farmer went to school; 0 otherwise (dummy)
Membership in scheme associations	1 if a farmer had membership; 0 otherwise (dummy)
Farming experience	Number of years spent in rice farming (continuous)
Household size	The number of household members (continuous)
Land size cultivated	Total land size in acres used to grow rice in the scheme (continuous)
Off-farm income activities	1 if the farmer had off-farm income activities; 0 otherwise (dummy)

Table 2(A): The distribution of socio-economic characteristics by gender (n=397)

Variable	Male (n=258)			Female(n=139)			t-test	p-value
Continuous variable	Mean	Std. dev	Std. Error	Mean	Std. dev	Std. Error		
Age of the farmer (years)	46.50	11.628	0.724	46.41	11.889	1.000	0.073	0.942
Farm experience	14.19	9.145	0.569	15.96	10.060	0.853	1.780	0.076*
Household size	6.13	2.159	0.134	5.08	2.043	0.173	4.721	0.000***
Land size cultivated (acres)	3.49	2.397	0.149	2.45	2.531	0.214	4.031	0.000***
Categorical variable	No. Obs		%	No. Obs		%	chi-square	
Marital status								
Married	245		95.00	89		64.00	64.739	0.000***
Not married	13		5.00	50		36.00		
Educational status								
Went to school	234		90.70	119		85.60	2.371	0.124
Not attended	24		9.30	20		14.40		
Membership in a scheme								
Member	158		61.20	65		46.80	7.591	0.006***
Not a member	100		38.80	74		53.20		
off-farm income activity								
With off-farm income	232		86.40	129		92.80	3.649	0.038**
Without off-farm	35		13.60	10		7.20		

****, **, and * are significance levels at 1%, 5%, and 10%, respectively.*

No, Obs = number of observations.

Table 2(B): continuous independent variables with extreme values (n = 397)

Variable	Mean	Std.Dev	Min	Median	Max
Age	46.62	11.670	22.00	45.00	78.00
Farming experience	14.81	9.501	1.00	12.00	50.00
Household size	5.76	2.175	1.00	6.00	14.00
Land size cultivated	3.13	2.492	0.5	2.50	10

many active working-age groups in rice farming in the southern highlands of Tanzania. The average number of years of rice farming between male and female farmers was also almost similar, with slightly higher rates for females (15.96) compared to their male counterparts (14.19%). The difference was not statistically significant ($p>0.05$). Male farmers had larger household sizes (6.13) compared to female farmers (5.08) and the differences were statistically significant ($p<0.01$), indicating more family labour is available for agricultural activities for males, while the smaller household size observed in female farmers may have limited their access to family labour. The average land size of rice cultivated was significantly higher for male farmers compared to their female counterparts, and the differences were significant at less than 1% level ($p=0.000$). Nnaji *et al.* (2022) also reported a larger cultivated farmland size and household size among male farmers than female farmers in Nigeria. This implies that female farmers are significantly farming rice in smaller pieces, which might limit agricultural machinery usage in rice production. This finding is also in good agreement with Doss *et al.* (2018), who found that women farmers in Tanzania have smaller landholdings compared to men.

The results further showed that 95% of male farmers were married, compared to 64% of female farmers who were married. This indicates that more male than female rice farmers were married. This finding is in line with the finding of Nnaji *et al.* (2019), who observed a similar trend among rice farmers in Nigeria. The results also revealed that the majority of rice farmers went to school. However, more female farmers (14.4%) did not attend formal education compared to their male counterparts (9.3%). This means that the illiteracy rate is relatively higher for female farmers in comparison with their male counterparts. More male farmers (61.2%) had membership in scheme associations compared to 46.8% of female farmers, and chi-square test analysis showed a strong association between having membership in scheme associations and gender. This connotes that many female farmers did not belong to the scheme associations, limiting their ability to accrue the potential benefits and opportunities available in the small-scale irrigation schemes. Similar, Coker *et al.* (2017) also reported more male rice farmers among cooperative members. The majority of farmers, both male and female, were involved in off-farm income activities; however, the findings showed a significant association with their gender at $p<0.05$, with more females participating in off-farm income activities, implying that female rice farmers have diversified sources of income. Because of the predominant use of machinery in land preparation, it falls short in addressing women labor-intensive agricultural activities such as weeding, transplanting, threshing, and harvesting, which causes a relatively greater number of women to engage in off-farm activities for their economic resilience to hire additional labour for these tasks (Kirui, 2019; Takeshima & Diao, 2021).

Gender pattern in agricultural machinery used in rice production

Table 3 shows a summary of the relationship between gender and the usage of agricultural machinery and farm tools. The finding showed only male farmers (0.8%) had used tractors, and none of the female farmers reported using tractors. The chi-square analysis showed no statistically significant association between tractor usage and gender ($P>0.05$). This indicates that tractors are rarely used in small-scale irrigation schemes. The finding further reveals no significant relationship between gender and usage of power tiller ($p >$

0.05). Both male and female farmers show no differential in usage of power tillers; however, the usage of power tillers is slightly higher for females (98.5%) than male farmers (96.5%), but this difference is not statistically significant. This presupposes that the use of power tillers is ungendered. A similar trend was also observed in ox ploughs, whereby the chi-square test showed no significant relationship ($p > 0.05$) between gender and ox plough usage, with only around 7% of both male and female farmers reporting to use ox ploughs. Mrema et al. (2020) also reported a similar observation. This indicates that agricultural machinery is now replacing the traditional methods of land preparation using human and animal power in the study area. As of 2015, Mbeya region accounted for 27% of all power tiller ownership in Tanzania, with Mbarali District within Mbeya region housing 80% of available power tillers (Mrema et al., 2020). These power tillers were predominantly utilized for rice and maize production as well as transportation purposes.

gendered in the study area, with 84.1% of male farmers in comparison to 59.7% of female farmers using agricultural machinery in rice harvesting. This aligns with findings from the studies by Paudel *et al.* (2020) and Aryal *et al.* (2021), who reported a similar trend of more male for combine harvesters in Nepal and India, respectively. Traditionally, machinery operations are male gender roles in sub-Saharan Africa (Sims et al., 2016). This is a plausible reason for the lower use of combine harvesters among female farmers in the study area.

Gender difference in access to agricultural machinery

A gender difference in access to agricultural machinery and farming tools was observed. The results in Table 4 show a significant difference at less than 1% level in access to combine harvesters and paddy threshers between males and females, with a mean score of 1.40 and 1.86 for male farmers, respectively, in comparison to the respective mean score of 1.16 and 1.74

Table 3: Distribution of machinery and farm tools usage by gender (n=397)

Machinery/Tool	Male n(%)	Female n(%)	Chi square	p-values
Tractors	2 (0.80)	0 (0.00)	1.083	0.298
Power tillers	249(96.50)	137(98.50)	1.408	0.235
Ox ploughs	18(7.00)	10(7.20)	0.007	0.936
Paddy threshers	37(14.30)	36(25.00)	8.042	0.005***
Combine harvesters	217(84.10)	83(59.70)	29.119	0.000***

**** is significant at the 1% level.*

The results further show that there is a significant relationship between gender and paddy thresher usage at $p<0.05$; however, 25% of females compared to 14.3% of their male counterparts reported using paddy threshers. This infers that female farmers are still using manual operation tools in rice harvesting in the study area. Kirui (2019) also reported a predominance of women in manual tasks in Africa. This explains why more female farmers reported using paddy threshers. The findings also showed that both males and females had used combine harvesters, but chi-square analysis showed a strong relationship between gender and combine harvesters ($p=0.000$). This implies that the use of combine harvesters is for their female counterparts, indicating gender disparity in accessing harvesting-related machinery and tools between male and female farmers. This implies that male farmers possess a distinct advantage in terms of accessing rice harvesting machinery in the study area. The finding is consistent with previous gender-related literature (Nwoye, 2001; Njuki *et al.,* 2014; Kuwornu *et al.,* 2017; Fischer *et al.,* 2018; Theis *et al.,* 2019; Kadir and Prasetyo, 2020; Afridi *et al.,* 2023) that reported the difference in access to mechanized farming in favor of males. Mottaleb *et al.* (2017) strengthen this pattern by emphasizing that males are more inclined to own and operate machinery compared to females. This observation could

potentially offer an explanation for the gender disparity in accessing combine harvesters. The differences in access to power tillers and tractors between male and female farmers are, however, not significant. On the other hand, there are no significant differences in access to ox-ploughs between male and female farmers ($p > 0.05$).

(2022), who reported a negative influence of age on technology adoption in Ethiopia.

In contrast to females, the odds ratio for male farmers' education showed a significant positive association with their access to power tillers (odds ratio: 3.455) and combine harvesters (odds ratio: 8.061), indicating that the

Table 4: farmer access to machinery and farm tools by gender (n=397)

Machinery /Tool	Sex	N	Mean	Mean diff	t-statistics	P-value
Combine harvesters	Male	258	1.40	0.240	5.592	0.001***
	Female	139	1.16			
Paddy threshers	Male	258	1.86	0.116	2.858	0.004***
	Female	139	1.74			
Ox ploughs	Male	258	1.93	0.002	0.081	0.936
	Female	139	1.93			
Power tillers	Male	258	1.03	0.020	1.186	0.236
	Female	139	1.01			
Tractors	Male	258	2.00	0.010	1.039	0.299
	Female	139	1.99			

****p<0.01*

Determinants of Agricultural Machinery Access Among Male and Female Farmers

The binary logistic regression estimation results in Table 5 present determinants of agricultural machinery access. Of the eight variables estimated in the model, six variables, including age, education, membership in the scheme association, farming experience, land size cultivated, and off-farm activities, had a statistically significant association with agricultural machinery access at $p<0.05$. The age of the farmer showed a significant negative association with access to power tillers among male farmers (odds ratio: 0.963), but not for females, and did not significantly affect access to combine harvesters among both males and females. This implies that as male farmers grow older, their likelihood of accessing power tillers decreases. In contrast, young farmers are more open to innovation and receptive to new technologies. The physical limitations of old farmers, the lower adaptability of new technologies, or their preferences for traditional farming methods may affect their access to agricultural machinery. This finding is similar to that of Ayenew *et al.* (2020) and Zegeye *et al.* likelihood of accessing agricultural machinery for male farmers increases with their education. This is because education equips more men with the necessary knowledge and skills to operate and maintain mechanical technology, making them more easily able to access agricultural machinery. Negera *et al.* (2022) and Zegeye *et al.* (2022) also found the positive role of education in facilitating technology adoption in Ethiopia. Membership in the scheme association also showed a positive and significant association with power tillers (odds ratio: 2.850) and combine harvesters (odds ratio: 2.438) access for male farmers. For female farmers, membership in the scheme association was positively associated with combine harvesters at an odds ratio of 2.693, but not with power tillers ($p > 0.05$). These results imply that membership in the scheme associations increases the chances of farmers accessing agricultural machinery. This is because irrigation associations serve their members in various ways, such as access to technologies and services, information sharing, experience sharing, technological demos, serving as guarantors, and as a source of funds. These results are similar to those of studies by

Table 5: Regression results for the determinants of agricultural machinery access by gender (n= 397)

Variable	Power tiller				Combine harvester			
	Male		Female		Male		Female	
	Odds ratio	C.I	Odds ratio	C.I	Odds ratio	C.I	Odds ratio	C.I
Age	0.963	0.932-0.994**	0.999	0.947-1.056	1.015	0.984-1.046	1.041	0.988-1.098
Marital status	0.324	0.032-3.224	1.542	0.564-4.213	3.254	0.604-17.522	1.627	0.535- 4.942
Education attainment	3.455	1.131-10.553**	0.303	0.059-1.623	8.061	1.480-43.890**	2.496	0.485-12.853
M.scheme	2.850	1.342-6.054***	1.696	0.704-4.082	2.438	1.199-4.960**	2.693	1.049-6.908**
Farming experience	1.136	1.062-1.214***	0.933	0.884-0.986**	1.019	0.982-1.058	0.908	0.851- 0.968***
Household size	0.946	0.781-1.147	0.931	0.727-1.192	0.866	0.735-1.021*	0.914	0.721-1.159
Land size cultivated	1.007	0.853-1.189	1.593	1.084-2.343**	1.106	0.976-1.253	1.418	1.144-1.757***
Off-farm income	1.609	0.568-4.560	7.033	1.476-33.515**	0.530	0.206-1.361	0.879	0.136-5.696
Cons	2.756	0.163-46.600	1.493	0.049-45.632	0.011	0.001- 0.159***	0.027	0.001-1.186*

***, **, and * are significant at 1%, 5%, and 10% levels, respectively.

Prob >Chi^2= 0.000, C. I= Conf. Interval; OR=M.Scheme = Membership in the scheme association

Addai *et al.* (2021), Neway and Zegeye (2022), and Nnahiwe *et al*. (2023), who highlighted the significant role of farmer organizations and group memberships in enhancing farmers' adoption of technologies and agricultural machinery access in Ghana, Ethiopia, and Kenya, respectively.

Farming experience is inconsistently found to be associated with agricultural machinery access among farmers. For males, farming experience is positively associated with access to power tillers (odds ratio: 1.136), but not with combine harvesters ($p>0.05$), indicating that the likelihood of accessing power tillers increases for male farmers with an increase in their farming experiences. Thus, more experienced male farmers are more likely to have access to power tillers than their counterparts. In contrast, farming experience was negatively associated with access to power tillers and combine harvesters for females. The odds ratio of 0.933 in power tillers and the odds ratio of 0.908 in combine harvesters indicate a slightly lower likelihood of accessing power tillers and combine harvesters with increasing farming experience for female farmers. This is because women traditionally assigned labor-intensive rice farming activities such as transplanting and weeding, while the available agricultural machinery was related to on-farm mechanization, male-dominated activities such as land preparation, high equipment costs, and limited access to finance (Badstue *et al.,* 2020; Mrema *et al.,* 2020). Similarly, Ayenew *et al.* (2020) found a positive relationship between farming experience and technology adoption in Ethiopia; however, it is contrary to women's farming experience in this study.

Land size cultivated is also positively associated with power tiller and combine harvester access at odds ratios of 1.593 and 1.418, respectively, for female farmers but not for males. This finding implies that when the amount of land cultivable by female farmers increases, there is a likelihood of increasing their access to agricultural machinery. The reason is that larger landholdings provide economies of scale, making it more cost-effective to invest in agricultural machinery, and women with larger land sizes may have greater financial resources and capacity to rent, acquire, and maintain agricultural machinery. While men are often prioritized and have greater access to resources, including agricultural machinery, regardless of the size of the land, this could explain why the positive association between land size and agricultural machinery access is observed primarily among female farmers. This is in conformity with studies by Anang and Zakariah (2022) and Negera *et al.* (2022), which highlighted the likelihood of using production technologies increasing with land size in Ghana and Ethiopia, respectively. Off-farm income is also positively associated with access to power tillers for female farmers (odds ratio: 7.033). However, this association does not extend to combine harvesters and is not significantly associated with agricultural machinery access for male farmers. This indicates that those additional sources of income for women have a potential role in facilitating agricultural machinery access but are not sufficient for large machines like combine harvesters. The reason is that the increased financial resources and flexibility from off-farm income activities enable women to have additional sources of income; this additional income provides them with the means to overcome financial barriers for purchasing or renting agricultural machinery. This finding concurs with the study by Aryal *et al.* (2021), who found positive relations between off-farm income and adoption of agricultural machinery in South Asia.

The variables such as marital status and household size did not show significant associations with agricultural machinery access in this study. These findings are contrary to other studies, such as a study by Rahman and Sujan (2021), which found that household size is associated with higher levels of mechanization in Bangladesh. A study by Ngochembo et al. (2022) in Cameroon also found household size tends to influence the adoption of agricultural innovations by rice farmers. A study by Neway and Zegeye (2022) found marital status tends to influence adoption of agricultural technology in Ethiopia. These contrasting findings suggest that the influence of these variables on agricultural machinery access depends on specific regional or contextual factors.

Conclusions and Recommendations

Conclusions

The study was designed to explore the socio-economic factors associated with agricultural machinery access by smallholder rice farmers in small-scale irrigation schemes in Mbarali District, Tanzania. It is noted that power tillers and combine harvesters were the most commonly used agricultural machinery by both male and female farmers. There are relatively equal uses of power tillers between male and female farmers; however, a notable gender gap is observed in combine harvesters. Male farmers are predominantly using combine harvesters in comparison to their female counterparts. In addition, there is a substantial gender disparity in access to combine harvesters, with male farmers consistently having more access compared to their female counterparts. While there is a notable gender disparity in the use and access to combine harvesters, there is a more equitable distribution in the use of power tillers between male and female farmers, indicating a potential increase in gender inclusivity in agricultural mechanization. There are gender-specific patterns of positive associations between the socioeconomic characteristics of the farmer and agricultural machinery access. Education, farming experience, and membership in scheme associations are positively associated with male farmers' access to agricultural machinery, whereas female farmers exhibit positive associations with agricultural machinery access through cultivable land size, engagement in off-farm income activities, and membership in scheme associations. These gender-specific patterns emphasize the significance of taking into account and addressing the particular characteristics involved in improving agricultural machinery access in small-scale irrigation schemes.

Recommendations

To promote gender equity in agricultural mechanization within small-scale irrigation schemes, efforts should prioritize enhancing agricultural machinery accessibility, with tailored initiatives supporting women involving a collaborative effort by the government, NGOs, private sector entities, financial institutions, and other stakeholders. These initiatives could include subsidies, cooperative ownership, community-based machinery sharing programs, tailored machine loans or grants for women farmers, and introducing user-friendly, small-scale machinery. Additionally, addressing land tenure issues, supporting off-farm income activities, tailored education programs, and considering the socio-economic context of farmers will help bridge the agricultural machinery access gap and encourage women's participation in scheme associations.

Policy implications

The policy should prioritize enhancing agricultural machinery access in rice farming, with a particular emphasis on supporting female farmers. This involves supportive policies for institutional changes, land access, training and capacity-building initiatives, and financial support. The design of agricultural policies should address gender-specific barriers, promote socio-economic factors enhancing female farmers 'access to agricultural machinery within the policy framework.

Further studies

To expand the current findings, further studies could investigate the effectiveness of targeted interventions addressing gender gaps in agricultural machinery. Moreover, exploring tailored technology solutions could contribute to creating a more inclusive and equitable agricultural mechanization in small-scale farming systems.

Acknowledgement

The authors acknowledge the Sokoine University of Agriculture (SUA) for their technical assistance and smallholder rice farmers for their valuable information, which made this study possible.

References

Achandi, E.L., Mujawamariya, G., Agboh-Noameshie, A.R., Gebremariam, S., Rahalivavololona, N., & Rodenburg, J. (2018). Women's access to agricultural technologies in rice production and processing hubs: A comparative analysis

of Ethiopia, Madagascar and Tanzania. *Journal of Rural Studies,* 60, 188-198.

Addai, K.N., Temoso, O., & Ng'ombe, J.N. (2021). Participation in farmer organizations and adoption of farming technologies among rice farmers in Ghana. *International Journal of Social Economics,* 49(4), 529-545.

Afridi, F., Bishnu, M., & Mahajan, K. (2023). Gender and mechanization: Evidence from Indian agriculture. *American Journal of Agricultural Economics,* 105(1), 52-75.

Ahmad, S.N., & Murtaza, M. (2021). Farm Machine and Female Labour Participation A Study of Indian Districts. *South Asian Journal of Social Studies and Economics,* 12(1): 36-45.

Akram, N., Akram, M.W., & Hongshu, W. (2020). Study on the socioeconomic factors affecting adoption of agricultural machinery. *Journal of Economics and Sustainable Development,* 11(3): 68-80.

Anang, B.T., & Zakariah, A. (2022). Socioeconomic drivers of inoculant technology and chemical fertilizer utilization among soybean farmers in the Tolon District of Ghana. Heliyon, 8(6), e09583.

Aryal, J.P., Thapa, G., & Simtowe, F. (2021). Mechanisation of small-scale farms in South Asia: Empirical evidence derived from farm households survey. Technology in Society, 65, 101591.

Ayenew, W., Lakew, T., & Kristos, E. H. (2020). Agricultural technology adoption and its impact on smallholder farmers welfare in Ethiopia. *African Journal of Agricultural Research,* 15(3): 431-445.

Babu, Z. E. N. A. (2017). Comparative analysis of farm power technologies in rice production for smallholder farmers in Mbarali District, Tanzania (Doctoral dissertation, Sokoine University of Agriculture).

Badstue, L., Eerdewijk, A.V., Danielsen, K., Hailemariam, M., & Mukewa, E. (2020). How local gender norms and intra-household dynamics shape women's demand for laborsaving technologies: Insights from maize-based livelihoods in Ethiopia and Kenya. Gender, Technology and Development, 24(3), 341-361.

Baudron, F., Misiko, M., Getnet, B., Nazare, R., Sariah., J. & Kaumbutho, P. (2019). A farm-level assessment of labor and mechanization in Eastern and Southern Africa. Agronomy for Sustainable Development, 39, 1-13.

Bryan, E., & Garner, E. (2022). Understanding the pathways to women's empowerment in Northern Ghana and the relationship with small-scale irrigation. Agriculture and Human Values, 39(3): 905-920.

Castelein, R.B., Broeze, J.J., Kok, M.M., Axmann, H.H., Guo, X.X., & Soethoudt, J.H. (2022). Mechanization in rice farming reduces greenhouse gas emissions, food losses, and constitutes a positive business case for smallholder farmers–Results from a controlled experiment in Nigeria. Cleaner Engineering and Technology, 8, 100487.

Clarke, L.J. (2000). Strategies for Agricultural Mechanization Development: The Roles of the Private Sector and the Government. Food and Agriculture Organization of the United Nations, Rome, Italy.

Coker, A.A.A., Akogun, E.O., Adebayo, C.O., Mohammed, S., Nwojo, M., Sanusi, H., & Jimoh, H.O. (2017). Gender differentials among subsistence rice farmers and willingness to undertake agribusiness in Africa: evidence and Issues from Nigeria. African Development Review, 29(S2), 198-212.

Daum, T., & Birner, R. (2020). Agricultural mechanization in Africa: Myths, realities and an emerging research agenda. Global Food Security, 26, 100393.

Daum, T., Seidel, A., Getnet, B., & Birner, R. (2022). Animal traction, two-wheel tractors, or four-wheel tractors? A best-fit approach to guide farm mechanization in Africa.

Doss, C., Meinzen-Dick, R., Quisumbing, A., & Theis, S. (2018). Women in agriculture: Four myths. Global Food Security, 16, 69-74.

Estudillo, J.P., Kijima, Y., & Sonobe, T. (2022). Introduction: Agricultural Development in Asia and Africa. In Agricultural Development in Asia and Africa: Essays in Honor of Keijiro Otsuka (pp. 1-17). Singapore: Springer Nature Singapore

Evans, M., Hastings, N., & Peacock, B. (2000). Bernoulli distribution. Statistical Distributions, 3rd ed. New York: Wiley, pp. 31-33.

FAO (2013). Agricultural Mechanization in Sub-Saharan Africa: Guidelines for preparing a strategy. Integrated Crop Management, 22(2013).

Fischer, G., Wittich, S., Malima, G., Sikumba, G., Lukuyu, B., Ngunga, D., & Rugalabam, J. (2018). Gender and mechanization: Exploring the sustainability of mechanized forage chopping in Tanzania. *Journal of Rural Studies,* 64, 112-122.

Fukai, S., Xangsayasane, P., Manikham, D., & Mitchell, J. (2019). Research strategies for mechanized production of rice in transition from subsistence to commercial agriculture: a case study from Khammouan in Lao PDR. Plant Production Science, 22(1), 1-11.

Hinnou, L.C., Obossou, E.A.R., and Adjovi, N.R.A. (2022). Understanding the mechanisms of access and management of agricultural machinery in Benin. Scientific African, 15, e01121.

Kadir, K., & Prasetyo, O.R. (2020). Adoption of Agriculture Mechanization on Paddy Farmers in Indonesia: Demographic Determinants, Internet Access Influence, and The Impact of Adoption on The Yield. *Jurnal Aplikasi Statistika & Komputasi Statistik,* 12(3), 118-130.

Kirui, O. (2019). The Agricultural mechanization in Africa: micro-level analysis of state drivers and effects. ZEF-Discussion Papers on Development Policy, (272).

Kurniawan, F.E. (2021). The dilemma of agricultural mechanization and the marginalization of women farmworkers in rural areas. Sodality: *Jurnal Sosiologi Pedesaan*, 9(2).

Kuwornu, J.K., Apiors, E.K., & Kwadzo, G. (2017). Access and intensity of mechanization: Empirical evidence of rice farmers in Southern Ghana. Brazilian Archives of Biology and Technology, 60.

Magezi, F., Nakano, Y., & Sakurai, T. (2021a). Can smallholder farmers benefit from mechanization in Sub-Saharan Africa? Evidence from rice farming in Tanzania.

Magezi, E.F., Nakano, Y., & Sakurai, T. (2021b). Determinants of Mechanization in Rice Production in Tanzania: Evidence from Panel Data. *Japanese Journal of Agricultural Economics,* 23, 77-82.

Magezi, E.F., Nakano, Y., & Sakurai, T. (2023). Mechanization in Tanzania: Impact of Tractorization on Intensification and Extensification of Rice Farming. In: Rice Green Revolution in Sub-Saharan Africa (pp. 177-194). Singapore: Springer Nature Singapore.

Makoi, H.J., & Matekere, E. (2018). Current policy priorities and regulatory approaches for irrigation and associated challenges of 'farmer-led' irrigation development in Tanzania. *Forest Research and Engineering International Journal,* 2(3): 152–161.

Malapit, H., Theis, S., Krupnik, T.J., Sultana, N., Rahman, S.U., Seymour, G., & Abedin, N. (2019). Gender and agricultural mechanization: a mixed-methods exploration of the impacts of multi-crop reaper-harvester service provision in Bangladesh (Vol. 1837). Intl Food Policy Res Inst.

Mohammed, K., Batung, E., Saaka, S.A., Kansanga, M.M., & Luginaah, I. (2023). Determinants of mechanized technology adoption in smallholder agriculture: Implications for agricultural policy. Land Use Policy, 129, 106666.

Mottaleb, K.A., Rahut, D.B., Ali, A., Gérard, B., & Erenstein, O. (2017). Enhancing smallholder access to agricultural machinery services: lessons from Bangladesh. *The journal of development studies,* 53(9), 1502-1517.

Mrema, G.C., Kahan, D.G., & Agyei-Holmes, A. (2020). Agricultural mechanization in Tanzania. In an evolving paradigm of agricultural mechanization.

Negera, M., Alemu, T., Hagos, F., & Haileslassie, A. (2022). Determinants of adoption of climate smart agricultural practices among farmers in Bale-Eco region, Ethiopia. Heliyon, 8(7), e09824.

Neway, M.M., & Zegeye, M.B. (2022). Gender differences in the adoption of agricultural technology in North Shewa Zone, Amhara

Regional State, Ethiopia. Cogent Social Sciences, 8(1), 2069209.

Ngailo, J.A., Mwakasendo, J.A., Kisandu, D. B., & Tippe, D.E. (2016). Rice farming in the Southern Highlands of Tanzania: management practices, socio-economic roles and production constraints. *Eur. J. Res. Soc. Sci.,* 4(4): 2056-5429

Ngochembo, G.G., Balgah, R.A., & Fonteh, M.F. (2022). Determinants for adopting agricultural innovations by rice farmers in the north-west region of Cameroon. *International Journal of Agricultural Extension,* 10(2).

Njuki, J., Waithanji, E., Sakwa, B., Kariuki, J., Mukewa, E., & Ngige, J. (2014). A qualitative assessment of gender and irrigation technology in Kenya and Tanzania. Gender, Technology and Development, 18(3), 303-340.

Nnahiwe, P., Hejkrlík, J., & Bavorová, M. (2023). Adopting modern agricultural technologies and impact on economic performance: evidence from cashew farmers in Kenya. International Food and Agribusiness Management Review, 2023, 1-26.

Nnaji, A., Ratna, N.N., & Renwick, A. (2022). Gendered access to land and household food insecurity: Evidence from Nigeria. Agricultural and Resource Economics Review, 51(1), 45-67.

Nnaji, J.O., Okonkwo, K.E., Abdulshakur, M.M., Yusuf, A.A., & Olanipekun, O.A. (2019). Comparative Analysis of Gender Participation in Rice (Oryza Sativa) Production Inenugu State, Nigeria. *Journal of Agriculture and Veterinary Science,* 12(11), 75-83

Nwoye Ezeh, D. (2001). Gender differences in small-scale rice farmers' access to technological inputs in Enugu State, Nigeria. ATPS working paper/African Technology Policy Studies Network; no. 23.

Paudel, G.P., Gartaula, H., & Craufurd, P. (2020). Gender differentiated small-scale farm mechanization in Nepal hills: An application of exogenous switching treatment regression. Technology in Society, 61, 101250.

Paudel, G.P., Kc, D.B., Justice, S.E., & McDonald, A. J. (2019). Scale-appropriate mechanization impacts on productivity among smallholders: Evidence from rice systems in the mid-hills of Nepal. Land Use Policy, 85, 104-113.

Rahman, M.S., & Sujan, M.H.K. (2021). Determinants of Small-Scale Mechanization for Potato Farming: A Case from Bangladesh. *Journal of Nepal Agricultural Research Council,* 7: 75-82.

Sims, B.G., Hilmi, M., & Kienzle, J. (2016). Agricultural mechanization: a key input for sub-Saharan Africa smallholders. Integrated Crop Management (FAO) eng v., 23(2016).

Singh, S.P. and Singh, K.K. (2023). Status and prospects of farm mechanization for sustainable agriculture. *RASSA Journal of Science for Society,* 5(1), 35-47.

Takeshima, H., & Diao, X. (2021). Agricultural mechanization and gendered labor activities across sectors: Micro-evidence from multi-country farm household data (Vol. 2066). Intl Food Policy Res Inst.

Thakur, N. (2023). Women Farmers and Technologies in Agriculture: A Review of Current Practices. Women Farmers: Unheard Being Heard, 169-182.

Theis, S., Krupnik, T.J., Sultana, N., Rahman, S.U., Seymour, G., & Abedin, N. (2019). Gender and agricultural mechanization: a mixed-methods exploration of the impacts of multi-crop reaper-harvester service provision in Bangladesh (Vol. 1837). Intl Food Policy Res Inst.

URT (United Republic of Tanzania) (2017). Mbarali District Council Socio-Economic Profile 2015. Dar es Salaam, Tanzania. 133pp.

URT (United Republic of Tanzania) (2018). Mbeya Region Socio-Economic Profile 2015. Dar es Salaam, Tanzania. 254pp.

Van Loon, J., Woltering, L., Krupnik, T.J., Baudron, F., Boa, M., & Govaerts, B. (2020). Scaling agricultural mechanization services in smallholder farming systems: Case studies from sub-Saharan Africa, South Asia, and Latin America. Agricultural

Systems, 180, 102792.

Weisstein, E. W. (2002). Bernoulli distribution. https://mathworld.wolfram.com/BernoulliDistribution.html [accessed 09/11/2023 at 16:11]

Yamane, H. (1967). Universal Matrices for Quantum Groups Associated, to Simple Lie Super algebras. pp. 108-112.

Zegeye, M.B., Fikire, A.H., & Assefa, A.B. (2022). Impact of agricultural technology adoption on food consumption expenditure: evidence from rural Amhara Region, Ethiopia. Cogent Economics & Finance, 10(1), 2012988.

Zhou, X., & Ma, W. (2022). Agricultural mechanization and land productivity in China. *International Journal of Sustainable Development and World Ecology,* 29(6), 530-542.

Zhou, X., Ma, W., Li, G., and Qiu, H. (2020). Farm machinery use and maize yields in China: an analysis accounting for selection bias and heterogeneity. *Australian Journal of Agricultural and Resorce Economics* 64(4): 1282-1307.