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The role of women in adopting maize-legume intercropping among smallholder farming households in Tanzania

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Abstract

In responding to agricultural uncertainties from climate change in Tanzania, intercropping remains among the suitable mitigation technologies. Concurrently, deciding what to intercrop remains a challenge. This study employed a multinomial probit model to examine the effects of involving women in household farming decisions on the adoption of maize-legume intercropping (MLI) by using 5 689 farming households (1 347 in 2010, 1 735 in 2012, 1 234 in 2014 and 1 373 in 2020) from the Tanzania National Panel Surveys. The adoption of MLI dominates across survey years but remains low, averaging around 50%. Household joint farming decisions declined from 64% in 2010 to 53% in 2020. Women's decisions solely/jointly with their partners strongly increased the adoption of MLI and weakly increased the adoption of intercropping with maize and other crops. Therefore, women's involvement in household decision-making should be promoted to increase MLI adoption and improve smallholders' livelihoods amid climate change and variability.

Key words: intercropping; women's decision-making; smallholder farming households; maize-legume intercropping

1. Introduction

The vulnerability of Tanzania and Africa to climate change is worsening with the increasing frequency of floods and droughts that affect agricultural production. This has increased the attention that agricultural stakeholders pay to climate-smart agricultural technologies for enhancing farming households' adaptation and resilience to climate change (Adam *et al*. 2025). The recommended technologies in Tanzania's crop sector include, among others, crop rotation, intercropping, manuring and agroforestry (Rioux *et al*. 2017; Yusuph *et al*. 2023).

Intercropping, in particular, is a common practice in Africa (Ndungu-Magiroi *et al*. 2017; Adam *et al*. 2025) and relatively economical (Maitra *et al*. 2021; Kinyua *et al*. 2023; Yusuph 2023), making it a suitable means for resource-deprived smallholder farmers (Maitra *et al*. 2021; Kinyua *et al*. 2023). Nevertheless, the choice of what to intercrop and the pattern remain complex amid ongoing climate changes and variability (Adam *et al*. 2025).

Legume-based intercropping is considered a special case due to its natural ability to fix nitrogen in the soil, which is necessary for flourishing intercropped crops, thus reducing the need for nitrogen fertilizers (Adam *et al*. 2025; Chitara *et al*. 2024). It provides complementary benefits by not competing for resources with non-leguminous crops, resulting in high, consistent and stable productivity of intercropped crops (Msongaleli 2024; Zhou *et al*. 2025). It is a natural preventer of pests and diseases (Chitara *et al*. 2024) and a relatively effective resilience method in all agroecological areas (Adam *et al.* 2025). Yet, despite this potential and government efforts to improve adoption in Tanzania, approximately only 25% to 34% of smallholder farming households adopt it (Kurgat *et al*. 2020; Mligo *et al*. 2022; Bongole 2023).

To increase the adoption of intercropping, particularly of maize-legume intercropping (MLI), a comprehensive understanding of the factors influencing smallholder farmers' adoption decisions is crucial. Globally, existing studies have identified several factors such as age of the household head, farming experience, farm size cultivated, land ownership, education, extension services, credit access, family labour, occupation, using hired labour, off-farm income and market access as reasons for adoption (Ekepu & Tirivanhu 2016; Degaga & Angasu 2017; Hastuti *et al*. 2021; Ouko *et al*. 2022). However, little is known of the effect of involving women in household farming decisions on the adoption of MLI, despite increasing evidence that it improves smallholders' productivity (Malabayabas *et al*. 2023), diversification (Sariyev *et al*. 2021) and risk management (Karakara *et al*. 2025).

Agricultural practices and the realised outcomes emanate partly from the way households' farming decisions are made (Lecoutere & Jassogne 2016; Euler *et al*. 2024; Awoke *et al*. 2025). Decision-making patterns are shaped by context, norms and beliefs and offer critical insights for promoting smallholders' adoption of agricultural technologies (Euler *et al*. 2024). In contexts where women are involved, household agreements can influence the adoption of agricultural technology (Lambrecht *et al*. 2016; Euler *et al*. 2024; Awoke *et al*. 2025).

Tanzania targets the achievement of gender inclusivity in agriculture (Ampaire *et al*. 2020; Smith *et al*. 2023). Yet a substantial gender gap exists, with fewer than 50% of farming households involving women in farming decision-making (Perelli *et al*. 2024; Karakara 2025; Kinyua *et al*. 2026; Macha *et al*. 2026). Analysing how women's involvement in farming decision-making affects intercropping adoption will show how their perspective can make a difference in responding to climate change and variability.

The need to involve household members in decision-making emanates from cooperative bargaining theory proposed by Ståhl (1972) and Marchant (1997), which assumes that household decisions are negotiated by household members, often between spouses. According to Doss (2013), this generates efficiency outcomes, which contrasts with the unitary model, which assumes the household is a single decision-making unit. Empirically, the influence of involving women in key farming decision-making (household joint farming decision-making) on the adoption of agricultural technology is contextspecific. While studies in Ethiopia, India, Ghana and the Democratic Republic of Congo have established that household joint farming decision-making significantly increases the adoption of agricultural technology, adoption intensity, and the adoption of better technologies (Lambrecht *et al*. 2016; Batung *et al*. 2021; Malabayabas *et al*. 2023; Euler *et al*. 2024), a study in Sub-Saharan Africa by Perelli *et al*. (2024) established an insignificant link in Ethiopia and South Africa. On the other hand, different results were found in Malawi and Tanzania, which have almost similar socio-economic and cultural features – a significantly positive link in Malawi and a detrimental link in Tanzania. Similarly, Lecoutere and Jassogne (2016) found in Uganda that the link was strongly significant in cash crops, but weak and mixed in food crops.

A similar mixed pattern is evident in Tanzania, where, while a study in Lindi district by Perelli *et al*. (2024) reported a significantly negative relationship, a study by Awoke *et al*. (2025) in Dodoma region reported that it was male dominance in decision-making that constrained the adoption of agricultural technologies. These contrasting findings suggest the need for location, technology and crop-specific evidence. The current study therefore adds to the literature, firstly by examining the link in maize-legume intercropping (MLI), which are both cash and food crops, and comparing it to the link in maize-other crops intercropping (MOI) and in maize monocropping. Secondly, the study relies on a relatively large sample for more accurate and reliable results, which differs from previous studies in Tanzania, which covered one region each, thereby lacking country-wide representation. This study will provide insightful information to policymakers in efforts to improve smallholder farmers' livelihoods.

2. Methodology

2.1 Data source

This study uses the Tanzania National Panel Survey (TNPS) data for the years 2010/2011, 2012/2013, 2014/2015 and 2020/2021. The TNPS is a nationally representative survey through which Tanzania's National Bureau of Statistics and the World Bank collect data. These data provide detailed information regarding the main crops grown by households; the gender roles played in decisions on agriculture, inputs and technologies used; and detailed household socioeconomic characteristics.

2.2 Sample size

Table 1 shows the sample used for this study. To capture the influence of female-only farming decisions, the study included both couple- and non-couple-headed households, as suggested by Doss (2013).

Table 1: The sample size of this study

Year	Households interviewed	Households that cultivated maize as their main crop		
		Male-headed	Female-headed	Total
2010	3 924	1 024	323	1 347
2012	5 010	1 323	412	1 735
2014	3 352	914	320	1 234
2020	4 709	990	383	1 373
Total		4 251	1 438	5 689

Source: Author's compilation, 2026, based on NBS (2014, 2017, 2022)

2.3 Data analysis

This study considers each TNPS wave as an independent cross-section rather than a panel, since the combined waves in total face a substantially unbalanced panel structure following household splitting, attrition in the 2010/2011 and 2012/2013 waves, and sample refreshment in 2014/2015 and 2020/2021. Also, although the first or last two waves could provide a balanced panel, household matching substantially reduced intercropper observations, limiting comparison and precision. Thus, treating each wave as an independent cross-section is more appropriate, as it preserves a large representative sample for accurate estimates (Wooldridge 2010; Hsiao 2014). Besides, in pooled models, survey-year dummies are included to account for time-fixed effects, and robust standard errors are clustered at the household level to correct heteroskedasticity and possible intra-household correlation (Wooldridge 2010).

Furthermore, alongside descriptive statistics, the multinomial probit model (MPM) was used to achieve this study's objective, because the outcome has more than two unordered categories: maize-monocropping, maize-legume intercropping (MLI), and maize-other crops intercropping (MOI). MPM is preferred following the violation of the independence of irrelevant alternatives (IIA) assumption in the multinomial logistic regression in the pooled model, a condition MPM relaxes, and is easily computed compared to nested and mixed logit models, which also relax the IIA assumption (Train 2009; Wooldridge 2010). MPM is estimated through the simulated maximum likelihood; however, the coefficients obtained lacked intuitive interpretation, thus marginal effects were computed (Train 2009; Wooldridge 2010; Green 2018) using STATA 17.

2.4 Theoretical and empirical presentation of the multinomial probit model (MPM)

The theory of the MPM is based on satisfaction/utility, U_{ij}, obtained from the choice made by the farming household i, from the alternatives j, given explanatory variables and the random errors, as follows:

$$U_{ij} = x'_{ij}\beta + \varepsilon_{ij}, \quad j = 0, 1, \dots \dots \dots J, \ \ [\varepsilon_{i0}, \varepsilon_{i1}, \dots \dots \dots .. \varepsilon_{iJ}] \sim N[0, \boldsymbol{\Sigma}], \tag{1}$$

where U_{ij} represents the unobserved satisfaction attained by the farming household i from choosing alternative $j. x'_{ij}$ represents the regressors, β represents the parameters to be estimated, which show how the regressors influence the choice of alternative j. ε_{ij} are the random factors affecting $[\varepsilon_{i0}, \varepsilon_{i1}, \dots \dots \dots .. \varepsilon_{iJ}] \sim N[0, \boldsymbol{\Sigma}]$, which indicates that the random errors are jointly normally distributed, and $\boldsymbol{\Sigma}$ is a variance-covariance matrix that allows for the correlation of the alternative random errors; this makes the MPM free from IIA. The probability of the farming household choosing alternative q indicates the probability of attaining higher satisfaction from the chosen alternative relative to the remaining alternatives. Mathematically,

$$P(Choice_{iq}) = P(U_{iq} > U_{ij}), \text{ where } \ j \neq q. \tag{2}$$

Empirically, the ith farming household with jth alternative will maximise satisfaction from the observed outcome Y_i, which takes the following values:

$$Y_i = \begin{cases} 0 \ \ if \ U_{i0} > U_{i1}, U_{i2} \\ 1 \ \ if \ U_{i1} > U_{i0}, U_{i2} \\ 2 \ if \ U_{i2} > U_{i1}, U_{i0} \end{cases} \qquad j = 0, 1, 2 \dots \dots \dots J \tag{3}$$

Considering that the available choice of alternatives is mutually exclusive, the sum of probabilities $(Y_i = 0) + P(Y_i = 1) + P(Y_i = 2) = 1$ for each household. Therefore, the MPM (Equation (4)) is estimated considering $j = 0$ as a reference category:

$$Y_{ij}^* = P(Y_i = j|x) = \alpha_{0j} + \alpha_{1j}Age_i + \alpha_{2j}Hsize_i + \alpha_{3j}Educa_i + \alpha_{4j}crop\_diseasepests_i + \alpha_{5j}farmsize_i + \alpha_{6j}AExtension_i + \alpha_{7j}\,marketdist_i + \alpha_{8j}hhjointdec_i + \alpha_{9j}femalesoledec_i + \alpha_{10j}nonfarmincome_i + \alpha_{11j}ownland_i + \alpha_{12j}livestockown_i + \alpha_{13j}creditac_i + \alpha_{14j}hirelabors_i + \alpha_{15j}gvntassista_i + \alpha_{16j}Amainocc_i + \beta_{ij}Azones_i + \gamma_{tj}year_{ti} + \varepsilon_{ij}, \quad (4)$$

where $P(Y_i = j)$ represents the probability that the ith farming household adopts maize-monocropping when $j = 0$, adopts maize-legume intercropping when $j = 1$, and adopts maize-other crops intercropping when $j = 2$. α_s are the unknown parameters, Age represents the age of the household head (years), $Hsize$ represents the number of household members (count), $Educa$ represents the household head's highest level of education attained (0 ≤ primary education, 1 ≥ secondary education), $crop\_diseasepests$ represent household experience of crop pests/ diseases (1 = experienced, 0 = no), $farmsize$ represents the cultivated area in acres, $AExtension$ represents household access to extension services (1 = yes, 0 = no), $marketdist$ represents distance to markets in kilometres, $hhjointdec$ represents household joint farming decisions (1 = yes, 0 = otherwise), $femalesoledec$ represents female-only farming decisions (1 = yes, 0 = otherwise), $nonfarmincome$ represents if the household has a non-farm activity (1 = yes, 0 = no), $ownland$ represents household land ownership (1 = yes, 0 = no), $livestockown$ represents household livestock ownership (1 = yes, 0 = no), $creditac$ represents household access to credit (1 = accessed, 0 = no), $hirelabors$ represents if the household hired labour (1 = yes, 0 = no), $gvntassista$ explains if the household received financial assistance from the government/non-government organisation (1 = yes, 0 = no), $Amainocc$ represents agriculture being the main household occupation (1 = yes, 0 = no), β_{ij} and γ_{tj} are controls for agroecological zone and years, respectively, and ε_{ij} denotes a random error term.

2.5 Measuring key household farming decision-making variables

Women's voices in agriculture at the household level are multidimensional, covering their decision-making power over agricultural production, productive resources and income use, their involvement in the community, and the time allocated to their workloads (Alkire *et al*. 2013). Economically, women's voice improves through decision-making power over agricultural production, productive resources and income use (Anderson *et al*. 2021). Sticking to economic aspects, this study focuses on decision-making power over production and income use because these have the most direct influence on agricultural outcomes and household welfare (Meinzen-Dick *et al*. 2011; Doss 2013), and they indirectly represent women's resource ownership, since women's ownership does not guarantee decision-making power over resource use (Doss 2013; Doss *et al*. 2014).

Thus, this study relies on the responses to two key questions of the Tanzania National Panels Survey (TNPS) dataset, which are "who decided what to plant on this plot in the long rainy season?" and "who in your household decided what to do with these earnings?" from the previous farming season to construct three variables: female-only decision-making, coded 1 when the woman was reported to be the sole decision maker in the household in relation to both questions, and 0 otherwise. A similar condition was used for men's sole decision-making (a reference category). Household joint decision-making (that involves women and their spouse) was coded 1 when at least one question indicated they made a joint decision, and 0 otherwise.

3. Household characteristics and hypotheses

As shown in Table 2, household joint farming decision-making consistently decreased from 64% in 2010 to 53% in 2020, while female-only decision-making consistently increased from 17% to 21%. Women's involvement in farming decision-making at the household level is hypothesised to positively influence MLI adoption, as Euler *et al*. (2024) and Lambrecht *et al*. (2016) note that it generates commitment, especially when they believe the technology will improve their livelihoods. As both a food and cash crop in Tanzania, MLI may attract women for its potential for household welfare, which is part of their main responsibilities. The average age of the household head ranges from 46 to 49, indicating a mature, experienced labour force with the knowledge required to make better farming decisions. The effect of age on the adoption of agricultural technology is uncertain, since it may reflect increasing exposure to farming technology and the accumulation of social and physical capital, or it may reflect reduced energy, smaller planning horizons and heightened risk aversion (Kassie *et al*. 2013).

On average, farming households had five to six members, and to supplement family labour, only 32% to 46% of the households hired labour over the study period. The effect of household size on adopting MLI is uncertain. Intercropping being a labour-intensive technology, large households with fewer dependents, or those with labour-hiring capacity, are expected to adopt it. About 84% to 85% of the farming households considered agriculture their main economic activity; however, some supplemented it with non-farm income. Wage income increased from 20% to 57%, and self-employment from 13% to 43% between 2010 and 2020. Since the main activity affects time allocated to farming (Kanyenji *et al*. 2020), households mainly engaged in agriculture are expected to adopt MLI for food diversity and income stability. The effect of non-farm income on adopting MLI is uncertain; it may finance farm investment (Ekepu & Tirivanhu 2016; Kassie *et al*. 2013), or divert essential resources (Kassie *et al.* 2013).

More than 90% of the farming households owned land in 2010 to 2012, and the rate decreased to 84% in 2020, possibly due to increased population pressure leading to the fragmentation of agricultural land. Similarly, households that own livestock decreased, from around 45% to 37% between 2010 and 2020, possibly reflecting increased diseases, management costs and pasture shortages. Land/livestock ownership represents a household's economic wealth (Kanyenji *et al*. 2020; Kurgat *et al*. 2020), and is hypothesised to influence MLI adoption.

The rate of farming households that accessed extension services as low and volatile, ranging between 11% to 15% over the study period, possibly reflecting a shortage of extension officers (Rioux *et al*. 2017; Yusuph *et al*. 2023), but is expected to positively influence MLI adoption, since it provides the information necessary for attracting adoption (Msongaleli 2024; Yusuph *et al*. 2023). Farming households that experienced pests and diseases decreased from 27% in 2010 to 17% in 2020, possibly reflecting increased awareness and application of pest repellents. Experience is expected to attract MLI adoption as a remedy against pest cycles.

The average farm size cultivated dropped from about four acres in 2010 to 2014 to around three acres in 2020. Farm size is hypothesised to positively influence MLI adoption, since small farms are relatively more prone to high fixed costs, unlike larger farms that are more flexible to intercrop (Ekepu & Tirivanhu 2016; Ouko *et al*. 2022). Farming households that were financially assisted fell consistently – from 23% in 2010 to about 6% in 2020. In addition, households that accessed credit decreased from more than 40% in 2010 to about 23% in 2020. The effect of credit on MLI adoption is uncertain. Credit finances adoption when credit repayment securities exist, while assistance – being non-refundable and risk-free – is expected to encourage MLI adoption (Kassie *et al*. 2013).

Table 1: Socioeconomic and demographic characteristics of maize farming households (mean values)

Variables	2010	2012	2014	2020	Pooled (2010–2020)
Household joint decisions	0.64	0.62	0.59	0.53	0.60
Female-only decisions	0.17	0.18	0.21	0.21	0.19
Age	48.44	48.77	46.10	48.29	48.00
Household size	5.52	5.63	5.42	5.75	5.59
Hired labour	0.32	0.38	0.46	0.39	0.39
Agriculture main occupation	0.85	0.84	0.85	0.85	0.85
Wage income	0.20	0.47	0.54	0.57	0.45
Business/self-employment	0.13	0.41	0.44	0.44	0.36
Land ownership	0.94	0.92	0.89	0.84	0.90
Livestock ownership	0.45	0.42	0.40	0.37	0.41
Access extension service	0.15	0.11	0.14	0.11	0.13
Pests/diseases experience	0.27	0.16	0.21	0.17	0.20
Environmental shocks	0.41	0.37	0.43	0.28	0.37
Farm size	3.76	3.90	3.77	3.30	3.69
Received financial assistance	0.23	0.13	0.08	0.09	0.17
Access credit	0.45	0.21	0.25	0.23	0.37
Distance to market	10.18	9.74	7.12	5.68	8.30
Non-formal education	0.26	0.26	0.26	0.25	0.26
Primary education	0.68	0.68	0.65	0.65	0.66
Secondary + education	0.06	0.07	0.08	0.10	0.08
Central zone	0.07	0.07	0.06	0.08	0.07
Southern Highland-Western zone	0.39	0.39	0.39	0.39	0.39
Lake – Northern zone	0.22	0.26	0.33	0.35	0.29
South-Eastern zone	0.31	0.28	0.22	0.19	0.25
Maize-legume intercropping	0.49	0.53	0.56	0.44	0.50
Maize-other crops intercropping	0.16	0.15	0.16	0.10	0.14
Maize monocropping	0.35	0.33	0.28	0.46	0.36
Observations	1 347	1 735	1 234	1 373	5 689

Source: Author's computation, 2026

Distance to market consistently decreased over the study period, from around 10 kilometres in 2010 to about 6 km in 2020. Greater distance is expected to discourage MLI adoption due to increased costs. About 68% and 65% of the household heads had attained primary education in 2010 to 2012 and 2014 to 2020, respectively, while those with at least secondary education rose from 6% to 10% between 2010 and 2020. The reasons for the effect are uncertain; highly educated households may consider intercropping an old technology for reviving fertility (Ekepu & Tirivanhu 2016), or may easily evaluate and adopt it (Ouko *et al*. 2022). Most farming households adopted MLI – 49% in 2010, increasing to 56% in 2014 before dropping to 43.5% in 2020, when monocropping was mostly practised (46%). This possibly reflects increased maize commercialisation, while neglecting MLI benefits. MOI remained the least-used technology throughout. Generally, MLI adoption suggests substantial dominance that needs improvement, since only around 50% of households adopted it.

4. Regression results and discussion

Various diagnostic tests were used to assess the suitability of the models. The likelihood ratio test on the multinomial probit models revealed the overall model fit across all models (2010 to pooled), as the p-value was strongly significant ($0.00 < 0.05$), suggesting strong explanatory power of the regressors (Train 2009), and thus we rejected the null hypothesis that all slope coefficients are jointly zero. Also we found the mean variance inflation factor (VIF) to be less than 2, indicating the absence of serious multicollinearity problems in all models that could inflate standard errors and distort significance tests (Wooldridge 2010, 2016).

The marginal effect (Table 3) shows that household joint and female-only farming decisions each significantly increased the adoption of intercropping, with higher significance in MLI. Implicitly, holding other factors constant, households that jointly made farming decisions were more likely to adopt MLI, by 7.7%, 14.9% and 7.4% in 2014, 2020 and in the pooled model, respectively, and to adopt MOI by 4.5% in 2010 relative to maize monocropping. In addition, female-only decisions increased the likelihood of adoption of MLI by 12.4%, 11.3% and 7.4% in 2014, 2020 and in the pooled model, and the adoption of MOI in the pooled model by 2.9%. The results reflect women's need to achieve food diversity and save time relative to handling various plots, as they are intensively involved in farming, caregiving and domestic activities (Tufa *et al*. 2022). Nevertheless, the higher significance of MLI relative to MOI can possibly be attributed to maize-legumes being both food and cash crops that women prefer for household wellbeing, unlike technologies that mainly benefit men (Leavens *et al*. 2019; Perelli *et al*. 2024).

Household head age is positive and statistically significant at the 10% level in MLI and at the 1% level in MOI relative to maize monocropping. This means that, holding other factors constant, older household heads are more likely to adopt maize intercropping relative to younger ones. The results are similar to the findings of Hastuti *et al*. (2021) and Ouko *et al*. (2022). Older farmers have accumulated substantial resources and the expertise essential for the successful adoption of farming technology (Ouko *et al*. 2022). Farmers being older also reflects a stable social capital, which positively influences the perception of intercropping.

Table 3: The marginal effects results for maize-legume intercropping (MLI) and maize-other crops intercropping (MOI) relative to maize monocropping (base category)

	2010		2012		2014		2020		Pooled (2010–2020)	
Variables	**MLI**	**MOI**	**MLI**	**MOI**	**MLI**	**MOI**	**MLI**	**MOI**	**MLI**	**MOI**
Age	0.000	0.001*	0.001*	0.002***	0.000	0.001	0.001	0.001	0.001*	0.001***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.000)	(0.000)
Household size	-0.006	0.004	-0.009*	0.004	-0.003	0.002	-0.007	0.003	-0.007***	0.003*
	(0.005)	(0.004)	(0.005)	(0.003)	(0.006)	(0.004)	(0.005)	(0.003)	(0.003)	(0.002)
Farm size	0.029***	0.000	0.016***	0.002	0.015***	0.006*	0.020***	0.008**	0.020***	0.004**
	(0.005)	(0.003)	(0.004)	(0.003)	(0.005)	(0.003)	(0.005)	(0.003)	(0.002)	(0.002)
Distance to market	-0.002	-0.001	-0.002**	-0.001	-0.003	0.001	-0.000	0.000	-0.003***	-0.001
	(0.001)	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)	(0.003)	(0.002)	(0.001)	(0.001)
Female-only decisions	0.045	0.041	0.031	0.044	0.124***	-0.007	0.113***	0.037	0.074***	0.029*
	(0.045)	(0.035)	(0.040)	(0.028)	(0.043)	(0.032)	(0.040)	(0.025)	(0.022)	(0.015)
Household joint decisions	0.035	0.045*	0.038	0.003	0.077**	0.004	0.149***	0.021	0.074***	0.015
	(0.034)	(0.027)	(0.031)	(0.022)	(0.035)	(0.026)	(0.032)	(0.020)	(0.017)	(0.012)
Access extension service	-0.005	-0.001	0.006	0.006	-0.071*	0.002	-0.061	0.016	-0.030	0.007
	(0.037)	(0.028)	(0.038)	(0.026)	(0.040)	(0.031)	(0.043)	(0.024)	(0.020)	(0.014)
Land ownership	-0.012	0.022	0.029	0.028	0.089**	-0.033	0.072*	0.013	0.064***	0.000
	(0.058)	(0.045)	(0.045)	(0.035)	(0.044)	(0.032)	(0.038)	(0.024)	(0.023)	(0.017)
Livestock ownership	0.051*	-0.022	0.037	0.018	0.085***	-0.060**	-0.026	-0.007	0.041***	-0.013
	(0.029)	(0.022)	(0.027)	(0.019)	(0.032)	(0.024)	(0.031)	(0.019)	(0.015)	(0.011)
Wage income	0.032	0.044*	0.048*	-0.034*	-0.008	0.019	0.032	0.010	0.029**	0.003
	(0.033)	(0.024)	(0.025)	(0.018)	(0.029)	(0.021)	(0.027)	(0.017)	(0.014)	(0.010)
Business/self-employment	0.010	-0.010	0.021	-0.009	-0.054*	-0.018	0.001	-0.005	-0.009	-0.008
	(0.040)	(0.030)	(0.025)	(0.017)	(0.029)	(0.021)	(0.027)	(0.017)	(0.015)	(0.010)
Secondary+ education	-0.041	0.078	-0.010	0.044	0.052	-0.078***	-0.016	0.040	0.002	0.019
	(0.058)	(0.050)	(0.052)	(0.043)	(0.052)	(0.030)	(0.048)	(0.035)	(0.027)	(0.021)
Hired labour	0.038	-0.009	0.029	0.008	-0.014	0.033	0.003	0.007	0.018	0.009
	(0.030)	(0.022)	(0.026)	(0.018)	(0.029)	(0.021)	(0.029)	(0.018)	(0.014)	(0.010)
Pests/diseases experience	0.039	-0.014	0.038	-0.006	0.096***	-0.034	0.012	-0.011	0.042**	-0.015
	(0.031)	(0.023)	(0.032)	(0.023)	(0.034)	(0.026)	(0.035)	(0.022)	(0.017)	(0.011)
Access credit	0.039	-0.030	-0.012	-0.003	0.015	0.023	0.085**	-0.022	0.032*	-0.011
	(0.037)	(0.027)	(0.032)	(0.023)	(0.034)	(0.024)	(0.034)	(0.022)	(0.017)	(0.012)
Received financial assistance	0.083***	0.034	-0.001	0.031	-0.027	0.046	-0.117**	0.028	0.017	0.039***
	(0.028)	(0.021)	(0.036)	(0.024)	(0.052)	(0.035)	(0.057)	(0.034)	(0.019)	(0.012)

	2010		2012		2014		2020		Pooled (2010–2020)	
Variables	**MLI**	**MOI**	**MLI**	**MOI**	**MLI**	**MOI**	**MLI**	**MOI**	**MLI**	**MOI**
Agriculture main occupation	-0.007	0.048	-0.012	0.069**	0.009	0.032	0.095**	0.008	0.017	0.041***
	(0.039)	(0.029)	(0.036)	(0.028)	(0.042)	(0.032)	(0.040)	(0.025)	(0.020)	(0.014)
Agricultural zones	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
Time fixed effects									yes	yes
Observations	1 347	1 347	1 735	1 735	1 234	1 234	1 373	1 373	5 689	5 689

Notes: Robust standard errors in parentheses; *** = $p < 0.01$, ** = $p < 0.05$, * = $p < 0.1$
Source: Author's computation, 2026

Household size shows mixed effects on intercropping adoption. An increase in household size by one person decreased the probability of adopting MLI and weakly increased the probability of adopting MOI. A negative link was unexpected, since intercropping is considered a labour-intensive activity; however, this possibly explains consumption pressure that forces larger households investing in main staple crops like maize and cassava to meet the short-term caloric demand relative to legumes. Also, it possibly reflects diminishing marginal returns as labour increases (Ekepu & Tirivanhu 2016).

Farm size cultivated significantly and strongly increased the likelihood of adopting MLI at 1% over the study period, and weakly increased the adoption of MOI at the 10% and 5% levels in 2014 and 2020, respectively. This means that, other factors remaining unchanged, households cultivating large farms can practise crop diversification without compromising the production of maize. The results tally with the findings of Kanyenji *et al*. (2020), Hastuti *et al*. (2021) and Amankwah (2023). Households cultivating large farms often possess more resources, enabling intercropping flexibility; however, those cultivating small farmlands are often cautious of production uncertainties and risks in new technologies (Hastuti *et al*. 2021).

In this study, non-farm activity was found to affect intercropping adoption heterogeneously. Wage employment significantly increased the probability of adopting MLI in 2012 and in the pooled model by supplementing farming income to finance adoption. The results tally with the findings of Amankwah (2023) and Chichongue *et al*. (2020). However, its influence on MOI is weak and contradictory, probably reflecting differences in preferences and resource requirements between the two intercropping options. In contrast, self-employment/business was found to be weakly detrimental to the adoption of MLI, possibly reflecting that people reinvest resources back into their businesses that are less exposed to climate change.

Land ownership is positive and statistically significant at the 10%, 5% and 1% levels in influencing the adoption of MLI. This means that, all else being constant, land ownership increased the likelihood of adopting MLI by 8.9%, 7.2% and 6.4% in 2014, 2020 and 2010 to 2020 respectively, relative to households in maize monocropping. A meaningful justification is that land owners are interested in improving their lands' long-term productivity and sustainability as they benefit from fertility rejuvenation and yield stability, thus intercropping, unlike renters (Chichongue *et al*. 2020; Amankwah 2023). Also, legume-based intercropping benefits emerge gradually, discouraging land renters from intercropping (Amankwah 2023). The experience of pests and diseases was positive and significant at 1% in 2014 and 5% in the pooled model, influencing MLI adoption relative to maize monocropping. Implicitly, the lived experiences give farmers stronger incentives to protect the future by adopting affordable technology that breaks pest/disease cycles (Kassie *et al*. 2013).

The effect of owning livestock is not homogeneous across maize intercropping options. Livestock ownership significantly increased the likelihood of adopting MLI in 2010, 2014 and from 2010 to 2020, as expected given the role of livestock as wealth that finances adoption (Kassie *et al*. 2013; Kanyenji *et al*. 2020; Kurgat *et al*. 2020). However, livestock ownership was significantly detrimental to the adoption of MOI in 2014. The negative result was unexpected, but limited land for keeping livestock might be a reason (Diro *et al*. 2022), especially for households that prioritise livestock-keeping over crop production.

All else being equal, access to extension services significantly decreased the probability of adopting MLI – by 7.1% among households that accessed it compared to those without access. This was unexpected based on intercropping agronomic and economic benefits; however, this reflects the limited number of available extension officers in the country, who also have limited knowledge of farming technologies (Rioux *et al*. 2017). It also reflects extension efforts that promote improved maize production under monocropping, giving less emphasis to beneficial technologies like intercropping (Mkonda 2021). Thus, households that accessed it opt for high-yielding maize monocropping.

The study further established that smallholder farmers located far from the market were significantly less likely to intercrop maize legumes compared to those close to the market. The results are consistent with the findings established by Kassie *et al*. (2013) and Degaga and Angasu (2017). The availability of legume markets attracts legume-based intercropping (Degaga & Angasu 2017). Also, greater distance is associated with increased costs, which reduces net returns, thus discouraging MLI adoption.

Farmers' access to credit significantly enhanced the likelihood of adopting maize-legume intercropping by 8.5% in 2020 and 3.2% in the pooled model relative to those without access. This possibly reflects relatively readily available legume markets in the country that assure credit repayment. Also, credit finances the labour and inputs needed for intercropping. The results differ from Diro *et al*. (2022), who found that farmers' access to credit increased monocropping practices. Financial assistance also significantly increased the likelihood of adopting MOI; this was expected, since assistance is non-repayable, thus freely invested in intercropping (Kassie *et al*. 2013). Financial assistance targets poor households that prioritise calorie needs favouring MOI, like maize-cassava over MLI.

Similar to Chichongue *et al*. (2020), it was found that agriculture being the main occupation significantly increased the probability of adopting MLI and MOI. This reflects that agriculture-dependent households will prefer intercropping to mitigate production risks and secure livelihoods. Regarding the education of the household head, this study found, similarly to Kanyenji *et al*. (2020) and Tufa *et al*. (2022), that household heads with at least secondary education were less likely to adopt MOI compared to those with primary or less education. Highly educated farmers are more likely to have a high-paying non-farm activity that discourages intercropping. Also, in addition to the significant explanatory variables above, years and agricultural zones significantly accommodate unobservable factors that might have influenced the adoption.

The pooled marginal effect (Table 4) confirms that farming households that involved women in farming decision-making, with older/experienced heads, with large farms, and that owned land and livestock were less likely to practise maize monocropping. A similar pattern is observed among households that had wage income, exposure to pests and diseases, access to financial assistance and hired labour, and considered agriculture their main activity. In contrast, greater market distance increased the likelihood of monocropping. Years significantly accounted for unobservable factors, such as increased awareness of intercropping benefits that increased MLI adoption.

Table 4: The pooled marginal effect results

Variables	Monocropping (2010–2020)	MLI (2010–2020)	MOI (2010–2020)
Age	-0.002*** (0.000)	0.001* (0.000)	0.001*** (0.000)
Household size	0.004 (0.003)	-0.007*** (0.003)	0.003* (0.002)
Farm size	-0.024*** (0.002)	0.020*** (0.002)	0.004** (0.002)
Distance to market	0.003*** (0.001)	-0.003*** (0.001)	-0.001 (0.001)
Female-only decisions	-0.103*** (0.020)	0.074*** (0.022)	0.029* (0.015)
Household joint decisions	-0.090*** (0.015)	0.074*** (0.017)	0.015 (0.012)
Access extension service	0.024 (0.019)	-0.030 (0.020)	0.007 (0.014)
Land ownership	-0.064*** (0.020)	0.064*** (0.023)	0.000 (0.017)
Livestock ownership	-0.028** (0.014)	0.041*** (0.015)	-0.013 (0.011)
Wage income	-0.032** (0.013)	0.029** (0.014)	0.003 (0.010)
Business/self-employment	0.017 (0.014)	-0.009 (0.015)	-0.008 (0.010)
Secondary+ education	-0.021 (0.025)	0.002 (0.027)	0.019 (0.021)
Hired labour	-0.027** (0.014)	0.018 (0.014)	0.009 (0.010)
Pests/diseases experience	-0.027* (0.016)	0.042** (0.017)	-0.015 (0.011)
Access credit	-0.021 (0.016)	0.032* (0.017)	-0.011 (0.012)
Received financial assistance	-0.056*** (0.018)	0.017 (0.019)	0.039*** (0.012)
Agriculture main occupation	-0.058*** (0.018)	0.017 (0.020)	0.041*** (0.014)
Agricultural zones	yes	yes	yes
2010 (reference year)			
2012	-0.048** (0.021)	0.058*** (0.022)	-0.010 (0.017)
2014	-0.081*** (0.023)	0.081*** (0.024)	0.000 (0.019)
2020	0.086*** (0.025)	-0.030 (0.025)	-0.056*** (0.017)
Observations	5 689	5 689	5 689

Notes: Robust standard errors in parentheses; *** = p < 0.01, ** = p < 0.05, * = p < 0.1
Source: Author's computation, 2026

5. Conclusion

This study uncovers the effects of involving women in household farming decision-making on adopting MLI relative to maize monocropping and MOI in Tanzania, using a multinomial probit model on 5 689 households across four TNPS waves (2010/2011, 2012/2013, 2014/2015 and 2020/2021). The rate of households adopting MLI has generally improved, despite a drop in 2020; it remains the dominant cropping system, although persistently low, at around 50%. Household joint farming decisions dominate, despite declining from 64% in 2010 to 53% in 2020, while female-only decision-making consistently improved, from 17% to 21%. Involving women in household farming decisions significantly increased intercropping adoption, particularly that of MLI, relative to when decisions were made by men alone. To ensure maximum adoption of MLI, women's involvement in decision making should be a policy priority.

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