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SOCIO-ECONOMIC DETERMINANTS OF SUSTAINED ADOPTION OF CLIMATE-SMART AGRICULTURAL TECHNOLOGIES IN THE WEST USAMBARA MOUNTAINS, TANZANIA

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ABSTRACT
This study examined the influence of socio-economic factors on the sustained adoption of climate-smart agricultural technologies in the West Usambara Mountains, Tanzania. A sample of 124 households was selected through simple random sampling from a population of 140 farming households involved in the Climate Change Agriculture and Food Security Project between 2011–2019. Data were collected through household surveys, focus group discussions, and key informant interviews. The analysis employed the Multivariate Probit Model and thematic analysis. The study found that age, gender, education, income, and household size influenced the adoption of weather information services, improved seeds, organic fertilisers, terraces and tree planting. Access to credit, technical training, and social organisations also played key roles in sustained adoption. This study concludes that socio-economic factors are crucial for the sustainable adoption of climate-smart agricultural technologies. Policymakers and agricultural extension workers should consider these factors when designing and implementing climate-smart agricultural interventions to ensure their long-term success.

Keywords: Sustained adoption, Climate-smart agricultural technologies, Climate change, Farming households.
Paper type: Research paper
Type of Review: Peer Review

1. Introduction

Agriculture in sub-Saharan Africa, particularly in Tanzania, faces significant challenges due to climate change, which has led to declining crop productivity (IPCC, 2023). Smallholder farmers, who typically have limited capacity to adapt to climate change, are the most affected (van Tilman & Clark, 2014; Ittersuma et al., 2016). In Tanzania, negative impacts of climate change, such as rising temperatures, frequent droughts, unpredictable rainfall patterns, and increased pest and disease outbreaks, have been extensively documented in empirical studies including studies by Lyamchai et al. (2011), Kabote et al. (2017), Mafie (2022) and the government reports (URT, 2014; 2015; 2016). Climate-Smart Agriculture (CSA) is an approach to transforming agricultural practices to address the impacts of climate change (FAO, 2013). CSA focuses on three core pillars such as increasing agricultural productivity and incomes, building resilience and adaptation capacity, and reducing greenhouse gas emissions from agricultural activities (World Bank, 2021). This holistic approach simultaneously addresses the economic, social, and environmental challenges that constrain crop production. In a such context, economic challenges are addressed by increasing agricultural productivity and farmer incomes; whereas social challenges are mitigated by promoting climate adaptation strategies and resilience building; while environmental challenges are tackled through practices that reduce emissions from agricultural activities.

The adoption of CSA technologies such as improved crop varieties, climate information services, organic fertilisers, terraces, minimum tillage, and tree planting can help mitigate the adverse effects of climate change and enhance crop yields (IPCC, 2023). However, studies conducted in regions such as the Democratic Republic of Congo, Nigeria, and Ghana have shown that socio-economic factors significantly influence the adoption and sustained use of CSA technologies (Nsele et al., 2022; Oledede & Wakatsuki, 2011). However, it is argued that adoption barriers vary across locations due to differences in local contexts, social systems, and geographical factors (Shuaibu et al., 2014). Nyengere et al. (2016) found that age and education negatively affected the sustained adoption of CSA technologies in Malawi, with older farmers and more educated individuals being less likely to continue using CSA innovations. Older farmers are often unable to engage in labour-intensive practices like constructing terraces, face significant challenges in adopting these technologies. Additionally, educated farmers may be more risk-averse, with many employed in non-farming activities. Gender, household size, and income also played significant roles, with male-headed households, larger family sizes, and higher incomes generally showing greater success in adopting CSA technologies. Similarly, Nsele et al. (2022) identified that factors such as membership in social organisations, access to credit, land ownership, and financial capital positively influenced the sustained adoption of CSA technologies in Lubumbashi, Democratic Republic of Congo. In contrast, in Imo State, Nigeria, Oledede and Wakatsuki (2011) observed that older farmers had a more positive relationship with the sustained adoption of CSA innovations, although many did not continue using the technologies despite earlier promotion campaigns.

Education was another important factor, with literate farmers being more likely to continue adopting improved technologies. Educated farmers are better able to understand agricultural instructions and apply them effectively, unlike their illiterate counterparts who often struggle to interpret written agricultural information. Between 2011 and 2019, the Climate Change Agriculture and Food Security (CCAFS) project was implemented in the West Usambara Mountains to address climate change-related agricultural challenges. The project focused on promoting CSA technologies such as improved seeds, terraces, organic fertilisers, tree planting, and weather information services. Terraces, for example, are constructed on sloping agricultural land to reduce water runoff, control soil erosion, and preserve soil fertility (Muriuki & Macharia, 2011; Kosmowski, 2015). Other technologies, such as organic fertilisers and drought-resistant seed varieties, aim to address inefficient production by improving soil fertility and increasing crop resilience to climate impacts (Kosmowski, 2015; Saab, 2016; Dhankher & Foyer, 2018). The use of organic fertilisers helps retain soil moisture after the rainy season and improving long-term crop productivity. Tree planting not only reduces greenhouse gas emissions but also enhances soil quality and nutrient availability, while weather information services help farmers make more accurate decisions, reducing risks associated with climate change (Soka & Ritchie, 2016; Muema, 2018; Elia, 2018).

Prior to the CCAFS project, farmers in the West Usambara Mountains faced low productivity due to climatic changes and land degradation, coupled with limited adoption of CSA technologies (Lyamchai et al., 2011; Minderhoud, 2011). Low productivity was a significant contributor to food insecurity and income poverty, particularly in rural areas. Although a few empirical studies including Nyasimi et al. (2017) and Ogada et al. (2020) explored the adoption of crop rotation and chemical fertilisers during the early and mid-implementation stages of the CCAFS project, there remains a gap in understanding the socio-economic factors influencing the sustained adoption of CSA technologies, especially after the project's conclusion. Understanding these factors is crucial for post-project planning and ensuring the long-term sustainability of CSA technologies. Such insights can inform decision-making processes and help agricultural extension officers design effective strategies to promote the continued use of CSA technologies. Therefore, this study aimed at assessing the socio-economic factors influencing the sustained adoption of CSA technologies in the West Usambara Mountains following the conclusion of the CCAFS project. The findings will contribute to the successful implementation of Tanzania's 2013 Agricultural Policy, which aims to increase crop productivity through climate change adaptation strategies.

2. Theoretical framework

The theoretical framework guided the conduct of this study was the Diffusion of Innovation Theory, which posits that the adoption and diffusion of innovations occur in distinct stages until an individual decides to use a particular innovation. According to this theory, the terms 'technology' and 'innovation' are often used interchangeably (Rogers, 2003). In this study, the term 'technology' is used to describe the Climate-Smart Agricultural (CSA) technologies promoted by the CCAFS project before its conclusion in 2019. The aim of innovation is to reduce uncertainty and overcome challenges that may hinder the achievement of specific goals or objectives. In the context of the CCAFS project, various innovations were introduced to address the climate change-related challenges that constrained crop production in the study area.

In the framework of this theory, adoption refers to the integration of an innovation into farmers' regular farming practices, while rejection denotes the decision not to adopt the technology. After experimenting with an innovation, farmers confirm their decision to adopt and continue using it if it offers relative advantages, such as resistance to pests and diseases, improved soil fertility, or increased crop yields (Rogers, 2003). Rogers (2003) and Oldenburg and Glanz (2008) further define sustained adoption as the continued application of a technology by farmers beyond the project period. This concept of sustained adoption forms the basis for this study, which aims to explore the socio-economic factors influencing the long-term adoption of CSA technologies after the CCAFS project ended. The theory assumes that various factors within a social system such as age, gender, education, technical training, access to credit, income, and membership in social organisations significantly influence the ongoing adoption of innovation over time. For this study, these socio-economic factors were identified as crucial variables that could explain the sustained use of CSA technologies after the conclusion of the CCAFS intervention. Accordingly, the study adopted key socio-economic variables, including age, gender, and education, to examine their impact on the continued adoption of CSA technologies in the study area. However, these factors were not well understood by farmers, decision-makers, or agricultural extension officers in the study area, which could hinder the implementation of sustainable agricultural interventions and limit efforts to improve crop productivity. The lack of a clear understanding of these socio-economic factors may contribute to the challenges in achieving long-term adoption of CSA technologies and scaling their benefits in the region.

3. Methodology

The study was conducted in the West Usambara Mountains, located in Lushoto District, Tanga Region, Tanzania, where the CCAFS project implemented interventions for ten years (from 2011 to 2019) aimed at increasing agricultural yields. The main crops grown in the region include maize, beans, Irish potatoes, fruits, and vegetables, cultivated on both hillslopes and lower lands. Sample determination was carried out using the hypergeometric formula, which is particularly useful when the survey population is small (Busbee, 2017). The formula is expressed as follows:

$$n = \frac{Z^2 Npq}{e^2(N-1) + Z^2 pq}$$

Where:

n = sample size
N = population size

p and q = proportions of the population (assumed to be 0.5 due to lack of prior information)
Z = Z-value at a 95% confidence level (1.96)
e = margin of error (±3%)

Thus, the calculation becomes:

$$n = \frac{1.96^2 \text{ x } 140 \text{ x } 0.5 \text{ x } 0.5}{0.03^2(140-1) + (1.96^2 \text{x } 0.5 \text{ x } 0.5)} = 124$$

Therefore, the sample size was estimated at 124 farming households, representing 88.6% of the population. The sampling unit was the farming household, with the head of household (either male or female) as the representative. A simple random sampling method was employed to select the sample from a total of 140 farming households that participated in the CCAFS project. The study used a combination of data collection methods, including household questionnaire surveys, focus group discussions (FGDs), and key informant interviews. Interviews were conducted with the District Agriculture, Irrigation, and Cooperative Officer (DAICO) and two Agricultural Extension Officers, who were involved in the CCAFS project. Additionally, seven FGDs were conducted, with one session held in each village. The farmers who participated in the FGDs had received interventions during the CCAFS project and were selected from those engaged in multiple project activities such as demonstration farms, exhibitions, exchange visits, and members of the Savings and Credit Cooperative Societies (SACCOS). Thus, the study employed a mixed-methods approach, which allowed for the triangulation of results. According to Noble and Heale (2019), combining different data collection methods helps to mitigate biases and enhances the validity of the findings.

For the analysis of quantitative data, the study employed both descriptive and inferential statistical techniques using STATA software version 17. Qualitative data were analysed through content analysis. The study used the Multivariate Probit (MVP) model to analyse the socio-economic factors influencing the sustained adoption of CSA technologies. This model was chosen because the error terms were allowed to be correlated, and it is suitable when the indicators of the dependent variable are mutually inclusive. Farmers can select multiple CSA technologies, making the use of the MVP model appropriate (Rahut & Ali, 2018). The dependent variables are dichotomous (1 if sustained adoption, 0 otherwise), as shown in Table 1. Independent variables are represented as both dummy variables and continuous variables (Wuensch, 2014). The multivariate probit model is specified as follows:

$$Y_{ji}^* = \beta_{ji} X_{ji} + \epsilon_i \quad \ldots \quad (1)$$

Where:

j represents the type of CSA technology (1 to 5),
Yi = 1 if Yi*>0 and 0 otherwise
$Yi*$ is an unobservable latent variable.

The model is extended into five simultaneous equations as follows:

$$Y_{ji1} = \beta_1 X_{ji1} + \epsilon_{i1} \quad \ldots \quad (2)$$

$$Y_{ji2} = \beta_2 X_{ji2} + \epsilon_{i2} \quad \ldots \quad (3)$$

$$Y_{ji3} = \beta_3 X_{ji3} + \epsilon_{i3} \quad \ldots \quad (4)$$

$$Y_{ji4} = \beta_4 X_{ji4} + \epsilon_{i4} \quad \ldots \quad (5)$$

$$Y_{ji5} = \beta_5 X_{ji5} + \epsilon_{i5} \quad \ldots \quad (6)$$

The model assumes that the error terms are independent and follows a multivariate limited dependent structure. These five error terms are considered to be normally distributed, as shown in the covariance matrix in equation (7):

$$\Omega = \begin{bmatrix} 1 & p_{x1x2} & p_{x1x3} & p_{x1x4} & p_{x1x5} \\ p_{x2x1} & 1 & p_{x2x3} & p_{x2x4} & p_{x2x5} \\ p_{x3x1} & p_{x3x2} & 1 & p_{x3x4} & p_{x3x5} \\ p_{x4x1} & p_{x4x2} & p_{x4x3} & 1 & p_{x4x5} \\ p_{x5x1} & p_{x5x2} & p_{x5x3} & p_{x5x4} & 1 \end{bmatrix}$$

Where Ω\Omega Ω is the covariance matrix, and $Pxix_j$ represents unobserved correlation between the stochastic components of different types of CSA technologies. The dependent and independent variables used in the MVP model are summarised in Table 1.

Table 1: Explanation of study variables, measurement and expected effect sign

Variable	Explanations of variables and measurements	Expected sign
Dependent variable:		
Sustained adoption of CSA technologies (Y_j)	Y_{ji1}=1 if continuous use of weather information, 0 otherwise.	
	Y_{ji2}=1 if continuous use of improved seeds, 0 otherwise.	
	Y_{ji3}=1 if continuous use of organic fertilisers. 0 otherwise	
	Y_{ji4}=1 if continuous use of tree planting, 0 otherwise.	
	Y_{ji5}=1 if continuous use of terraces, 0 otherwise.	
Independent variables:		
Socio-economic factors:		
Age (X_1)	Age of respondent in years (years)	-
Sex (X_2)	1 if the respondent is male; 0 if female	+
Education (X_3)	1 if attended formal education; 0 otherwise	+
Household size (X_4)	Number of household members	+
Income (X_5)	Household income per year (Tsh.)	+
Farm size (X_6)	Size of agricultural land (hectare)	+
Access to credit (X_7)	1 if the farmer had access to credit; 0 otherwise	+
Technical training (X_8)	1 if the farmer attended technical training; 0 otherwise	+
Social organisation (X_9)	1 if the farmer is a member of a social organisation; 0 otherwise	+

4. Findings and Discussions

4.1 Socio-economic factors influencing sustained adoption

This section presents findings focusing on the influence of socio-economic factors in the sustainable adoption of climate-smart agricultural technologies in the West Usambara Mountains, Tanzania. During the period of conducting this study it was observed that at the onset of the CCAFS project, fewer than 50% of farmers had adopted at least one Climate-Smart Agriculture (CSA) technology. However, the study found that, following the conclusion of the project, the sustainable adoption of CSA technologies increased significantly as follows: organic fertilisers (82%), improved seeds (85%), tree planting (68%), and weather information services (75%) showed higher rates of sustained adoption. In contrast, the adoption of terraces remained largely unchanged, with only a slight increase observed after the project's completion. The focus group discussions (FGDs) with farmers revealed that most farmers had not adopted climate-resilient technologies during the previous decade, rather they used a variety of agricultural technologies to mitigate the adverse effects of climate change, which in turn have significantly reduced crop productivity. Although adoption rates have improved, fewer farmers have sustained the use of physical soil conservation practices, such as terraces, due to the high labour demands and the greater investment costs associated with these practices.

These disparities in the sustained adoption of CSA technologies could be attributed to various socio-economic factors. The uptake of CSA technologies is influenced by multiple factors, some of which can impact one or more categories of CSA technologies simultaneously, as the adoption of these technologies is mutually inclusive. To analyse these factors, the study employed a multivariate probit model (Table 2), which allows for the simultaneous analysis of multiple explanatory variables on different categories of CSA technologies while accounting for unobserved and unmeasured elements (error terms) that may be correlated (Kassie et al., 2012). The findings revealed that several socio-economic factors such as age, sex, education, income, land size, technical training, access to credit, and involvement in social organisations—were positively associated with the sustained adoption of single or multiple CSA technologies three years after the project phased out in 2019 (Table 2). These results align with the propositions of the Diffusion of Innovation Theory, which asserts that socio-economic factors, including age, gender, training, access to credit, and participation in social networks play a significant role in the continuous use of innovations, even after the interventions have ended.

Table 2: Multivariate probit regression analysis of factors (n=124)

Variables	Weather information services		Improved seeds		Organic fertilisers		Tree planting		Terraces	
	Coef. (S.E.)	P>z	Coef. (S.E.)	P>z	Coef. (S.E.)	P>z	Coef. (S.E)	P>z	Coef. (S.E.)	P>z
Age	**-0.002**** (0.011)	0.050	**-0.015***** (0.010)	0.002	**0.022***** (0.010)	0.006	-0.005 (0.009)	0.560	0.003 (0.011)	0.806
Sex	**0.777***** (0.319)	0.014	-0.456 (0.301)	0.130	0.224 (0.278)	0.419	-0.046 (0.284)	0.871	-0.223 (0.334)	0.504
Education	**0.315*** (0.446)	0.080	**0.862**** (0.433)	0.046	0.348 (0.367)	0.343	**0.688***** (0.377)	0.008	0.303 (0.476)	0.524
Household size	0.043 (0.072)	0.552	-0.028 (0.067)	0.678	-0.064 (0.062)	0.304	**0.106*** (0.061)	0.084	**0.182***** (0.072)	0.011
Income status	**0.000*** (0.000)	0.057	0.000 (0.000)	0.985	**0.000***** (0.000)	0.002	0.000 (0.000)	0.208	0.000 (0.000)	0.459
Farm size	**0.288***** (0.112)	0.010	**0.155**** (0.100)	0.022	-0.054 (0.086)	0.530	0.051 (0.085)	0.552	-0.129 (0.105)	0.221
Technical training	0.010 (0.321)	0.975	**0.772***** (0.306)	0.002	0.103 (0.287)	0.719	**0.119*** (0.283)	0.074	0.196 (0.349)	0.575
Credit	0.290 (0.337)	0.389	-0.351 (0.329)	0.286	**0.475***** **(**0.302)	0.013	-0.088 (0.290)	0.761	**0.696***** (0.391)	0.005
Social organisation	**0.750*** (0.396)	0.058	**0.674*** (0.410)	0.100	0.242 (0.339)	0.476	**0.172***** (0.332)	0.003	-0.489 (0.452)	0.279
Constant	-1.732 (0.996)	0.082	0.229 (0.904)	0.800	-1.837 (0.885)	0.038	-0.436 (0.852)	0.609	-3.551 (1.018)	0.000

Log likelihood = -299.658
Wald Chi^2 = 132.05, Prob> Chi^2 = 0.0002
***, **, * Significant at 1%, 5% and 10% respectively

Results of this study indicate that age of a farmer is a significant predictor of the sustainable adoption of three climate-smart agricultural (CSA) technologies such as weather information, improved seeds, and organic fertilisers. Specifically, age had a negative relationship and significant influenced sustainable adoption of weather information (β = -0.002, p = 0.050) and improved seeds (β = -0.015, p = 0.002) as indicated in Table 2. This suggests that older farmers are less likely to continue using weather information and improved seeds. The findings were corroborated by FGDs which revealed that adopting new technologies often requires farmers to experiment through multiple trials and participate in demonstration plots, particularly for crops like maize, beans, and Irish potatoes. Older farmers, who are generally less exposed to new technologies, lack information and participated to fewer trials tend to abandon these innovations or never adopt them at all. Conversely, younger farmers were typically more motivated by technological innovation and the economic benefits it provides, regardless of associated costs. They were particularly keen on technologies that improve yields in crops such as Irish potatoes, tomatoes, fruits, and cereals like soybeans.

The findings of this study contradict those of Sisay et al. (2023), who observed a positive relationship between the age of the household head and the sustained adoption of improved seeds in Ethiopia's Great Rift Valley. In contrast to the current study, Sisay et al. (2023) found that government subsidies and free or discounted seeds were crucial factors encouraging adoption in their region, which was not the case in this study area. Additionally, the study revealed that age had a positive and significant influence on the sustained adoption of organic fertilisers (β = 0.022, p = 0.006) as indicated in Table 2. Many elderly farmers, who tend to own livestock such as cattle and sheep, can easily access manure, which serves as a primary source of organic fertiliser. Therefore, households headed by older individuals were more likely to continue using organic fertilisers, as they have greater access to the necessary resources. These findings align with those of Kolapo et al. (2022), who also reported a positive relationship between age and the use of organic fertilisers in Nigeria. The study also found that the sex of the farmer significantly influenced the sustained adoption of weather information services, with a positive relationship (β = 0.777, p = 0.015) as indicated in Table 2.

In the study area, male-headed households were more likely to continue using weather information services, as men traditionally have greater access to agricultural information sources such as extension agents and media, including radio. Key informants further emphasised that males are generally the primary controllers of household resources and decision-making, thus they were more likely to access and utilise agricultural information. As one key informant noted:

> "Due to the dominance of the patriarchal system in Lushoto District, males control all household resources and decision-making power. Hence, males usually have more access to agricultural information disseminated through radio and extension agents than females" (Key informant, Lushoto District, June 2022).

This finding was corroborated by the survey results (Table 2), which indicated that male-headed households were more likely to adopt weather information services. During FGDs, it was revealed that women often have limited access to such information, as farming and family-related responsibilities are traditionally assigned to men in the study area. These findings support previous studies, such as those by Kansiime et al. (2020), who observed similar gender-based disparities in agricultural information access in rural Tanzania. Furthermore, the study aligns with Zakati et al. (2019), who found that male-headed households were more likely to invest in CSA technologies than female-headed households.

The level of education of the farmer was positively correlated with the sustained adoption of weather information services (β = 0.315, p = 0.080) as shown in Table 2. Literate farmers were more likely to continue using weather information services, as education enabled them to understand the importance of such information in agricultural planning. This finding suggests that formal education provides farmers with the knowledge necessary to appreciate the benefits of weather data in managing climate risks and enhancing productivity. The study also found a significant positive relationship between education and the sustained adoption of improved seeds (β = 0.862, p ≤ 0.046) and tree planting (β = 0.688, p = 0.008) as shown in Table 2. Farmers with formal education were more likely to continue using these CSA technologies, as they were better equipped to understand and implement the guidance provided by agricultural extension officers. Key informants confirmed that educated farmers found it easier to grasp training on CSA technologies and apply the knowledge to improve their farming practices.

The study further found that household size had significant relationships with the sustained adoption of tree planting (β = 0.106, p ≤ 0.084) and terraces (β = 0.182, p = 0.011) (Table 2). Households with a larger number of adult members were more likely to adopt and maintain tree planting and terrace construction, as these activities require substantial labour. This was reflected in the FGDs, where participants highlighted that larger households have more hands available for tasks such as farm clearing, tree pruning, and weeding, which are crucial for these activities. These findings are consistent with those of

Diallo et al. (2019), who reported that larger household sizes in Mali contributed to the sustained adoption of climate-resilient agricultural practices.

Income was another important factor influencing the sustained adoption of weather information and organic fertilisers. The study revealed a significant positive relationship between household income and the continued use of weather information ($\beta = 0.001$, $p = 0.057$) and organic fertilisers ($\beta = 0.001$, $p = 0.002$) as detailed in Table 2. Higher-income households were more likely to invest in CSA technologies, as they could afford the costs associated with acquiring and maintaining such technologies, including radio and television for accessing weather information. The findings suggest that income enabled farmers to purchase organic fertilisers, such as compost and manure, and to pay for labour required for the application of these technologies. This was further confirmed by FGDs, where participants explained that a portion of their income from both farm and non-farm activities, such as business and wage employment, was invested in CSA technologies.

The farm size was also found to significantly influence the sustained adoption of weather information services ($\beta = 0.288$, $p = 0.010$) and improved seeds ($\beta = 0.155$, $p = 0.022$) as detailed in Table 2. Farmers with larger farms were more likely to adopt and sustain the use of weather information and improved seeds, as they could better manage the risks associated with climate variability on their larger plots. The findings are consistent with those of Sisay et al. (2023), who observed that larger land holdings were associated with the adoption of improved agricultural practices, including the use of climate-smart technologies.

Access to technical training was another key factor influencing sustained adoption. The study found a positive relationship between technical training and the continued use of improved seeds ($\beta = 0.772$, $p = 0.002$) and tree planting ($\beta = 0.119$, $p \leq 0.074$) as shown in Table 2. Farmers who received technical training on CSA technologies were more likely to continue using improved seeds and adopting tree planting, as they acquired the necessary skills to apply these technologies effectively. FGDs participants emphasised the role of technical training in increasing their awareness of CSA technologies, such as improved seeds and agroforestry practices, and enabling them to apply these innovations on their farms. One participant remarked that training had equipped them with the knowledge to establish tree nurseries, which not only supported their own farms but also generated income by selling seedlings to other farmers.

Finally, access to credit was positively related to the sustained adoption of organic fertilisers ($\beta = 0.475$, $p \leq 0.013$) and terraces ($\beta = 0.696$, $p = 0.005$) in Table 2. Farmers with access to credit were more likely to continue investing in CSA technologies, as credit facilitated the purchase of necessary inputs and paid labour for implementing these technologies. FGDs confirmed that microfinance institutions and local government loans provided critical support for farmers to invest in CSA technologies, even when they lacked access to commercial banks. As a participant in one of FGDs explained that:

> “We usually obtain microcredit from Crisis Management Groups and SACCOS since most of us do not meet the criteria for loan application from commercial banks. We use such credits for improving agricultural activities by investing in improved technologies such as purchasing farm equipment, fertilisers, and improved seeds” (FGDs, Yamba Village, June 2022).

This means that farmers' membership in social organisations influenced the sustained adoption of three CSA technologies in the study area, including weather information services ($\beta = 0.750$, $p = 0.058$), improved seeds ($\beta = 0.674$, $p = 0.1$), and tree planting ($\beta = 0.172$, $p = 0.003$). Membership in social organisations increased the likelihood of continued adoption of improved seeds, which can enhance crop resistance to adverse climatic conditions. Furthermore, most farmers who were members of social organisations integrated tree planting with other crops, as they are more aware of CSA practices through frequent interactions with agricultural extension officers and experts during meetings. Key informant interviews also revealed that some farmer-based organisations have established farms focused on climate-resilient farming activities, such as climate-smart crop production and livestock management. These organisations provide opportunities for farmers to learn collectively and share knowledge and skills.

Similar insights were shared during FGDs with farmers, who noted that social organisations, such as SACCOS and Crisis Management Groups, facilitated access to valuable information. For example, agricultural extension officers and researchers disseminate critical information about CSA practices, including weather patterns and seasonal conditions.

The findings suggest that farmers' affiliation with social organisations enhances their access to information, knowledge, and technical skills, which in turn supports the continued adoption of CSA technologies like improved seeds and tree planting. In contrast, a study in South Africa found that membership in cooperatives was not a significant factor in the continued adoption of drought-tolerant and pest-resistant seeds (Senyolo et al., 2021).

5. Implications of the Study's Findings

The findings of this study provide valuable insights for improving agricultural extension services by informing both extension workers and farmers about key socio-economic drivers that can be emphasised during the planning and implementation of post-project interventions. These interventions can help ensure the sustained adoption of CSA technologies in the West Usambara Mountains and other similar regions. The Lushoto District Council can use the findings to enhance decision-making or review strategies and plans aimed at fostering long-term agricultural adaptation to climate change in the West Usambara Mountains and comparable geographical locations. Moreover, the study's findings align with the assumptions and predictions made by the Diffusion of Innovation theory, which was employed to assess the influence of socio-economic factors on the sustained adoption of innovation following the completion of the CCAFS project. Finally, the findings will help researchers identify areas for further study, contributing to the continued use of CSA technologies and supporting the sustainable increase in crop productivity, particularly in mountainous ecosystems like the West Usambara Mountains.

6. Conclusion

Smallholder farmers in the West Usambara Mountains are making significant efforts to adapt to adverse climatic conditions in order to improve crop productivity. These efforts are facilitated through the adoption of Climate-Smart Agricultural (CSA) technologies promoted in the region. This study concludes that socio-economic factors play a pivotal role as predictors of the sustained adoption of CSA technologies, especially following the conclusion of the CCAFS project. The findings confirm the propositions put forward by the Diffusion of Innovation Theory, which posits that socio-economic factors are closely linked to the continuous use of innovations. This study emphasises the critical importance of these socio-economic factors in ensuring the long-term adoption of CSA technologies. Agricultural extension officers should prioritise engagement with households led by elders through interventions such as experimental plots and exchange visits with other farming households. This engagement would enable these households to adopt and sustain the use of CSA technologies, aligning with the practices of more active adopters. Furthermore, female farmers, like their male counterparts, must be granted equitable access to agricultural information, especially in terms of understanding weather conditions. This knowledge would empower them to use climate-related information effectively to mitigate challenges and increase crop productivity in their households. The study's findings offer valuable insights for the review and improvement of post-CCAFS project interventions, providing guidance for the design of future sustainable projects aimed at fostering the long-term adoption of CSA technologies and improving crop productivity in the face of climate change. These insights can significantly contribute to the implementation of Tanzania's agricultural policies and strategies, promoting climate resilience through informed adaptation measures. Moreover, the study contributes to the broader knowledge base on climate-smart agricultural practices, offering a foundation for future research in this area. The findings also support national efforts to enhance climate change adaptation strategies, ensuring that the agricultural sector remains resilient to ongoing climatic changes. Hence, this study not only adds to the existing literature but also highlights critical gaps that can serve as a basis for further research both within Tanzania and in similar regions facing climate challenges.

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