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Enhancing Cotton Productivity through Adoption of Climate Smart Agriculture: A Case Study of Smallholder Farmers in Bariadi District, Tanzania

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Abstract

Climate variability threatens cotton farming in Tanzania, highlighting the need for sustainable strategies to boost smallholder productivity and resilience. This study aimed to establish the effects of Climate Smart Agriculture (CSA) practices on cotton yield among smallholder farmers in Bariadi District, Simiyu Region, Tanzania. A cross-sectional research design was employed, and data were collected using structured questionnaires from a sample of 384 smallholder cotton farmers. Descriptive analysis revealed varied levels of CSA adoption, with diversified crop planting, intercropping, soil and water conservation, and integrated pest management being among the most practiced. The Ordinary Least Squares (OLS) regression analysis was used to estimate the effects of CSA practices and selected socio-economic factors on cotton yield. The results showed that adoption of intercropping, integrated pest management, soil and water conservation techniques, irrigating with motor powered pump, and access to CSA related training had statistically significant positive effects on cotton yield. Moreover, farm size and having alternative sources of income particularly government employment and commercial work were also positively associated with increased cotton production. The study concludes that CSA practices significantly contribute to higher cotton yield and potentially enhance household income. Therefore, it is recommended that local government authorities and Ministry of Agriculture strengthen agricultural extension services and prioritize regular on-farm training and demonstration programs to improve farmers' awareness and practical adoption of CSA practices.

Background information

Agriculture is the backbone of livelihoods across Sub-Saharan Africa (Nyathi et al., 2025; AGRA, 2022) employing nearly two-thirds of the population. In many Sub-Saharan African countries, agriculture contributes approximately 30% to the region's GDP (Hodjo et al., 2023). Smallholder farmers cultivate many crops including cotton for business purpose. However, the sector faces growing threats from climate change, including erratic rainfall patterns, prolonged droughts, soil degradation, and increasing pest infestations (FAO, 2023; Alotaibi et al., 2023; Ruiz & McCue, 2024). These challenges have led to declining agricultural productivity (Ruiz and McCue, 2024; Cunningham et al., 2021) particularly among smallholder farmers who lack access to modern technologies and they have opted for climate change adaptation strategies to secure cotton yield (Fadeyi, et al., 2022).

In Eastern Africa, agriculture is equally vulnerable, with climate change projected to reduce crop yields by up to 30% by 2050 if no adaptive measures are taken (World Bank, 2022). Cotton, an important cash crop in many parts of the region, has been particularly affected due to its sensitivity to water stress, pest , disease infestations and low yield (Malinga & Laing, 2023; Babu et al., 2024; Faisal et al., 2025; Tlatlaa et al., 2023). In countries like Ethiopia, Mali, Kenya, South Africa and Tanzania, cotton farming is largely dominated by smallholder farmers with limited capacity to respond to climate risks (Salisali, 2016; Bwana *et al.,* 2020).

In Tanzania, cotton is the second-largest export crop after tobacco and supports over 500,000 smallholder farmers, primarily in the Western Cotton Growing Area (WCGA), which includes Simiyu Region and Bariadi District in particular (Tanzania Cotton Board, 2023). Despite its economic importance, cotton yields remain low and unstable due to climate-related constraints and poor farming practices and volatile market (Cornelia & Bernhard, 2015). Smallholder farmers in Tanzania including those in Bariadi District continue to rely on rain-fed systems, outdated agronomic techniques, and lack access to extension services or climate-resilient innovations (Abdallah, 2020; Yao, 2023).

To address these challenges, Climate Smart Agriculture (CSA) has been promoted as a sustainable solution to boost crop productivity while enhancing resilience to climate shocks (AkhRegmi & Paudel, 2024; Tilahun et al., 2025; Ma & Rahut, 2024). CSA is an integrated approach that involves the adoption of techniques such as intercropping, conservation agriculture, efficient irrigation, integrated pest management (IPM), and access to weather and agronomic information (Lipper et al., 2014). While numerous studies including (Bongole, 2023; Jones et al., 2023; Yusuph et al., 2024; Msongaleli, 2024;Erick et al., 2025) have shown the benefits of CSA in improving yields for staple crops like maize, leaf vegetables and rice in Tanzania, less is known about its effectiveness in cotton production. In the Bariadi District, climate variability particularly unreliable rainfall and prolonged dry spells has increasingly threatened cotton productivity. While some farmers have begun adopting CSA practices, the uptake remains uneven and poorly documented. There is a critical knowledge gap regarding which specific CSA practices are most effective in enhancing cotton yield under local conditions, and what socio-economic factors influence their adoption. Therefore, this study was undertaken to examine the effects of CSA practices on cotton yield among smallholder farmers in Bariadi District. By identifying the most impactful practices and associated socio-economic drivers, the study aims to provide evidence-based insights to guide agricultural policy, extension services, and investment in climate-resilient cotton farming systems.

Theoretical underpinnings

This study is anchored in Rogers' (2003) Diffusion of Innovation Theory**,** which explains how new ideas and technologies spread within a social system. According to this framework, the diffusion process is shaped by three core elements: the traits of the individuals adopting the innovation, the attributes of the innovation itself, and the communication pathways through which the innovation is conveyed. In the context of this research, household characteristics such as gender, education level, marital status, age, income sources, farm size, and farming experience correspond to the adopter traits highlighted in the theory. The innovation attributes namely, Climate Smart Agriculture (CSA) practices including diversified cropping, intercropping, soil and water conservation, integrated pest management, and irrigation using motorized pumps align with the theory's emphasis on the perceived features of innovations. Furthermore, the institutional mechanisms that influence dissemination, such as access to agricultural training, credit facilities, and farm inputs, represent the communication channels that facilitate the diffusion process within cotton smallholder farmers in the study area.

Methodology

Study Area

The study was conducted in Bariadi District at Sapiwi and Dutwa wards. The study area was selected because it is characterized by its semi-arid climate, with erratic rainfall patterns and high temperatures posing challenges to agricultural production, particularly cotton (Malamsha & Lughuyu, 2024). In addition, the study areas were selected because the primary economic activity is agriculture, with cotton farming being a key sector (URT, 2017).

Research design, sampling procedure and sample size

The study used a cross-sectional research design, with all cotton smallholder farmers in the study area serving as the sampling frame. The sampling unit was the individual cotton smallholder farmer, and a multistage sampling method was used to select respondents. First, Bariadi District was purposively selected, followed by Sapiwi and Dutwa wards, where cotton farming is the main economic activity. Next, five villages were purposively chosen three from Sapiwi and two from Dutwa. Finally, cotton smallholder farmers were selected through simple random sampling.

The total population of 9,717 cotton smallholder farmers was used to calculate the sample size of 384 farmers, applying Yamane's formula as follows:

$$n = \frac{N}{1+N\,(e)^2} = \frac{9717}{1+9717(0.05)^2} = 384 \ldots\ldots\ldots\ldots (i)$$

In this formula, n represents the sample size, N is the total population (9,717 cotton farmers), and e is the margin of error or precision level (set at 5 percent). According to Bariadi Agricultural Marketing Cooperative Society (AMCOS), the village populations were as follows: Igegu (2,850), Sapiwi (1,800), Nyamikoma (1,567) from Sapiwi ward, and Itemelo (1,800) and Ipundula (1,700) from Dutwa ward.

The sample size for each village was then calculated using Salkind's (2010) proportional sampling formula, as shown in equation (ii) and Table 1:

$$n_b = \frac{N_h}{N} \text{ x } n \ldots\ldots\ldots\ldots (ii)$$

Here, n_b is the sample for each village, N_h is the population of the village, N is the total population across all five villages, and n is the total sample size of 384 farmers. For example, the sample for Igegu was calculated as follows: n_b= (2,850 / 9,717) × 384 ≈ 113.

Table 1: Sample size composition of the villages in the study area

Ward	Village	Population	Sample size
Sapiwi	Igegu	2850	113
	Sapiwi	1800	71
	Nyamikoma	1567	62
Dutwa	Itemelo	1800	71
	Ipundula	1700	67
	Total	9717	384

Data collection methods

Information was obtained from both primary and secondary sources to enhance the accuracy and depth of the findings. Primary data were gathered through a household survey using semi-structured questionnaires administered to cotton smallholder farmers affiliated with cooperatives (AMCOS) in Sapiwi and Dutwa wards. Secondary data were obtained by reviewing agricultural policies, scholarly literature, books, articles, and other relevant documents to provide background and supporting insights for the study.

Measurement of the study variables

In the study area, cotton smallholder farmers were interviewed to examine how Climate Smart Agriculture (CSA) practices influence cotton yield. Based on their farming experience, farmers reported adopting several CSA practices, including crop diversification, intercropping, soil and water conservation, irrigation using motor-powered pumps, and integrated pest management (Bongole, 2023; Erick et al., 2025; Sekabira et al., 2022). In this study, these CSA practices were treated as independent variables. Additional independent variables, along with the dependent variable cotton yield are outlined in Table 2, which provides descriptions and measurement details for each variable used in the analysis.

Table 3.7.1: List of variables and their measurement scales

Variable	Scale	Measurement
Cotton growers yield	Ratio	Kilograms per hector
Age of a Cotton grower	Ratio	Years
Years of practicing CSA Practices (experience)	Ratio	Years
Farm size	Ratio	Hectors
Education	Ordinal	Informal education, primary education, Secondary education or tertiary education
Marital Status	Nominal	Single, married, widowed and divorced
Other Source of Income besides farming	Nominal	Peasant, Agri-non farm entrepreneur, government employee and other sources of income
CSA practices implemented by a cotton grower	Nominal	Diversified crop planting, Intercropping, Soil and water conservation technique, Integrated pest management and irrigating with motor powered pump
Access to funds for adoption of CSA	Nominal	Yes and No
Access to information and training	Nominal	Yes and No
Access to agricultural inputs	Nominal	Yes and No

Data analysis

The quantitative data were analyzed by using SPSS version 20 and Stata version 16. SPSS was used to analyze descriptive statistics of the socio-economic, technological and institutional factors of the surveyed households. In the case of inferential statistics, the quantitative data were coded and entered in the stata version 20 for analysis. The inferential statistics applied Ordinary Least Squares (OLS) regression to analyze the influence of climate smart agriculture practices on cotton yield among smallholder farmers in the study area.

Estimation of the model

The Ordinary Least Squares (OLS) regression model was employed in this study to assess the effect of Climate Smart Agriculture (CSA) practices on cotton yield among smallholder farmers. OLS is suitable because the dependent variable cotton yield is continuous and measurable in quantitative units (e.g., kilograms per hectare). This method allows for estimating the linear relationship between multiple independent variables (adopted CSA practices and other socioeconomic factors) and the outcome variable cotton yield. Moreover, OLS is widely used in agricultural economics due to its simplicity, interpretability, and ability to provide unbiased and efficient estimates under the assumption of linearity, homoscedasticity, and normally distributed residuals (Mahaboob et al., 2018; Fox, 2016).

The Ordinary Least Squares (OLS) regression model (equation iii) was applied as follows;

$$Y = \beta_0 + \beta_i X_i + \beta_i D_{kj} + \varepsilon_i$$

Where Y is the dependent variable (Yield), β_0 is the intercept of the model, β_i is the coefficients of the explanatory variables to be estimated, X_i corresponds to the i^{th} continuous explanatory variable of the model ($i = 1\ to\ 4$), D_{kj} corresponds to the i^{th} categorical/dummy explanatory variable of the model ($k = 1\ to\ 11$) and ε is the random error with expectation 0 and variance σ^2.

Results

Socio-economic characteristics of the respondents

Table 2 presents the socio-economic characteristics of cotton smallholder farmers in the study area. A total of 384 respondents participated, with 41.4% from Dutwa Ward and 58.6% from Sapiwi Ward. The sample was predominantly male (69.5%), while females accounted for 30.5%.In terms of education, most farmers had attained primary education (56%), followed by secondary education (27.3%), informal education (11.5%), and tertiary education (5.2%). Regarding marital status, the majority were married (63.8%), while 22.7% were single, 13% were widowed, and only 0.5% were divorced. In terms of other sources of income besides farming, the vast majority identified as peasants (78.4%), followed by Agri-non farm entrepreneur s (17.7%), government employees (3.7%), and a small fraction (0.3%) under other categories.

Table 2: Socio-economic characteristics of the respondents

Variable	Frequency	Percent
Ward		
Dutwa ward	159	41.41
Sapiwi ward	225	58.59
Sex		
Male	267	69.53
Female	117	30.47
Education		
Informal education	44	11.46
Primary education	215	55.99
Secondary education	105	27.34
Tertiary education	20	5.21
Marital Status		
Single	87	22.66
Married	245	63.8
Widow	50	13.02
Divorced	2	0.52
Other Sources of Income besides farming		
Peasant	301	78.39
Agri-non farm entrepreneur	68	17.71
Government employee	14	3.65
Other	1	0.26

Climate-Smart Agriculture Practices and Socio-Economic Characteristics

Table 3 summarises the climate-smart agriculture (CSA) practices adopted by cotton farmers along with other key socio-economic characteristics. Among the 384 farmers surveyed, nearly half (49.5%) practiced diversified crop planting, while 41.4% used intercropping methods. Soil and water conservation techniques were applied by 7.6% of the farmers, irrigating with motor powered pump (1.0%) and very few adopted integrated pest management (0.5%).

Regarding access to resources, only 10.7% of the farmers reported having access to credits to support CSA adoption, while a striking 89.3% did not (Table 3). Extension services played an important role, with 83.1% of farmers confirming they received support from extension officers promoting CSA practices. Access to information and training was reported by 86.2% of farmers, showing a strong flow of knowledge within the farming community. Finally, 59.6% of cotton farmers had access to agricultural inputs, whereas 40.4% lacked such access (Table 3).

Ordinary Least Squares (OLS) regression results

An Ordinary Least Squares (OLS) regression was conducted to estimate the effects of Climate Smart Agriculture (CSA) practices and socio-economic factors on cotton yield among smallholder cotton farmers in Bariadi District. The model showed a good fit with an **R-squared of 0.2537** and an **adjusted R-squared of 0.2126**, indicating that about 21% of the variation in cotton yield is explained by the predictors in the model.

Significant Factors Affecting Cotton Yield

Farm size

Study findings showed that farm size was positively and significantly related to cotton yield, with a regression coefficient (β) of 64.02 and a p-value below 0.01. This means that as the size of a farmer's land increases, their cotton yield also tends to increase. Specifically, for every additional unit of land (hectare), the cotton yield is expected to rise by approximately 64.02 units, assuming all other factors remain constant. The small p-value ($p < 0.01$) indicates that this relationship is statistically significant, meaning there is strong evidence that farm size is an important factor influencing cotton yield in the study area.

Table 3: Climate smart agriculture practices adopted by farmers and other socio-economic characteristics

CSA practices and socio-economic factors	**Frequency**	**Percentage**
Diversified crop planting	190	49.48
Intercropping	159	41.41
Soil and water conservation technique	29	7.55
Integrated pest management	2	0.52
Irrigating with motor powered pump	4	1.04
Access to credits		
Yes	41	10.68
No	343	89.32
Access to extension services		
Yes	319	83.07
No	65	16.93
Access to information and training		
Yes	331	86.2
No	53	13.8
Cotton Grower has access to Agricultural Inputs		
Yes	229	59.64
No	155	40.36

Table 4: OLS Regression of Climate Smart Agriculture Effects on Cotton Yield

Dependent Variable: Cotton Yield	Coefficient	Std. Err.	P>t
Age	-1.6562	1.7345	0.340
Years of practicing CSA	27.0292	17.9499	0.133
Farm Size in Ha	64.0187***	15.1958	0.000
Level of education			
Informal education	60.6510	57.2088	0.290
Secondary education	-39.5652	42.4701	0.352
Tertiary education	-36.6537	80.7915	0.650
Marital status			
Single	1.8644	43.7970	0.966
Widow	68.6095	55.1393	0.214
Divorced	-125.8892	232.4816	0.588
Other Source of Income Besides Farming			
Agri-non farm entrepreneur	114.1314**	46.6475	0.015
Government employee	281.4357***	97.2645	0.004
Other	-435.0019	317.9133	0.172
Diversified Crop Planting			
No	28.9294	42.8105	0.500
Intercropping			
No	-90.5841**	39.0213	0.021
Soil and Water Conservation Technique			
No	-130.8486***	39.3812	0.001
Integrated Pest Management			
No	-185.4597***	48.1778	0.000
Irrigating with motor powered pump			
No	-124.5501**	55.2460	0.025
Accessed credit for Adoption of CSA Practices			
No	-20.2551	53.7549	0.707
Access to information and training			
No	-203.7884***	54.5326	0.000
Access to agricultural inputs			
No	10.1291	35.6809	0.777
Constant	1131.2670***	113.6792	0.000

R-squared =0.2537; Adj R-squared=0.2126, significance levels of 1%, 5%, and 10% are indicated by ***, **, and * respectively.

Other sources of income such as government employee

The findings revealed that government employment was strongly and significantly linked to higher cotton yields, with a regression coefficient (β) of 281.44 and a p-value less than 0.01. On average, government employees produced approximately 281.44 more units of cotton compared to farmers in other occupational groups, holding all other variables constant. The low p-value ($p < 0.01$) confirms that this difference is statistically significant, providing strong evidence that government employees consistently achieved higher yields than their counterparts in the study.

Agri-non-farm entrepreneur

The study results indicated that being a Agri-non-farm entrepreneur was significantly associated with higher cotton yields, with a regression coefficient (β) of 114.13 and a p-value below 0.05. This means that, on average, Agri-non-farm entrepreneur s produced about 114.13 units more cotton compared to farmers from other occupational groups, assuming all other factors remain constant. The p-value ($p < 0.05$) indicates that this difference is statistically significant, meaning there is solid evidence that Agri-non-farm entrepreneur s achieved higher yields compared to others in the study.

Intercropping

The results showed that intercropping had a significant positive effect on cotton yields. Specifically, when farmers did not practice intercropping, their yields were about 90.58 kg/ha lower ($\beta = -90.58$, $p < 0.05$), compared to those who did intercrop, assuming all other factors remained constant. The negative coefficient means that the absence of intercropping reduced yields, highlighting the important role of intercropping in boosting cotton productivity. The p-value ($p < 0.05$) confirms that this result is statistically significant, providing strong evidence that intercropping contributes to higher cotton yields.

Soil and water conservation technique

The results indicates that soil and water conservation techniques had a strong positive effect on cotton yields. When farmers did not apply these practices, their yields were reduced by about 130.85 kg/ha ($\beta = -130.85$, $p < 0.01$), compared to farmers who used them, assuming all other factors remained constant. The negative coefficient indicates that the absence of these techniques significantly lowered yields, underlining the important role they play in improving cotton productivity. The p-value ($p < 0.01$) shows that this result is statistically significant, providing strong evidence that adopting soil and water conservation practices leads to better yields.

Integrated pest management (IPM)

The study findings revealed that integrated pest management (IPM) had the most substantial positive impact on cotton yield among the factors examined. Specifically, the yield decreased by 185.46 kg/ha when IPM was not applied ($\beta = -185.46$, $p < 0.01$), showing a highly significant relationship. This means that farmers who implemented IPM practices achieved notably higher cotton yields compared to those who did not. The strong effect can be attributed to IPM's ability to effectively control pest populations, reduce crop damage, and improve overall plant health, ultimately enhancing productivity.

Irrigating with motor powered pump

The results showed that irrigating with motor-powered pump had a significant positive effect on cotton yield. When motor-powered pumps were not used for irrigation, the yield declined by 124.55 kg/ha ($\beta = -124.55$, $p < 0.05$), indicating a meaningful relationship. This suggests that farmers who irrigated with motor-powered pumps achieved notably higher yields compared to those relying on less efficient or traditional methods. The positive impact is likely due to the ability of motor-powered pumps to provide a steady and sufficient water supply, reduce water stress, and improve nutrient uptake, all of which contribute to better crop growth and higher cotton yield.

Access to Climate Smart Agriculture practices related training and information

The analysis revealed that access to CSA-related training and information had a significant positive impact on cotton yield. Farmers who did not have access to such training and information experienced a yield decrease of 203.79 kg/ha ($\beta = -203.79$, $p < 0.01$), indicating a highly significant relationship. This finding suggests that farmers who received training and information on climate-smart practices achieved considerably higher yields compared to those who lacked such support. The positive effect is likely because training equips farmers with knowledge on best practices, efficient resource use, and adaptive strategies, all of which help improve cotton yield and resilience to climate related challenges.

Discussion

The socio-economic profile of cotton farmers in Bariadi District highlights important structural factors shaping agricultural practices and livelihood outcomes. The predominance of male farmers and those with primary-level education aligns with patterns reported in other Tanzanian farming communities, where limited education often constrains technology adoption and farm productivity (Mmbando & Baiyegunhi, 2016). The dominance of married households suggests the importance of family labor in cotton production, consistent with findings by Chami (2018).

In addition, the uptake of climate-smart agriculture (CSA) practices among cotton farmers is shaped by both technical and socio-economic factors. Consistent with Ma and Rahut (2024) and Ewulo et al. (2025) access to extension services and training plays a crucial role in improving farmers' knowledge and willingness to adopt CSA innovations. However, limited access to credit remains a key barrier, as echoed in Agyekum et al. (2024), who emphasized that financial support is essential to scale CSA practices effectively.

The adoption of Climate-Smart Agriculture (CSA) practices has been shown to significantly enhance cotton yields among smallholder farmers in Bariadi District. Our analysis identified several key CSA practices including intercropping, soil and water conservation techniques, integrated pest management (IPM), and irrigating with motor powered pump that positively influence cotton yield.

Intercropping emerged as a highly beneficial practice, with farmers who adopted it achieving significantly higher yields compared to those using monoculture systems. This finding is consistent with recent evidence showing that intercropping optimizes resource use efficiency by improving light interception, nutrient uptake, and soil moisture utilization (Ma & Rahut, 2024). Beyond immediate productivity gains, intercropping also enhances soil fertility through complementary plant interactions, contributing to long-term system sustainability and resilience against environmental stresses.

The adoption of soil and water conservation techniques emerged as a significant factor in enhancing cotton yields, underscoring their role in maintaining soil fertility and optimizing moisture availability. These practices not only reduce soil erosion but also strengthen the soil's capacity to retain water, which is essential for stabilizing yields under increasingly erratic rainfall patterns linked to climate change (Li et al., 2023). Moreover, their integration into farming systems contributes to long-term sustainability by improving soil structure, enhancing nutrient cycling, and reducing vulnerability to land degradation.

Integrated Pest Management (IPM) demonstrated the strongest positive impact on cotton yield, highlighting its critical role in sustainable crop production systems. By combining biological, cultural, and mechanical control methods, IPM not only reduces dependence on chemical pesticides but also fosters ecological balance within the agroecosystem (Zhou et al., 2023). This holistic approach enhances pest suppression, minimizes crop damage, and improves overall plant health, ultimately translating into higher and more stable yields. Moreover, IPM's emphasis on environmental stewardship positions it as a cornerstone strategy for resilient and climate-smart cotton farming.

The use of motor-powered pumps for irrigation emerged as a key driver of cotton productivity, with farmers utilizing this technology attaining significantly higher yields. This underscores the pivotal role of efficient and reliable water management in optimizing cotton production, particularly in regions prone to rainfall variability. Consistent with recent research, motorized irrigation not only improves water use efficiency but also enables timely water delivery during critical growth stages, thereby safeguarding yields under water-limited conditions (Kifle et al., 2022). Furthermore, its adoption reflects the increasing importance of mechanization in enhancing smallholder resilience and productivity.

Furthermore, access to CSA related training and information was positively correlated with higher cotton yields. This highlights the role of agricultural extension services in facilitating the adoption of improved practices. Recent research emphasizes that informed farmers are more likely to implement CSA techniques effectively, leading to better outcomes (Asante et al., 2024).

Conclusion

The study concludes that the adoption of Climate Smart Agriculture practices is not just beneficial it is essential for improving cotton yield and building resilience among smallholder farmers in the face of climate variability. However, for these benefits to be fully realized, farmers must be supported with targeted interventions such as access to training, irrigation technologies, and off-farm income opportunities. The results highlight the importance of practical, context-specific support systems that enable farmers to adopt and sustain CSA practices.

In conclusion, promoting CSA adoption among cotton farmers in Bariadi District is a viable pathway toward sustainable agricultural productivity, improved livelihoods, and long-term climate resilience. Policymakers, extension agents, and development partners should prioritize actions that break down barriers to CSA implementation and ensure that no farmer is left behind in the transition toward climate-smart cotton production.

Recommendations

Based on the findings of this study, several practical and actionable recommendations are proposed to enhance cotton yields among smallholder farmers in Bariadi District through increased adoption of Climate Smart Agriculture (CSA) practices.

Firstly, the Ministry of Agriculture, in collaboration with local government authorities and NGOs, should strengthen access to CSA training and extension services. This can be done by recruiting and deploying more extension officers who are well-trained in CSA practices. These officers should conduct regular on-farm training, set up demonstration plots, and utilize mobile platforms to deliver advisory services in local languages. This

approach ensures that even farmers with limited formal education can understand and implement practices such as intercropping, efficient irrigation, soil conservation, and integrated pest management.
Secondly, the District Agricultural Office should partner with the National Irrigation Commission and agro-tech companies to scale up the availability of efficient irrigation technologies. This can involve providing subsidized drip or sprinkler irrigation kits to farmers, especially those in drought-prone areas. Establishing Water User Associations (WUAs) will help farmers manage shared irrigation infrastructure and ensure sustainability through local oversight and maintenance.
Thirdly, local governments and farmer cooperative unions should facilitate improved access to agricultural inputs by organizing farmers into cooperatives. These cooperatives can engage in bulk purchasing of key inputs such as pest control products, irrigation equipment, and improved cotton seed varieties. Additionally, cooperatives can serve as platforms for technical training and sharing of best practices among members.
Another critical recommendation is to promote off-farm income opportunities to enable farmers to invest in CSA technologies. District Development Officers, in partnership with the Ministry of Labor and Employment, vocational training centers, and private sector actors, should implement rural employment schemes and small business initiatives. Programs could include agro-processing, community infrastructure development, and vocational skills training. These alternative income sources can reduce financial barriers that limit CSA adoption.
Furthermore, village agricultural committees, supported by the Tanzania Agricultural Research Institute (TARI), should lead community-based land management programs that promote intercropping and soil conservation. This could involve distributing starter seed packs for legume intercrops and training lead farmers in techniques like contour farming and mulching, which help preserve soil structure and moisture.
Finally, Ward Agricultural Officers should work with local farmer groups to establish CSA champions at the village level. These are lead farmers who will model best practices, host demonstration activities, and provide peer guidance. To keep them motivated and impactful, they should receive technical support, inputs, and community recognition.
In sum, these recommendations call for coordinated action from government agencies, research institutions, NGOs, and local community structures to drive adoption of CSA practices and enhance cotton productivity in a sustainable, inclusive manner.

Declarations

Author Contribution Statement
Fredrick Alleni Mfinanga: Data collection, supervision and wrote the original manuscript.
Barikiel Israel Panga: Analysed data.
Jacqueline Temba: Literature review, results presentation, discussion, article formatting, proofreading and editing.

Conflict of Interest

Authors declare no conflict of interest.

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