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RESEARCH ARTICLE

Exploring the Adoption and Impact of Conservation Agriculture among Smallholder Farmers in Semi-Arid Areas: Evidence from Chamwino District, Tanzania

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Abstract: The adoption of Conservation Agriculture (CA) technologies by smallholder farmers is expected to affect agricultural productivity and ultimately improve food security and farm incomes. However, there is still limited empirical evidence on the adoption and effects of CA technologies among smallholder farmers in the semi-arid areas of Tanzania. This study was designed to assess the adoption of CA by smallholder farmers in semi-arid areas. The study used a cross-sectional survey design in four villages in Chamwino districts where CA projects are promoted. A random sample of 260 households was interviewed in this study, including 134 CA adopters and 126 non-CA adopters. Data were collected and analyzed using KoBo and SPSS statistics respectively. Descriptive statistics were used to examine extension approaches applied and analyze the extent of CA adoptions. A logistic regression model explored the determinants influencing farmers' decisions to adopt CA. In addition, two independent samples t-tests were used to calculate the effect of CA adoption on crop yields and farm incomes. The results show that robust extension services led to a better quality of CA practices on CA farms. Gender, access to extension services, access to agricultural inputs, participation in farmer groups, and access to credit for agriculture significantly influence the adoption of CA. CA adopters achieved better average crop yields and higher farm income per unit area than those who did not adopt CA. Thus, the study recommends that the government and other development actors devote more resources to agricultural extension services and mechanization to support and increase the scaling up of CA technologies. There is also a need to establish and strengthen monitoring and evaluation systems to ensure coherence, impact and sustainability of CF programs in semi-arid areas of Tanzania.

Keywords: Adoption; Impact; Conservation agriculture; Semi-arid areas; Tanzania

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1. Introduction

Several dimensions of massive land degradation in semi-arid areas led to low agricultural productivity and decreased food security and farm income [1-3]. The problem of increased food insecurity is due to declining yields of food crops which are attributed to many causes that include: The use of conventional farming systems, low utilization of new technologies, decline in soil fertility, regular droughts, and low and erratic rains with uneven distribution [4].

Conservation Agriculture (CA) is largely promoted as one of the few win-win technologies affordable to farmers that potentially improve farmers' yields while at the same time conserving the environment [5]. The CA practices appear as a potential technology against Climate Change [1,6]. However, despite more than a decade of CA promotion in southern Africa, the rate of adopting conservation agriculture in Africa (including Tanzania) is insufficient compared to other parts of the world. The areas under CA are still very low compared to the rest of the world. Africa has about 1.1% of the continent's total arable land under CA, while South America has about 63% of the region's cropland under CA [7]. Based on the benefits attached to conservation agriculture, there is a need to emphasize and speed up its adoption and utilization in Africa, including Tanzania.

Tanzania has about 33,000 ha, of which 11,000 ha are under smallholder farmers, and 22,000 ha are under large commercial farms [5]. The most CA practices applied by farmers are cover crops, ox ripping and crop residues while the least used CA practices are power tiller ripping and green manure cover crops [8]. Despite various initiatives to promote CA, studies have shown that there has been little adoption of CA among smallholder farmers in Tanzania [5,9,10]. CA adoption remains low even in the areas where CA projects are promoted and implemented [10]. Furthermore, except for a few studies conducted on CA in Tanzania which include [8-10,12,13], there are still few empirical studies on the adoption of CA technologies in the study area which are characterized by recurrent droughts and a shorter rainy season resulting in low crop productivity and household food insecurity.

Chamwino district is one of the seven districts of the Dodoma region located in a semi-arid zone. The district is characterised by regular droughts, low and erratic rains with uneven distribution, low soil fertility, low soil moisture, soil erosion, and low crop yield per unit area. The dry season is usually much longer (May to December) than the wet season, which runs from January to April, with February or March usually experiencing a drought (DCT—Situation Assessment Report, 2020). One of the features of Chamwino district is land degradation due to increasing population pressure, conventional tillage-based systems, free-range grazing, competition of crop residue for various uses, and the burning of crop fields, thus combined leading to environmental degradation. These challenges and the result of climate change remain important because of their impacts on the environment, agricultural productivity, and food security [7]. On the other hand, Chamwino District is one of the districts in the Dodoma region where CA technologies have been introduced and promoted by development partners through community-based projects with the collaboration of the Local Government Authority (LGA) to address the challenges of climate change and food insecurity.

Although CA technologies seem to have enormous potential in semi-arid areas, there is still a lack of information on the adoption of CA technologies in the study area. Moreover, there is a gap between the benefits of CA and low levels of adoption. This situation requires further research to assess the adoption of CA technologies and their effects on smallholder farmers. Therefore, this study examined the extension approaches used to disseminate CA knowledge, analysed the extent of adoption of CA technologies, determined the factors of farmers' decision to adopt CA technologies, and evaluated the effect of CA technologies on farm income among smallholder farmers in the study area. This study also intended to generate knowledge and information that can contribute in design and improving intervention strategies including effective extension approaches to accelerate CA adoption.

Figure 1 shows the conceptual framework for modelling the factors for the adoption of CA and its benefits to the livelihood of smallholder farmers. This study hypothesizes that the adoption of CA technologies was influenced by the independent variables which were extension approaches that were used to disseminate CA knowledge, demographic factors, land tenure systems, household income and access to credit. The moderating variables for the study were agricultural policy, legal framework, farmers' training in CA and access to extension services. Moderating variables can affect the relationship between the independent and dependent variables as these factors affect the decision of farmers to adopt CA. Therefore, if a farmer adopts CA technologies, it is expected to increase crop yield (kg/Acre), farm income (TZS/Acre), and household assets.

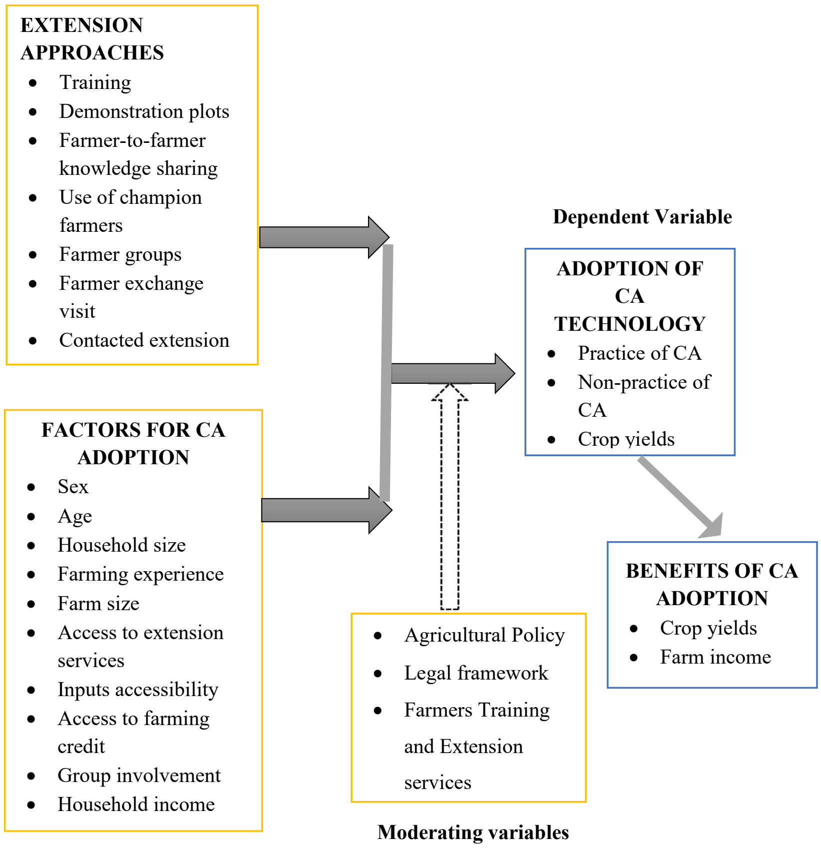

Figure 1. The conceptual framework.

Source: Modified from Rogers (2003).

2. Study Area, Data and Methods

2.1 Location of the Study Area

This study was conducted at two (2) targeted wards, namely Nghahelezi and Mlowa located in Chamwino district in Dodoma Region. The latitude for the Chamwino district is 6.0986° S, and the longitude is 36.0431° E. The study areas comprised four villages, as shown in Figure 2. CA technologies have been promoted and implemented in the Wards by the Diocese of Central Tanganyika (DCT) through its Department of Development Services Coordination (DSC) in collaboration with different partners, including Canadian Foodgrains Bank (CFGB), Tearfund Canada (TFCA) and Mennonite Central Committee (MCC) as International Development Partners. The study areas are characterised by regular droughts and low and erratic rains with uneven distribution. The land is degraded due to increasing population pressure, traditional ways of farming, livestock grazing, and fire which lead to degradation and deforestation. These challenges and climate change result in decreased water sources, crop productivity and food security [9].

2.2 Data

The study employed a cross-sectional survey design. The design was also chosen due to the limited time available for data collection of a representative sample for the entire population. Also, the design enabled qualitative and quantitative data collection at a single point [14]. Two categories of smallholder farmers were involved in a household sample: farmers currently practising CA (CA adopters) and farmers who have never tried to practice CA before but have been exposed to CA technologies (non-CA adopters). Adopters included farmers who participated directly in the CA project and farmers adopting CA without participating in the CA project as copy farmers. A random sample of 260 households was interviewed in the study areas, of which 134 were CA adopters and 126 were non-CA adopters.

The study used both qualitative and quantitative data from primary and secondary data sources. Primary data were obtained by using structured questionnaires with both open and closed-ended questions via KoBoToolbox as mobile data collection tools, field Observation and a checklist of key informant interviews. Secondary data

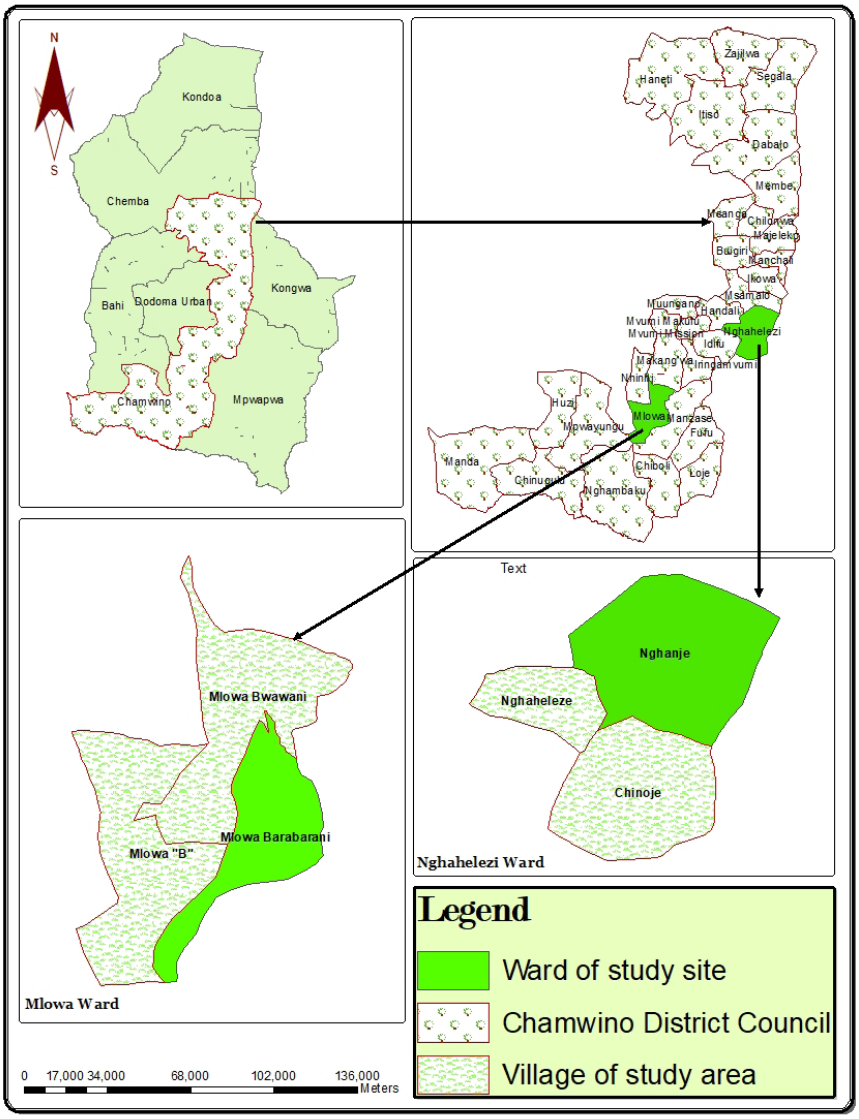

Figure 2. The map of Dodoma Region shows the location of the study area.

Source: Own generated by using ArcGIS (Geographical Information System).

were collected through the documentary review, which includes existing program documents such as situational assessment reports, baseline reports, annual impact reports, evaluation reports and data collection tools used by development partners. In addition, pre-testing was conducted to control validity. Changes were made to improve its usefulness in addressing the relevant questions and ensure proper coding of the KoBo survey form. The period of collecting data was for two weeks in July 2022.

2.3 Analytical Methods

Descriptive statistics such as mean, standard deviation, and frequency were used to compare and realize the demographic, socio-economic and institutional characteristics of the two group respondents along with inferential statistics like t-test and Chi-square tests.

Further, descriptive statistics were also used to examine the extension approaches that were applied to disseminate CA knowledge and the extent of CA adoptions existing between variables among smallholder farmers in the study area.

In addition, inferential statistics were used to analyze the factors affecting the adoption of CA technologies among smallholder farmers in the study area. The conditional probability of receiving treatment when there are two treatment conditions (treatment vs. control) is estimated using binary logistic regression [14]. In this study, the Logit model was employed to identify determinants of adopting conservation agriculture in the study area. In estimating the logit model, the dependent variable is the adoption status of conservation agriculture which takes a value of 1 if the household is an adopter and 0 otherwise. According to Gujarati [15], the Logit model is specified as follows:

$$P = \frac{e^{Zi}}{1 + e^{Zi}} \quad (1)$$

where P is the probability of adopting rainwater harvesting.

$$Z_i = \beta_0 + \sum_{i=1}^{n} \beta_i X_i + \mu_i \quad (2)$$

where, i = 1, 2, 3 … n,

β_0 = intercept;

β_i = regression coefficient to be estimated;

X_i = household characteristics which affect the adoption of conservation agriculture, and

μ_i = a disturbance term.

The probability that a household is non-adopter is:

$$1 - P = \frac{1}{1 + e^{Zi}} \quad (3)$$

Independent variables:

SEX = Sex (1 = Male, 0 = Female)

AGE = Age (In years)

HHSIZE = Household size represents labour availability (Total number of persons in the household)

FAREXPER = Farming experience (The number of years the farmer has been in farming)

FARSIZE = Size of the farm (Total household farm size in ha)

EXTENSION = Access extension services (1 = Yes, 0 = No)

FARINPUT = Farm input accessibility (1 = Yes, 0 = No)

FARGROUP = Involvement in farmer-based group (1 = Yes, 0 = No)

FARCREDT = Access to credit for farming (1 = Yes, 0 = No)

On the other hand, two independent samples t-tests were used to compute the effect of CA adoption on crop yields, estimated costs of production and farm income among smallholder farmers. This test is concerned with testing equality of means for two groups (comparing CA adopters and non-CA Adopters). This test assumes that the two samples are from two independent populations [16]. Results from the analysis were interpreted, and the gaps were addressed through Key Informants' Interviews (KII's). Data from KII's and open-ended questions were analyzed using qualitative content analysis. By analyzing the meaning and contextual relationship from the content of text data and/or concepts, content analysis was used to make qualitative interpretations and conclusions [17].

3. Results and Discussion

3.1 Descriptive Analysis of Sample Households' Characteristics

Socio-demographic and farm characteristics among smallholder farmers can influence the adoption of agricultural technology, which can also affect farm productivity and ultimately affect farm incomes in terms of observable characteristics at the individual, household, and farm levels. Tables 1 and 2 for continuous and categorical variables reveal differences in socio-demographic and farm characteristics between adopters and non-adopters of CA technology.

The results in Table 1 show that of 260 smallholder farmers interviewed, 51.5% were females, of whom 29.2% were CA adopters, and 22.3% were non-CA adopters, whereas males were 48.5% of whom 22.3% were CA adopters and 26.2% non-CA adopter. The findings represent the true picture since women also perform most household farming activities in rural areas. According to CA project reports, females participate more than males in CA and other project activities. If the productive resource were managed jointly between males and females at the household level, it is likely to increase the adoption of CA as new technology. Likewise, men's involvement is crucial in CA adoption because men are the primary decision-makers and have more access to and control over land and other productive resources than women due to socio-cultural norms and values [17,18].

The average age of the total respondents in Table 1 was 47 years, and for CA adopters, it was 49 years, slightly higher than for non-CA adopters (46 years). The low participation of young farmers in CA practices may limit the adoption and sustainability of CA technology. Similarly, the results of farming experience show an average of 28 years for CA adopters and 25 years for non-CA adopters. The positive relationship implies that farmers with long farming experience are better able to evaluate the effects of new technology compared to a less experienced household in farming [11,19].

The findings in Table 2 revealed that the majority of smallholder farmers (66.9%) had received primary school education, 26.2% had no formal education, 5.4% had secondary education, and very few obtained college/tertiary education (1.5%). Comparatively to non-CA adopters, most CA adopters had completed primary school, and fewer did not attend formal education. This indicates that the average highest educational levels of CA adopters were greater than non-CA adopters. The household head's education level implies individual farmers' ability to access information and make informed decisions to adopt new technologies [20].

Household size implies the availability of labour within a family. The result revealed that the total mean was five members, representing the true picture since most smallholder farmers rely on family labour in their day-to-day farming activities. The mean difference in household size was 0.15, implying that the household size for CA adopters was slightly larger than for non-CA adopters. The fact is that both practices of CA and CA plus are labour-intensive compared to conventional farming. Thus, households with larger average sizes may have been more likely to adopt CA than households with smaller average sizes [19].

Total annual household income was a potential measure of a household's wealth status. All respondents' estimated household income was TZS 1,218,233 per year through farming and off-farming activities. It was TZS 1,144,179 for CA adopters, which was TZS 154,079 less than non-CA adopters. This reveals that households with lower annual incomes have a higher adoption rate of CA technology than those with higher yearly incomes. Furthermore, it shows that most respondents' income is still insufficient to cover their essential living expenditures, possibly due to low production from small farms for CA adopters and low crop productivity for non-CA adopters.

Farm size is vital in adopting new technology. The average farm size of the total respondent was 2.7 ha; for CA adopters was 2.8 ha, and for non-adopters was 2.5 ha. It may indicate that farmers with large land holdings are more likely to set aside extra farms for the practice of CA as new agricultural technology. On the other hand, farmers with small farm sizes may adopt CA as labour and land-saving technologies to increase agricultural production and, eventually, farm income [9,20].

Furthermore, most respondents owned land (94.6%), while only a few rented land (5.4%) (see Table 1). Compared to rented land, owned land provides incentives for long-term investment and soil conservation benefits to improve the future productivity of the land.

3.2 Extension Approaches Used to Disseminate CA Knowledge in the Study Area

The agricultural extension approaches used to disseminate CA knowledge among smallholder farmers are presented in Table 3. The result shows that 64.8% of respondents received training through CA animators/champion farmers, project extension workers and government extension workers. This is because training is used as an educational approach to impart experience to farmers about the use and benefits of CA technologies and promote the implementation of CA. Therefore, farmers who received training in CA are more likely to adopt CA technologies than farmers who did not.

The study reveals that 54.6% were CA animators/champion farmers, which involves a farmer who practices CA and teaches other farmers about CA while also liaising farmers with project staff, government extension and other stakeholders. According to key informant interviews, the Animator lives in the same villages as their fellow CA farmers live in the same reality, and knows the context more deeply than an external extension agent. The animator model empowers CA farmers and communities and possibly is the more effective and sustainable approach to community-wide CA adoption. Working with Animators is also a less expensive model than using extension workers [23]. According to KIIs and other studies, CA animators/champion farmers strengthened the effectiveness of increasing CA awareness within farmer groups. Additionally, they are more important for increasing awareness than CA practice adoption. Therefore, this should support other agricultural extension approaches rather than replace them [25]. Other participatory approaches used were demonstration plots (51.9%), farmer groups (38.9%), and farmer-to-farmer knowledge sharing (32.4%). Based on its features and benefits, the farmer-to-farmer extension approach appears more effective [25].

Also, the result shows that government extension workers computed 21.3%, which implied a shortage of government extension workers, where they worked at the ward level rather than the village level, resulting in frequent

Table 1. The socio-demographic and farm characteristics of respondents interviewed in the study area.

Variables	Total sample (n = 260)	CA adopters (n = 134)	Non-CA adopters (n = 126)	Mean difference	t-value
Age (Years)	47.7	49.4	45.8	3.6	1.52
Household size	5.3	5.3	5.2	0.15	0.37
Estimated annual Household Income (TZS)	1,218,233	1,144,179	1,298,258	(154,079)	–1.06
Farming experience (Years)	26.3	27.6	25.0	2.64	1.03
Farm size (ha)	2.68	2.84	2.52	0.32	1.01

Note: *Represent significance at a 10% probability level.

Table 2. Socio-demographic and farm characteristics of respondents interviewed in the study area.

Variables	CA adopters (n = 134)		Non-CA adopters (n = 126)		Total (n = 260)		χ²
	freq	%	freq	%	freq	%	
Sex							
Male	58	43.3	68	54.0	126	48.5	1.48
Female	76	56.7	58	46.0	134	51.5	
Marital status							
Married	94	70.1	100	79.4	194	74.6	
Separated/Divorced	18	13.4	10	7.9	28	10.8	3.78
Single	2	1.5	6	4.8	8	3.1	
Widowed/Widow	20	14.9	10	7.9	30	11.5	
Education level							
Primary	96	71.6	78	61.9	174	66.9	
No formal	32	23.9	36	28.6	68	26.2	2.21
Secondary	4	3.0	10	7.9	14	5.4	
College/Tertiary	2	1.5	2	1.6	4	1.5	
The main source of income							
Farming	134	100.0	118	93.7	252	96.9	4.39*
Employed	0	0.0	4	3.2	4	1.5	
Own business	0	0.0	4	3.2	4	1.5	
Land ownership							
Owned	128	95.5	118	93.7	246	94.6	0.22
Rented	6	4.5	8	6.3	14	5.4	

Note: *Represent significance at a 10% probability level.

limited monitoring to track farmers' progress. Though government extension workers' involvement is low, there is a need to encourage rotations where they are not there since they are key extension agents to influence the adoption of new technologies. Through project extension workers (NGOs), around 51.9% of farmers were reached. This indicates that project extensions have been crucial communicators of information on disseminating CA technologies, training CA animators/champion farmers, mobilizing farmer groups, and assisting individual farmers in improving their agriculture practices and practical learning skills [26]. Although the challenge is the continuation after the phase of the project close, it has also been observed that project extension workers strive for results to meet the project goals.

According to KIIs, it was noticed that the project's extension was well equipped than the Government extension, including motorcycles, fuels, refresher training and other incentives. As a result, agricultural extension approaches need to be improved by recruiting adequate government workers, regularly training extension agents, providing adequate logistics, and integrating with other

Table 3. The extension approaches used to disseminate CA knowledge in the study area.

Extension approaches as a source of CA knowledge	Non-CA adopter (%)	CA adopter (%)	Total (%)
Training	24.4	89.6	64.8
CA animators/Champion farmers	41.5	62.7	54.6
Project extension workers (NGOs)	19.5	71.6	51.9
Demonstration plots	48.8	53.7	51.9
Farmer groups	36.6	40.3	38.9
Farmer-to-farmer sharing of knowledge/neighbor farmer	31.7	32.8	32.4
Government extension worker	17.1	23.9	21.3
Farmer exchange visit	4.9	6.0	5.6
Learnt through the radio	0.0	1.5	0.9

Note: *Results are based on multiple responses.

extension approaches. There is also a need to improve and promote a combination of extension approaches that will accommodate current changes and specific contexts to successfully adopt and scale up CA technologies. Furthermore, evaluating and monitoring agriculture extension approaches is critical to determine their relevance, effectiveness, efficiency, impact and sustainability, providing the basis and contexts for future improvements.

3.3 Factors Contributing to the Adoption of Conservation Agriculture Technologies in the Study Area

The results in Table 4 for the model summary and variables in the equation indicate that about 63.5% of independent variables included in the model were good predictors for adopting CA technologies by smallholder farmers (*Nagelkerke* $R^2 = 0.635$). Wald-chi-square test indicates sex ($P = 0.036$), access to extension services ($P = 0.001$), access to farm inputs ($P = 0.000$), and involvement in farmer-based groups ($P = 0.000$) had a significant positive influence on the probability of adopting CA technologies by smallholder farmers ($P < 0.05$). On the other hand, access to farming credit ($P = 0.044$) had a significant negative influence on the probability of adopting CA technologies by smallholder farmers ($P < 0.05$). Female farmers were associated with a significant increase in the likelihood of adopting CA four times compared to male farmers (OR = 3.78, 95% CI).

On the other hand, results show that female farmers' participation in CA training and farmer groups is higher than male farmers. So, female farmers' empowerment may positively influence CA adoption by contributing to the efficient use of household resources, better time management, and increased crop productivity. Continuing to raise awareness of farmers on gender roles and priorities, whether women farmers can mobilize the support of male household members to joint decision-making, and gain access to and control over resources for the benefit of the entire household [19,20]. Therefore, it is essential to focus on engaging men to change gender norms and values for greater gender equality in decision-making, access to productive resources and extension services.

Results in Table 4 indicate farmers who accessed extension services were associated with a significant increase in the likelihood of adopting CA by ten times compared to farmers who did not access extension services (OR = 9.74, 95% CI). Access to extension services has also been identified as a key factor in CA adoption. According to the findings, 68.5% of respondents used extension services, with 47.7% being CA adopters and 20.8% being non-CA adopters. Many authors have also found a positive and significant relationship between extension services and the adoption of new technology in agriculture [10,20,26,28].

On the other hand, results indicate that farmers with access to farm inputs were associated with a significant increase in the likelihood of adopting CA by 12 times compared to farmers who did not access farming inputs (OR = 11.61, 95% CI). Results reveal that 53.1% of farmers access inputs for farming activities, of whom 40.8% were CA adopters and 12.3% were non-CA adopters. Most CA farmers were using inputs from their sources, such as improved seed (88.1%), farm yard manure (88.1%), GM/CC seeds (82.1%), and pesticides (28.1%). However, it has been noticed that direct participants of the CA project have been promoted with improved seeds, both GM/CC and main crops, thus resulting in dependency for some farmers who have stopped implementing CA because they have not received seeds as previously.

The results also indicate farmers involved in farmer-based groups were 16 times significantly more likely to adopt CA than farmers not involved in a farmer-based group (OR = 16.06, 95% CI). According to the study's findings, 47% of respondents participated in farmer-based groups, 37% were CA adopters, and 10% were non-CA adopters, proving the power of social capital in promoting the adoption of CA technologies. Those farmer groups appeared to be well organized and frequently met, so the integration of savings activities with farmer-based groups through the VSLA methodology tended to build strong groups. Farmer groups enabled collective action, access to information, learning from experience (learning-based), farm inputs, linking groups with service providers, and other extension services through animators/champion farmers, project extension staff, or government extension workers [27].

The results also reveal that farmers who accessed farming credit had a significant decrease in the likelihood of adopting CA by 79% compared to farmers who did not access credit (OR = 0.21, 95% CI). The negative and significant relationship with CA technology adoption may be explained by the fact that most CA adopters did not have access to farming credit; only 31.8% had access to credit, of which CA adopters consisted (23.3%), and non-CA adopters consisted (8.5%). The reason behind this is that the use of household labour, such as planting stations by hand hoe, was more likely to be adopted than the use of hiring labourers and service providers such as minimum tillage ripping; thus, many farmers practice CA on small farms size by an average of 0.4 ha (0.9 acres) or less, primarily for consumption [3,28]. Results show that 46.2% of respondents participated in informal financial groups, of whom 35.4% were in VSLA as part of the CA project and 10.8% in VICOBA and other methodologies, which enabled farmers to use their savings to finance farming activities. Similarly, the study also revealed that the up-front costs of CA were no initial investment (9.0%), minor initial investment (53.7%), moderate initial investment (35.8%) and a large initial investment (1.5%). Also, ripping services and weeding costs were low compared to conventional farming.

Furthermore, age and household size were positively related to CA adoption, while farm size and farming experience were negatively related to CA adoption. However, their effects were not significant (P > 0.10). Larger sizes of cultivated land were associated with farmers being less likely to adopt CA technology compared to farmers with smaller land sizes. Similarly, the study reveals the size of farmers' landholding of CA adopters was 46.3% in size of 2.0 ha and below and 53.7% in size of 2.4 ha and above. In contrast, the farmers' landholding of non-CA adopters was 52.4% between 2.0 ha and below and 47.6% between 2.4 ha and above. The findings show that the size of the cultivated landholding and other socioeconomic, farm, and institutional characteristics, may influence the adoption and uptake of CA technologies [10,22].

3.4 Extent of Using Adoption of CA Technologies in the Study Area

Table 5 shows the extent of farmers' adoption of CA technologies. Overall, the size of CA farms increased with time, from an average of 0.2 ha (0.4 acres) to 0.4 ha (0.9 acres) per CA farmer within an average of two (2) cropping seasons. The farm under non-CA adopters was higher than CA adopters since the average size of total cultivated land was 2.7 ha (6.7 acres).

On top of the increase in a farm under CA, results show that the CA principles applied consistently by all respondents as follows: Minimum soil disturbance was 50.0%, soil cover was 46.2%, and the third principle was crop rotation/associations by 42.3%. The main crops grown under CA were sorghum (80.6%) and pearl millet (26.9%) as multiple responses. Also, cover crops planted by a majority of CA farmers were Lablab (61.2%), Cowpeas (47.8%), Canavalia (38.8%), Mucuna (9.0%) and Pigeon peas (6.0%), and most farmers use more than one type of cover crops in single CA field.

Figure 3 displays CA practices applied by CA adopters in the recent cropping seasons. It shows that the use of hand hoe was higher than that of CA mechanization. Since they mainly depend on household labour, some farmers afford to hire labourers and use service providers who have trained oxen for ripping or ripping by two-wheel tractors [2,3]. The project seems to be working hard to promote CA mechanization by ripping with two-wheeled tractors and oxen. Such mechanization helped to reduce labour and enable farmers to expand CA farm sizes.

Soil cover is a mandatory CA principle because of the semi-arid zone in the study area. More importantly, ensuring soil cover from the previous season's crop and GM/

Table 4. Logistic regression results for determinants of CA technologies adoption.

Variables	B	SE.	Wald	df	Sig.	Exp (B)
Sex (1)	1.328	0.634	4.396	1	0.036**	3.775
Age (Years)	0.013	0.051	0.066	1	0.797	1.013
Household size	0.167	0.114	2.145	1	0.143	1.182
Farming experience (Years)	–0.006	0.047	0.017	1	0.896	0.994
Farm size (ha)	–0.036	0.061	0.349	1	0.554	0.965
Access extension services (1)	2.276	0.700	10.570	1	0.001***	9.737
Access to farm inputs (1)	2.451	0.592	17.157	1	0.000***	11.605
Involvement in farmer-based groups (1)	2.776	0.671	17.109	1	0.000***	16.058
Access credit for farming (1)	–1.563	0.775	4.067	1	0.044**	0.210
Constant	–5.392	1.794	9.033	1	0.003***	0.005

Note: *Nagelkerke R^2 = 0.635, Cox & Snell R^2 = 0.476.

*** and ** represent significance at 1% and 5% probability levels, respectively.

Table 5. The characteristics of CA farms in the study area.

Descriptive statistics	Minimum	Maximum	Mean
Size of the farm started practicing CA (ha)	0.04	0.8	0.2
Current farm size under CA (ha)	0.04	2.2	0.4
Experience in practicing CA (Years)	1	6	2.3

CC. The percentage of farmers using GM/CC was higher than maintaining crop residues due to the challenges of free-grazing livestock and burning crop residues. Some of the farmers have kept seeds of GM/CC, mainly Lablab, Cowpeas, Canavalia and Mucuna, ready for planting in the future.

The third CA principle is crop associations with either intercropping or crop rotation. Unlike crop rotation, intercropping was higher with 91% compared to 23.9% of crop rotation among CA adopters (Figure 3). Crops involved in intercropping were millet or sorghum with cowpeas, lablab, Canavalia, mucuna, green grams or pigeon peas. The advantages of crop associations were those stated on crop residues or GM/CC. Still, it offered extra advantages of increasing crop diversity and spreading the risk of diseases and insects, thus making farmers more resilient to climate change impacts. However, it was observed that the project has pushed for more mechanization and more soil cover with both crop residues and GM/CC. The project also mobilized cash crops like sunflower, sorghum, lablab and cowpeas, which incentivise youth and men to join CA.

Nevertheless, other good agronomic practices or CA plus practices applied by farmers in the study area are shown in Table 6. According to Nyamangara et al. [27], CA needs to be combined with other agronomical practices to address the production challenges and effects of poor rainfall distribution patterns.

According to the study, Figure 4 displays the major challenges for adopting CA technology mentioned by CA adopters. Insects and pests also challenge GM/CC by 64.2%. However, results in Table 6 revealed that 34.3% of CA adopters applied Integrated Pest Management (IPM) approaches to control insects on GM/CC. This indicates the importance of continuing to mobilize and train farmers on the benefits of using Integrated Pest Management (IPM)

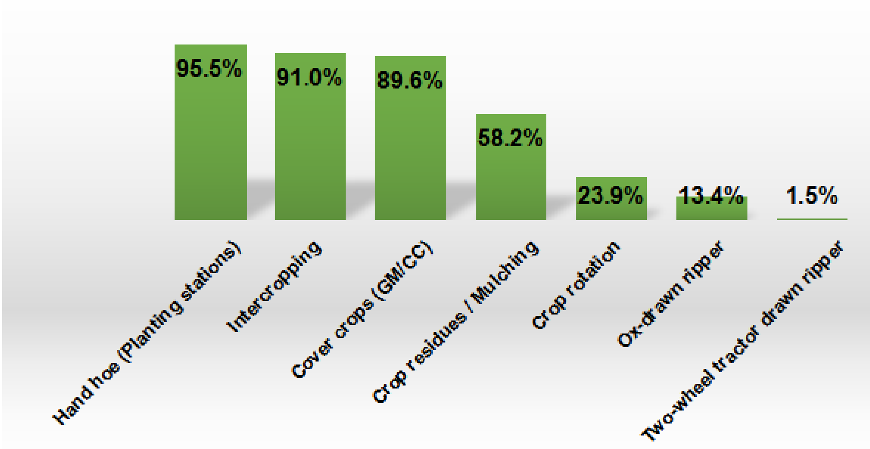

Figure 3. Conservation agriculture practices applied in the recent cropping seasons by CA adopters in the study area.

Table 6. Other agronomic practices applied by respondents in the study area.

Other agronomic practices applied	Non-CA adopter (%)	CA adopter (%)	Total (%)
Weed management	71.4	86.6	79.2
Early land preparation	46.0	79.1	63.1
Spot application of farmyard manure	28.6	88.1	59.2
Precision planting	27.0	88.6	57.7
Improved and right seed varieties	17.5	88.1	53.9
Early planting	27.0	77.6	53.1
Spot application of liming/ashes	1.6	86.6	45.4
Integrated Pest Management (IPM)	4.8	34.3	20.0
Conservation agriculture with trees	0.0	10.4	5.4
Fodder establishment	0.0	6.0	3.1
Soil and water conservation	0.0	6.0	3.1
Compost	0.8	3.0	2.3

Note: *Results are based on multiple responses.

to get harvest yields of cover crops.

The effect of climate change, specifically erratic rainfall, was the second challenge, with 55.2% of the respondents mentioning it. Since the study areas are characterized by regular droughts and low and erratic rains with uneven distribution, CA technologies are among the climate-smart strategies that deal with the effect of climate change compared to the conventional farming system. It has also been seen that this situation affects not only the main crops (maize, millet or sorghum) but also the growth of GM/CC.

Another challenge pointed out was more work and time-consuming for the first time in land preparation observed by 46.3% of the respondents. Since CA by hand hoes is relatively labour intensive, requiring more labour for its preparation and application of other good agronomic practices compared to conventional farming. Thus, CA mechanization will likely increase the rate of CA adoption in the study area.

Livestock on free grazing and fire was also pointed out (46.3%) as a challenge that affects the scarcity of mulch and/or crop residues. Accordingly, the context and prevailing challenges, sometimes farmers tend to apply some innovations to cope with those CA challenges and changes, such as concentrating mulch and/or crop residues closer to the stems of crops due to scarcity of mulching materials.

However, to increase the adoption of CA, the respondents suggested the following; increasing the availability of extension services (62.3%), raising public awareness of the CA program (52.3%), providing farmers with improved or certified seeds (39.2%), increasing government intervention (36.9%), improving access of improved CA tools (35.4%), continuing to increase training for CA animators and champion farmers (23.1%), and put laws and regulations on crop residues management (17.7%).

3.5 Benefits of CA Technologies on the Livelihood of Smallholders Farmers in the Study Area

From the output of the independent sample t-test in Table 7, it can be noted that yields, revenue (gross income) and farm income (profit) for CA adopters were significantly higher than non-CA adopters at a 1% significance level ($P < 0.001$). At the same time, total estimated costs for CA adopters were statistically significantly higher than non-CA adopters at a 10% significance level ($P < 0.1$). Also, results in Table 7 indicate that CA technologies increased crop yield by 171% (157% for pearl millet and 187% for sorghum) compared to non-CA farmers. The costs associated with farming can affect its profitability. According to Mkonda et al. [21], it has been observed that one obstacle to the adoption of new technology is the cost of adopting it. The cost of CA was slightly higher than that of non-CA because most CA farmers were using good agronomic practices (CA plus), such as precision planting, improved seed varieties and spot application of farm yard manure and ashes, which increases workload. Although CA does not need to use more labour and costs, soil cover suppresses weeds and ripping, as CA mechanization still costs less than ploughing tools in conventional farming. The results suggest that CA practices and CA Plus, as practised by farmers in this study area, were reliable means to

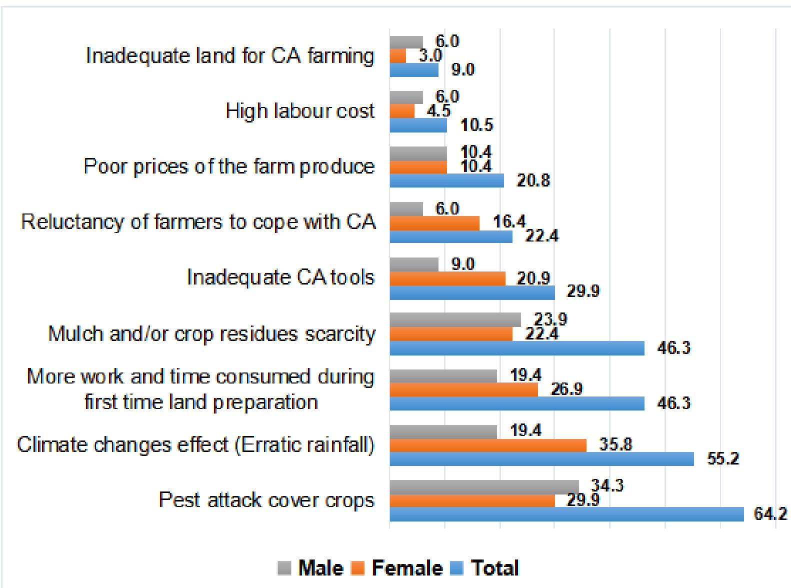

Figure 4. The major challenges faced by CA adopters (%) on gender-based in the study area.

Note: *Results are based on multiple responses.

Table 7. Crop yields, production costs and farm income among smallholder farmers in the study area.

Variables	Total sample (n = 240)	CA adopters (n = 130)	Non-CA adopters (n = 110)	Mean difference	t-value
Yields of Sorghum/Pearl Millet (kg/Acre)	370	521	192	330	10.32***
Revenue (Gross Income) for Sorghum/ Pearl millet (TZS/Acre)	171,573	243,773	84,933	158,840	10.91***
Total estimated costs for Sorghum/ Pearl millet in (TZS/Acre)	99,735	103,928	94,689	9,239	1.95*
Farm income for Sorghum/pearl millet (TZS/Acre)	67,307	134,011	11,525	145,536	12.78***

Note: *** and * represent significance at 1% and 10% probability levels, respectively.

increase crop yields. Likewise, the study reveals that the farmer's uptake of CA technologies was likely when the expected benefits of CA adoption exceeded the expected adoption costs [22,24].

Moreover, farmers were asked to mention the benefits of CA technologies through household questionnaires. Most of the respondents (98.5%) considered increasing/improving crop yield to be a major benefit, while 73.1% indicated that CA technologies improve soil fertility. 76.1% stated that the adoption of CA technologies has improved food security, as well as 20.7%, said it plays a great role in increasing their farmlands. Others include multiple harvests in a single land, access to credit and savings as well an increase in income (Figure 5). In fact, a great number of respondents considered an improvement in crop yield as a major benefit of CA technologies. This is associated with the fact that most of the respondents as well as more than 75% of all Tanzanians depend on agricultural production as their major source of living. The results are consistent with studies by Kaweesa et al. (2018) and Ngoma et al. (2021) who showed that the perceived benefit of conservation measures positively and significantly affects farmers' decision to adopt conservation structures.

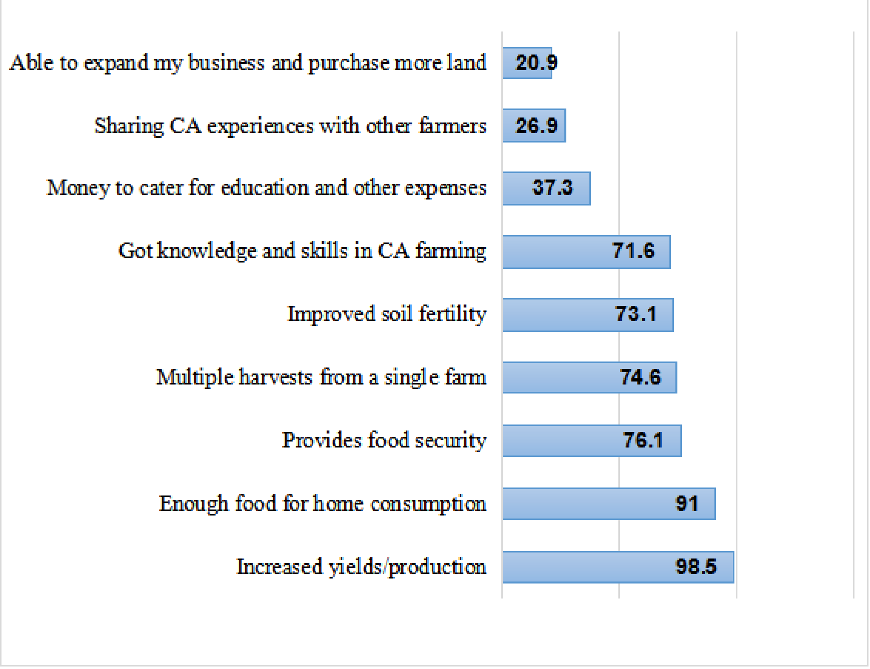

Figure 5. Other benefits received by being a CA farmer (%) in the study area.

Note: *Results are based on multiple responses.

4. Conclusions and Recommendations

The study sought to determine the influence of socio-economic factors on the adoption of conservation agriculture and its benefits to the livelihood of smallholder farmers in Chamwino District, Tanzania. The study employed both descriptive and inferential statistics to analyse the data. The findings revealed that the most extension approaches used to disseminate CA knowledge in the study area are training, CA animators/champion farmers, project extension workers (NGOs), demonstration plots, farmer groups, farmer-to-farmer sharing of knowledge/Neighbor farmer, government extension worker, and farmer exchange visit.

Further, findings revealed that robust extension services led to a higher quality of CA practices on the CA farms. The study also observed that the youth appeared not much involved in the CA activities; this is reflected in the average age of farmers among the overall respondents. The sex of the respondents, access to extension services, access to farm inputs, involvement in farmer-based groups and access to credit for farming significantly influenced smallholder farmers' decision to adopt CA technologies more than other factors included in the model. The perceived benefits of CA principles were improved food security, soil health and moisture retention, reduced weed pressure and reduced soil preparation leading to time savings, increased crop diversity and significantly increased farmers' income. A small percentage of CA farmers applied mechanization to expand their CA farms by using ox-drawn or two-wheel tractor rippers. Households that adopted CA technologies earned better on average crop yields and farm income per unit area than conventional farming.

Based on the findings, the study recommends that further training and extension support for CA adoption should be targeted towards smallholder farmers in semi-arid areas so as to increase awareness of the availability and usefulness of the technologies; there also a need to strengthen the contact between farmers and extension agents/CA promoters due to limited resources by using mechanisms that enhance grass root capacity building, for instance, working with farmers' groups and community-based organizations; farmers should be provided with more opportunities for access to friendly credit facilities to enhance CA adoption practices. Further, it also brings to a close that conservation agriculture projects/programs should target areas where expected benefits are higher, in order to encourage the use of CA technologies. This includes establishing and strengthening monitoring and evaluation systems to ensure the coherence, impact and sustainability of CA programs and agricultural policies.

Author Contributions

N.Y.S. designed the study and analyzed the statistical data from the study. P.D. contributed to the data analysis and participated in the literature searches. Y.J.M. supervised the entire study and wrote the first draft of the manuscript. All authors have read and approved the final manuscript.

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Data Availability

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Conflict of Interest

The authors declare that there is no conflict of interest concerning the publication of this manuscript.

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