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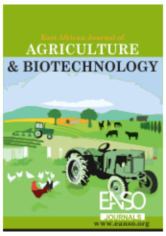

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Original Article

Usage of Agroecological Climate-Smart Agriculture Practices among Sorghum and Maize Smallholder Farmers in Semi-Arid Areas in Tanzania

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Improved Seed Varieties, Cereal-Legume Intercropping, Mixed Cropping, Agroforestry, Adaptation.

ABSTRACT

Climate change variability and its impact on agricultural production in sub-Saharan Africa pose a significant challenge to food security. In Tanzania's semi-arid regions, there is growing concern regarding the use of agroecological Climate-Smart Agriculture (CSA) practices by smallholder farmers that adhere to agroecological principles. This study aimed to investigate the use of agroecological CSA practices among smallholder farmers in Tanzania's semi-arid regions, specifically in Dodoma and Tabora regions. In addition, this study sought to identify the key factors influencing the use of these practices to enhance food security, income, and climate resilience. Data were collected from 299 households in Dodoma and Tabora using various methods including questionnaire surveys, focus group discussions, and key informant interviews. Binary logistic regression was used to analyse factors influencing the usage of agroecological climate-smart agriculture practices. The findings revealed that most households in the study area use agroecological CSA practices. These practices include cereal-legume intercropping, mixed cropping, crop residue retention, crop rotation, and improved seed variety. Water harvesting, terraces, and cover crops were not used by many households. Several factors positively influenced the use of agroecological CSA. They include assistance from non-governmental organizations (NGOs), training in CSA practices, drought perception, access to credit, distance to market, membership in an organisation, education level of the household head, and total household income. To promote the use of agroecological CSA practices, both governments and NGOs should prioritise training programs. Moreover, providing frequent extension services and facilitating easier access to credit for farmers can further support the widespread use of these practices. In doing so, local communities can adapt better to the challenges of climate change, ensuring improved food security and climate resilience in the region.

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INTRODUCTION

Climate change and variability such as rising temperatures and shifting rainfall patterns, have a considerable impact on agriculture, posing severe challenges to global food security. In Africa alone, climate change has decreased total agricultural output growth by 34% since 1961 (Ortiz-Bobea et al., 2021), and it is predicted that by 2080 there will be a 3 to 16 % decrease in global agricultural productivity, with a significantly higher average decline of 10 to 25 % in the developing countries (Bang et al., 2019; Gebre et al., 2021). The Intergovernmental Panel on Climate Change (IPCC) predicts losses in maize, sorghum, millet, and peanut production of between 27 and 32%, with warming of approximately 2°C, over pre-industrial levels by 2050 (Mbow et al., 2019). Similarly, average maize, wheat, and rice yields in Sub-Saharan Africa will decrease by 14 %, 22 %, and 5%, respectively, by 2050, while sorghum, millet, and groundnut yields will decrease by 27-32 % (Serdeczny et al., 2017). In Tanzania, a 2°C increase in seasonal temperature by 2050 is predicted to reduce average maize, sorghum, and rice yields by 13, 9, and 8 %, respectively (Rowhani et al., 2011). To maintain ideal income and food security levels and meet the increasing demands of the population, smallholders in semi-arid areas in Tanzania farmers must become more adaptable.

The use of agroecological CSA practices is gaining recognition due to its potential to increase crop productivity, promote sustainable livelihoods for farmers, and reduce reliance on non-renewable inputs while increasing resilience to climate shocks (Fentie & Beyene, 2018). Agroecological practices, such as agroforestry, intercropping, crop diversification, crop rotation, cover crops, organic manure, and integrated livestock management, combine ecological processes and ecosystem services to produce significant amounts of food while mitigating climate change (Nyantakyi-Frimpong, 2017; Shikuku et al., 2017; Singh & Singh, 2017). The guiding principles for these practices include maximizing the recycling of biomass to maximize nutrient availability; minimizing the use of external and non-renewable farm inputs; increasing soil cover; increasing species and genetic diversity of the agroecosystem; and enhancing beneficial biological interactions (Wezel, 2017; Wezel et al., 2020).

Despite the potential benefits, the uptake of agroecological CSA practices among farmers in semi-arid regions of Tanzania where climate change poses significant challenges is insufficient (Mkonda & He, 2018 a). Farmers prioritize the

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short-term advantages of adopting agricultural practices, often selecting those that are most convenient and cater to their current requirements. They tend to favour climate-smart agriculture (CSA) technologies that offer high crop yield while producing low greenhouse gas emissions, to establish sustainable climate resilience (Wassie & Pauline, 2018). Several factors influence the extent to which farmers use agroecological practices, including their age, education, access to credit and extension services, membership of a social group, and characteristics of the practices (Kurgat, *et al.*, 2020; Bongole *et al.*, 2020). However, there is no consensus among studies on the direction in which these factors are influenced, and their effects vary depending on the context and specific technology studied.

Given the site-specific nature of agroecological CSA practices, it is important to understand usage and the factors that influence their usage among smallholder farmers in semi-arid areas of Tanzania. Previous studies in the region have evaluated the use of crop-livestock diversity, irrigation, chemical fertilizer use, and agroforestry (Kurgat *et al.*, 2020), and in particular, the use of stress-tolerant crops, inorganic fertilizers, insecticides, and herbicides have been studied in Lushoto (Ogada et al., 2020). However, few studies have analyzed the use of CSA practices that strictly adhere to agroecological principles. This is particularly important as agroecological CSA practices can help farmers reduce their dependence on external inputs such as chemical fertilizers and pesticides.

This study attempts to advance the knowledge of agroecological CSA practices in semi-arid areas of Tanzania by assessing the frequency of usage and the factors influencing the use of CSA practices consistent with agroecology principles. First, the study assessed the socioeconomic characteristics of the sampled households. The second objective was to assess the characteristics of the agroecological CSA practices in the study area. A third objective was to assess the frequency of usage of agroecological CSA practices. Finally, the fourth one was to analyse factors influencing the usage of agroecological CSA practices in the study area.

METHODOLOGY

Description of the Study Area

The study was carried out in the Tabora and Dodoma regions. These regions represent Tanzania's semi-arid areas, which are distinguished by erratic and low mean annual rainfall, drought, insufficient soil moisture, soil infertility, higher daytime temperatures, and evaporation rates that exceed precipitation rates (Synnevåg et al., 2015). The Tabora region was represented by Igunga district, which has temperatures ranging from 20°C to 33°C. It is one of Tanzania's driest districts, with an annual rainfall ranging from 500 mm to 700 mm (Matata *et al.*, 2018). Cotton, sunflower, groundnuts, green gram, onions, and cowpeas are the main cash crops grown in this district. Sweet potatoes, sorghum, and maize are the most important food crops grown. Livestock kept by most households in this district includes cattle, goats, pigs, sheep, and donkeys. Similarly, Chamwino district represented Dodoma region. The district receives 500 to 800 mm of rain per year. The average high and low temperatures are 31°C and 18°C, respectively (Mgoba & Kabote, 2020). Sorghum, millet, maize, groundnuts, tomatoes, onions, and vine grapes are among the crops grown in the district. Livestock keeping is also common in the district, which is like the Igunga district. These two districts were chosen for the study due to the following criteria: 1. The districts have a rainfed cropping pattern, 2. They have agricultural potential to support various crop production, 3. The districts are in semi-arid areas which experience negative impacts of climate change and variability, and 4. The districts have participated in different climate-smart agriculture projects and programs from the government and NGOs.

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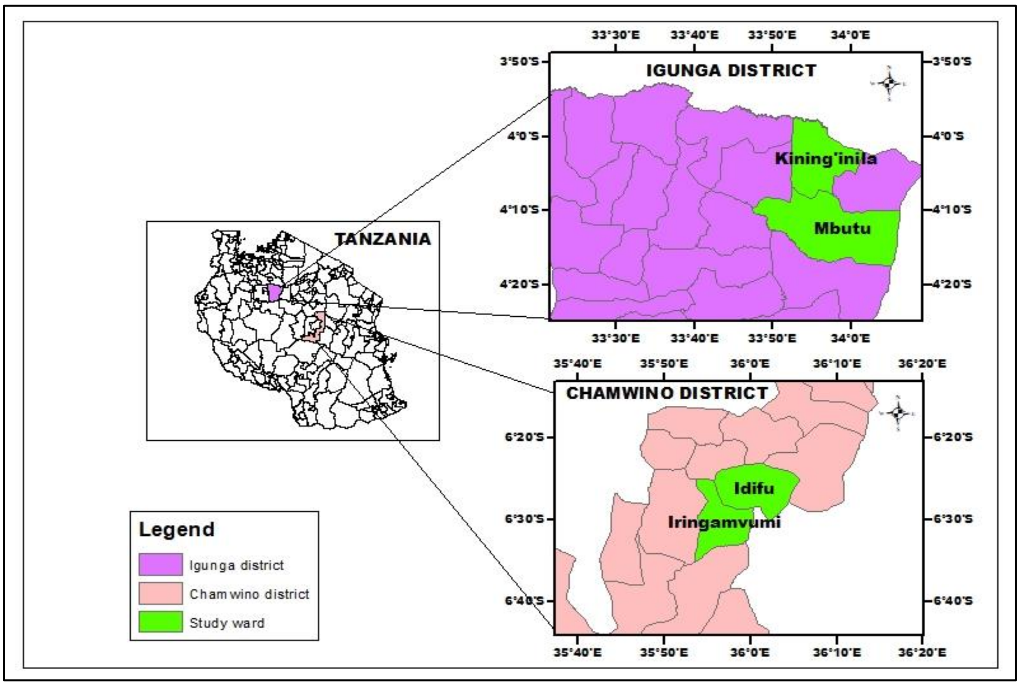
Figure 1: Map of the study area



Sampling Procedure

To ensure a thorough representation of the agroecological (CSA) practices in the study area, a multi-stage random sampling procedure was used to select households. This approach was chosen because of the varying nature of agroecological CSA practices in the semi-arid regions. By recognising their characteristic diversity, this study captured the different dimensions of agroecological CSA usage. Moreover, this selection process aligns with areas where agroecological CSA initiatives are actively promoted, facilitating an investigation into the impact of these interventions on CSA usage. For that matter districts, divisions, wards, and villages that use CSA practices were purposefully selected from the semi-arid regions of Dodoma and Tabora in the initial stage. During the second stage, districts were chosen based on their participation in various climate change adaptation projects promoted by the government and several non-governmental organizations (NGOs). Researchers selected two wards in each district that were involved in climate change adaptation activities and programs with the assistance of extension officers and ward authorities. The wards included Idifu and Iringa mvumi wards in Chamwino district and Mbutu and Kining'inila ward in Igunga district. Villages were purposefully selected from each ward based on villages cultivating sorghum and maize crops while employing other agroecological CSA practices. The sampling frame for this study consisted of a population comprising all farmers actively participating in climate change adaptation projects and programs promoted by the government and various NGOs in the study areas. The sampling frame was constructed with the help of the ward and extension officers. The total population size was 1200 farmers. The number of sample households was then found to be 299 using a simplified formula (Yamane, 1967). The household head were selected by simple random sampling method.

$n = \frac{N}{1+N(e^2)}$ Where: N is the size of the population of farmers who practice CSA and n is the size of the sample and e is the level of precision (5%).

Data Collection Methods

Data were collected from selected households by using questionnaires. Household interviews were also conducted to collect information on farmer characteristics and farm characteristics, as well as

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agroecological CSA practices used. To gather more in-depth information on the agroecological CSA practices used by many smallholder farmers, direct observation, key informant interview (KII), focus group discussion and informal discussions were used. Face-to-face administration of structured questionnaire was used to collect data. A review of relevant literature was also done to get more information on agroecological CSA practices. Employing multiple data collection methods has provided a more comprehensive understanding of Agroecological CSA practices used in the study area.

Data analysis

Analysis of Household Socio-Economic Characteristics of Sampled Households

Data for household socioeconomic characteristics were analysed using descriptive statistics. Means and standard deviation were calculated for continuous socioeconomic characteristics variables, whereas frequencies were calculated for descriptive socioeconomic variables.

Assessment of Characteristics of Agroecological Climate-Smart Agriculture Practices

Thematic content analysis was used to analyse the data gathered through focus group discussions, key information interviews, and field observations. Other information from literature was used to supplement the characteristics of agroecological CSA practices.

Assessment of Usage of Agroecological Climate-Smart Agriculture Practices

The frequency of each agroecological CSA practice expressed as a percentage of the total sample was used to analyse data on the use of agroecological CSA practices. Multiple response analysis was used to obtain the frequencies of the agroecological CSA practices used, types of crops grown, and types of improved sorghum and maize seed varieties grown by the sampled households.

Analysis of Factors Influencing the Usage of Agroecological Climate Smart Agriculture Practices

Binary logistic regression, was used to analyse usage of climate-smart agriculture practices among small holder farmers. The study chose binary logistic regression as it enables us to model the probability of an event occurring for a categorical response variable with two possible outcomes (Nyenza et al., 2013). According to this model, a farmer uses CSA practices if the perceived benefits outweigh those of non-usage. The binary logistic model consists of a dependent variable that encompasses various agroecological CSA practices. Such practices include improved seed variety, crop residue retention, crop rotation, cereal-legume intercropping, mixed cropping, livestock diversification, animal manure use, minimum tillage, change in planting date, crop switching, and agroforestry, cover crops, water harvesting and terraces. Practices were allocated a value of 1 if farmers use specific CSA practices and a value of 0 otherwise. We selected these practices based on their features of agroecological practices (Wezel, 2017). They also comply with Tanzania's Ministry of Agriculture's guidelines for adaptation and mitigation, resilience, and enhancing agricultural productivity and sustainability. The independent variables influencing smallholder farmers' usage of agroecological CSA practices comprised a mix of household demographic and socioeconomic and institutional characteristics (Table 1). We examined how household age gender, age, education, total household acreage, and farming experience influenced agroecological CSA practices. We also examined how total household income, credit accessibility, distance to the market, training in CSA practices, and weather information influenced the usage of agroecological CSA practices. The independent variables were selected from previous studies and a review of relevant literature (Alomia-Hinojosa et al., 2018; Amadu et al., 2020; Kassie et al., 2015; Teklewold et al., 2019 b; Tolessa et al., 2017).

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Table 1: Description and summary statistics of variables used in the binary logistic regression

Variable Name	Variable description	Measurement
HH gender	Household head gender	Dummy = 1 if male 0 = female
HH_age	Household head age	Continuous
Education	Years of schooling	Continuous
Experience farming	Number of years of experience in farming	Continuous
HHSize	Household size	Continuous
TLU	Tropical Livestock Unit (TLU)	Continuous
HH_Totalincome	Log of household total income	Continuous
Total_number_Plots	Total number plots	Continuous
TotalHH_acreage	Total household acreage owned	Continuous
Distance_to_market	Distance to market	Continuous
Acsess_to_credit	Access to credit	Dummy 1 = yes 0 = no
Membership	Membership in organization	Dummy 1 = yes 0 = no
Access_to_Extension	Access to extension services	Dummy 1 = yes 0 = no
How_often	Number of contacts with extension officer	Continuous
NGO_Assistance	NGOs assistance	Dummy 1 = yes 0 = no
Get_info	Access to weather information	Dummy 1 = yes 0 = no
Training	Training on CSA practices	Dummy 1 = yes 0 = no
Drought	Drought perception	Dummy 1 = yes 0 = no
District_location	District	Dummy 1 = Chamwino 0 = Igunga

HH= Household

RESULTS AND DISCUSSION

Household Socio-Economic Characteristics of Sampled Households

The study's results indicate that there are significant differences between the two districts in terms of farming experience, education level, crop and livestock sales, and total household income. In the sampled households, there were almost three times as many male-headed households as female-headed households. Additionally, the proportion of male household heads was higher in Igunga district than in Chamwino district (*Table 2*). It is worth noting that in many societies, men are often considered household heads, regardless of their financial situation, age, or ability to make decisions for other members of the household (Takwa, 2011). This power dynamic may have an impact on the types of agroecological CSA practices that are used in a household, as well as other agricultural investment decisions. Furthermore, the study found that the average age of the household head was double the experience in farming (*Table 3*), indicating that farmers gain more experience as they age. This may affect the types of practices used by farmers, as some practices are labor-intensive and require specialized knowledge that older farmers may find challenging to use.

Crop farming was the most significant economic activity in both districts. In addition to crop farming, livestock keeping was also practiced. There were farmers who focused solely on crop farming and others who combined crop farming with livestock keeping *(Table2*). Small businesses, brewing, and trading are among the household's additional significant sources of income in addition to crop farming and livestock keeping. This indicates that household heads earn a variety of incomes. Having a variety of livelihood options assists farmers in adapting to climate change and variability as food production becomes riskier (Musumba et al., 2022). The findings also show that farmers are involved in livestock keeping, which generates more income than crop sales. The income from livestock sales was higher than from crops, indicating that farmers earn more from livestock than selling crop. Farmers make three times more income from livestock than from crops on average, due to higher sales from livestock (*Table 3*). In contrast to Chamwino district, Igunga district had twice as many acres planted in maize, while Chamwino district had more acres planted in sorghum (*Table 3*).

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Assessment of Characteristics of Agroecological Climate Smart Agriculture Practices

Most of agroecological CSA practices used by many farmers have agroecological principles (*Table 4*). FAO identified these principles as the ten elements of agroecology (FAO, 2018). These practices support at least one of the following elements: diversity, synergy, efficiency, and resilience (*Table 4*). Furthermore, these practices support the three pillars of climate-smart agriculture in terms of productivity, adaptation, and mitigation (*Table 4*). Through their agroecological characteristics, crop residue retention, improved seed varieties, mixed cropping, and cereal legume intercropping have the potential to adapt to and mitigate climate change and variability. They promote agroecosystem sustainability through water and soil conservation and cropping varieties (Singh & Singh, 2017). When selecting and promoting agroecological practices financial and labour considerations should be considered. This is because, some practices, like cereal-legume intercropping and crop residue retention, are thought to be cost-effective while others, like improved crop varieties and livestock diversification, minimum tillage and agroforestry, water harvesting and terraces may be more costly and demand substantial labour input (Akinyi et al., 2022; Monti et al., 2019; Naazie et al., 2023). This highlights the importance of sufficient income, and human labour availability for successful implementation.

Furthermore, diversity has emerged as a recurring agroecological principle, emphasizing the importance of cultivating different crops or livestock to enhance ecological resilience. Recycling, synergy, efficiency, and resilience are prominent across different practices. This highlights the holistic approach of agroecology that optimizes resource use, maximizes system synergies, and builds adaptive capacity. Many practices contribute to productivity gains by increasing crop yields and sources of income. They also support adaptation by reducing risks associated with climate change, such as crop failures, water scarcity, pest, and disease outbreaks. In addition, these practices have the potential to reduce the use of synthetic fertilizers, increase soil carbon storage and reduce greenhouse gas emissions (Abdallah et al., 2021; Akinyi et al., 2022)

Table 2: Descriptive statistics for categorical household socio-economic characteristics

Variable	Values	Chamwino district		Igunga district		Overall	
		f	%	f	%	f	%
Household head gender	Female	60	34	25	20	85	28.1
	Male	116	66	98	80	214	71.9
	Total	176	100	123	100	299	100.0
Main economic activity	Crop farming only	70	40	36	29	106	35.5
	Crop farming and Livestock keeping	105	60	85	71	190	64.5
	Total	175	100	121	100	296	100.0
Other occupation	Small business (Shop)	22	12.6	12	9.7	34	11.4
	Brewing local beer	8	3.4	3	2.4	11	2.7
	Trading crops and livestock	9	6.3	5	4.0	14	4.7
	None	136	77.7	104	83.9	240	81.2
	Total	175	100.0	124	100.0	299	100.0

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Table 3: Descriptive statistics for continuous household socio-economic characteristics

Variable	Chamwino district		Igunga district		Overall	
	Mean	SD	Mean	SD	Mean	SD
Household head age (years)	46.84	15.32	43.48	13.31	45.45	14.59
Household size(number)	4.92	2.49	6.24	3.08	5.00	2.82
Education of household head (years)	6.66	3.10	6.84	3.02	6.73	3.07
Farming experience (years)	20.13	15.42	14.87	8.77	17.96	13.32
Total number plots	2.52	2.04	1.61	1.60	2.14	1.92
Total households' acreage owned(acre)	7.88	7.67	7.12	6.59	7.57	7.24
Distance to market (km)	0.50	1.35	2.18	2.23	1.19	1.95
Distance to farm (km)	3.12	3.03	2.01	1.59	2.66	2.59
Tropical livestock unit	1.20	2.25	0.72	1.12	1.01	1.88
Acreage grown for sorghum(acre)	2.83	2.09	0.49	1.10	1.86	2.09
Acreage grew for maize(acre)	1.68	1.46	3.67	4.90	2.51	3.49
Sales from livestock (TZS)	353,064.33	641,889.10	458,647.08	1,376,205.80	396,389.66	1,009,146.90
Income from crop sales (TZS)	470,354.46	960,103.02	439,855.93	579,137.07	457,771.15	823,442.66
Income from casual labour (TZS)	50,867.05	276,833.95	28,455.29	271,217.75	41,554.05	274,274.91
Income from non-agricultural business (TZS)	192,511.63	510,179.07	209,806.72	980,287.59	199,584.19	737,944.73
Remittance (TZS)	34,136.91	78,528.76	75,747.97	722,313.25	51,725.09	472,720.11
Household total annual income (TZS)	1,126,897.40	1,592,987.20	1,210,564.50	2,938,197.80	1,161,479.80	2,244,614.90

Table 4: Description of agroecological climate smart agriculture practices used in the study area

Agroecological CSA practice	Definition	Cost of implementation	Agroecological principle	Climate smartness	
Cereal-legume Intercropping	Simultaneous cultivation of two or more crops on the same plot of land (Nassary et al. 2020)	Low cost High labour demand	Diversity, Synergy, Efficiency, Resilience	Productivity	Increases productivity, supporting the sustainable use of resources such as land and water; and diversifies income sources (Nassary et al., 2020).
				Adaptation	It reduces crop failure risk, enhances water holding capacity, suppresses weed growth, and broadens dietary options (Teklewold et al., 2019 a)
				Mitigation	Help to nitrogen fixation, increased water retention, and reduced crop failure due to drought, pests, and diseases (Nassary et al. 2020).
Improved crop varieties	Maturing crops, flood-tolerant and/or drought-tolerant crops, and disease-resistant	Moderate to high cost Less labour is required	Diversity Co-creation of knowledge	Productivity	Increase crop yield even when there is insufficient rainfall (Loboguerrero et al., 2019)
				Adaptation	Can act as a buffer against the risks associated with climate change (Sanou et al. 2016).

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Agroecological CSA practice	Definition	Cost of implementation	Agroecological principle	Climate smartness	
	and pest-resistant crops (Webber et al. 2014)			Mitigation	Can act as a buffer against the risks associated with climate change (Sanou et al. 2016).
Crop residue retention	Practice of leaving crop remains such as leaves, stalks, and roots on the plant after harvesting (Rusinamhodzi, van Wijk, et al., 2015 b)	Low cots Competition for the use of crop residues.	Recycling, Resilience Synergy	Productivity	Helps in conserving soil moisture and nutrients, input use-efficiency, suppressing weeds, conserving resources, improving soil health, enhancing yield moderating soil temperature, and adapting to climate change (Rusinamhodzi, van Wijk, et al., 2015 b)
				Adaptation	Improves soil structure, long-term fertility, and nutrient-use efficiencies (Murphy et al., 2016)
				Mitigation	Decreases the usage of synthetic fertilizers and associated GHG emissions while increasing soil carbon storage (Harvey et al., 2014).
Animal manure	Are organic waste products left over from raising livestock (Harvey et al., 2014)	Labour intensive	Recycling	Productivity	Increases crop yields and income (Abdallah et al. 2021)
				Adaptation	Increases soil carbon storage, decreases the requirement for synthetic fertilizers, and lowers associated greenhouse gas emissions (Harvey et al., 2014)
				Mitigation	Increases soil carbon storage, decreases the requirement for synthetic fertilizers, and lowers associated greenhouse gas emissions (Harvey et al., 2014)
Livestock diversification	Production of one or more livestock on available	Labour-intensive, High cost	Diversity, Recycling	Productivity	Increase crop yield (Asante et al., 2018)
				Adaptation	Decreases the usage of synthetic fertilizers (Nicholls & Altieri, 2018)
				Mitigation	Farm productivity increases for grazing, feeding, and food crops (Teixeira et al., 2018)
Crop rotation	Raising and managing a variety of crops over a set period of time or area (Ouda et al., 2018)	Labour intensive	Synergy, Resilience	Productivity	Farm productivity increases for grazing, feeding, and food crops (Teixeira et al., 2018)
				Adaptation	Reduces the prevalence of pests and diseases that affect a certain crop, improves soil fertility and structure with nitrogen-fixing plants, and lessens soil erosion (Debaeke et al., 2017).
				Mitigation	Reduces the use of nitrogenous fertilizers when leguminous crops are added (Teklewold et al., 2019 a)
Mixed cropping	Growing two or more crops simultaneously with no distinct row	Labour intensive	Diversity, Synergy,	Productivity	Farm productivity increases (Raseduzzaman & Jensen, 2017)
				Adaptation	Minimizes the risk of losses in case climate variability (Nicholls & Altieri, 2018)

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Agroecological CSA practice	Definition	Cost of implementation	Agroecological principle	Climate smartness	
	arrangement (Gebregergis, 2016).		Efficiency, Resilience	Mitigation	Decreases the usage of synthetic fertilizers (Wezel et al., 2020)
Agroforestry	a land use management system that combines trees and shrubs with crops and/or livestock in a mutually beneficial way (Akter et al., 2022)	Moderate to high cost Less labour-intensive	Diversity, Synergy, and Resilience Co-creation of knowledge	Productivity	Trees in agroforestry systems can provide fruits, nuts, timber, and other products, while crops can provide food and income (Van Noordwijk, 2021) Trees in agroforests can provide shade, windbreaks, and nutrient cycling benefits to the crops, which can increase crop yields and improve soil fertility (Akter et al., 2022)
				Adaptation	Can help farmers adapt to climate change by providing a more resilient and diversified farming system (Akter et al., 2022)
				Mitigation	Reduce greenhouse gas emissions and sequester carbon.
Minimum tillage	a type of tillage system that involves minimal soil disturbance, leaving a significant portion of the soil surface covered with crop residues or other organic matter.	High cost at the beginning Less labour	Diversity Co-creation of knowledge Recycling Synergy Resilience	Productivity	Improving soil health and reducing input costs. Help to maintain soil structure and reduce compaction, which can improve root growth and nutrient uptake (Fahad et al., 2022; Rosa & Gabrielli, 2023)
				Adaptation	Minimum tillage can contribute to increasing agricultural systems resilience to climate change and extreme weather events. By improving soil health and structure, minimizing tillage can increase soil water storage capacity, reduce adverse effects of drought and flooding, soil erosion, maintain soil fertility, reduce nutrients loss. (Rosa & Gabrielli, 2023).
				Mitigation	Minimum tillage can help reduce the emission of carbon dioxide and other greenhouse gases from the soil. In addition, increasing soil organic matter and reducing soil weeds can help capture carbon and reduce carbon dioxide in the atmosphere. (Rosa & Gabrielli, 2023).
Change in planting date	adjustment of the date on which seeds are sown or planted in the soil for crop production. (Moradi et al., 2013)	Low cost	Resilience and Synergy	Productivity	Help to optimize the use of available resources such as water and nutrients and reduce the risk of crop failure due to drought stress.
				Adaptation	A shift in planting date can reduce the risk of crop failure due to heat stress and increase the resilience of a farmer's farming system to climate change.
				Mitigation	Reduce greenhouse gas emissions from agriculture by avoiding the need for irrigation during periods of high-water demand,

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Agroecological CSA practice	Definition	Cost of implementation	Agroecological principle	Climate smartness	
					which can reduce energy use and associated emissions from pumping and transporting water.
Crop switching	refers to the process of changing the type of crop that is being grown in response to climate change. (Tessema et al., 2019).	Low to medium	Diversity and Resilience	Productivity	Allows farmers to select crops that are suitable for specific soil conditions, nutrient requirements, and pest management capabilities
				Adaptation	Farmers can diversify their crops and reduce the risks associated with climate variability and change
				Mitigation	Crop switching allows for the selection of crops with lower greenhouse gas emissions, contributing to overall mitigation efforts in agriculture (Tessema et al., 2019)
Water harvesting	Water harvesting is the practice of collecting and storing rainwater or groundwater for agricultural purposes (Sarma et al., 2023).	Moderate to high cost	Resilience	Productivity	Ensures that yields remain stable throughout the year (Schaller et al., 2017).
				Adaptation	Can help crops and fodder grow even when there is insufficient rain or during non-growing seasons. (Schaller et al., 2017).
				Mitigation	Decrease methane emissions compared to inappropriate irrigation practices (Schaller et al., 2017)
Terraces	Terraces are a type of agricultural practice that involves creating stepped or graded terraces on sloped terrain in order to cultivate crops (Mylona et al., 2020)	Labour-intensive, High cost	Diversity Efficiency Recycling Resilience	Productivity	Enhances agricultural productivity by reducing soil erosion and retaining water (Deng et al., 2021)
				Adaptation	Increase resilience to climate change and its impacts by reducing plot steepness, affecting soil composition, hydrology, and plant growth (Deng et al., 2021)
				Mitigation	Provides level surfaces, reduces erosion, improves water retention, and enhances overall productivity in mountainous areas, thereby reducing greenhouse gas emissions (Deng et al., 2021)

Usage of Agroecological Climate-Smart Agriculture Practices by Smallholder Farmers in Chamwino and Igunga Districts

Most households in Igunga and Chamwino districts use agroecological practices like crop residue retention, improved seed varieties, mixed cropping, and cereal legume intercropping (Figure 2). These practices can adapt to climate change, and promote sustainability through water and soil conservation, and crop variety (Singh & Singh, 2017). In Chamwino, sorghum, millet, maize, groundnuts, and cowpeas were frequently intercropped, while maize and green grams were intercropped in Igunga. Intercropping cereals with legumes can reduce nitrogen fertilizer needs, decrease erosion, enhance soil fertility, and boost yield per area (Jensen *et al.*, 2020; Wakweya *et al.*, 2021; Akinyi *et al.*, 2022). This approach can prevent complete crop failure and encourage sustainable farming. Cereal-legume intercropping can offer families a nutritious diet of grains, protein-rich beans, and vitamin-filled green leaves, enhancing food security (Bezner Kerr et al., 2021)

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Improved crop varieties and soil management can buffer climate change risks, boost yields, and increase income (Sanou et al., 2016; Loboguerrero et al., 2019). Most farmers in Chamwino and Igunga use improved varieties (early maturing and drought-tolerant). Macia, NACO-Mtama1, and Tegemeo are the most popular improved sorghum varieties in these districts. SeedCo was the most popular improved maize variety in both districts. Improved seed varieties were sourced from NGOs, cooperatives, and agro-dealer stores. In Chamwino District, Macia sorghum varieties were supplied by Farm Africa, which also connected farmers to markets like Tanzania Breweries Limited (TBL), which buys farmers' sorghum at the end of the season. Thus, most Chamwino farmers adopted the sorghum seed varieties due to market assurance. TBL also helped farmers get loans from National Microfinance Bank (NMB) via farmer groups. However, some Igunga farmers still grew local maize varieties. The high cost of improved maize varieties may be a factor, as farmers must buy them each season. During the focus group discussion, farmers said they preferred local maize due to its taste and insect resistance.

> *"Local maize varieties taste great when roasted or used to make stiff porridge and they are not damaged by insects after being harvested. Improved maize varieties, some of which have no taste, are vulnerable to insect damage after harvest and are sold at high prices"* (Asserted one farmer during a focus group in Mbutu village Igunga district.

Similarly, Stephen et al. (2014) found that farmers in Tanzania did not use improved seeds due to cost and scarcity.

Crop residue was used by few smallholder farmers in Chamwino and Igunga districts for improving soil health. Farmers produce crops away from homesteads, leaving crop residue on their farms, which is consumed by cattle. The remaining residue is then incorporated into the soil during land preparations. During focus group discussions, held at Idifu village in Chamwino district participants stated that:

> *'' We often sell crop residue to local livestock keepers whereby their livestock feed on crop residue on our lands, which is a good source of income for us. In addition, if they don't have money, they sometimes agree to cultivate the land next cropping season in exchange for money"*

The majority of participants in the focus group reported frequently selling their crop residue to livestock keepers. Crop residue retention enhances soil structure, fertility, and nutrient-use efficiency by increasing soil organic carbon (Rusinamhodzi, et al., 2015 a). It also reduces weed emergence and biomass, and delays weed emergence (Chauhan & Abugho, 2013).

Mixed cropping involves growing multiple crops in the same field. It was observed that the majority of households in all districts practiced mixed cropping as a common farming method. This was found to be a prevalent practice among households. In the focus group discussion participants revealed that millet, sorghum, sunflower, and groundnuts/green grams were the most popular mixed cropping patterns. This practice is a risk-management strategy for farmers, allowing them to increase production and reduce crop failure and boost yields and income (Bowles et al., 2020). Utilizing resources more efficiently, some crops can protect others from wind and rain, and improve soil nutrients, leading to higher yields (Matata *et al.*, 2018). Combining cereals and legumes is especially beneficial, as cereals benefit from the nitrogen-fixing bacteria in leguminous plants' roots (Iijima et al., 2016).

Livestock diversification is one of the strategies farmers use to improve their livelihoods, allowing them to sell livestock to food or other household expenses if crops fail. Most households in the sample used different kinds of livestock in their households. This means that farmers can reduce the risk of crop failure and low yields related to the impact of climate change. Abera et al. (2021) found that large livestock households tend to choose a combination of pastoral, and non-farm livelihood strategies. Livestock diversification increases the resilience of farmers, helps them

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cope with climate risks and improves their welfare and economic results.

Manure from livestock is used by small-scale farmers in their homestead plots. This is because other plots, aside from the homestead, are located approximately 3 Km away (Table 3), making it difficult for them to transfer manure to their farms. Farmers also fertilize soils with manure from livestock by shifting livestock and growing crops in areas where livestock were previously housed. The use of organic manure in crop production is encouraged by livestock keeping, which is attributed to smallholder farmers' lower rates of fertilizer use, decreasing rainfall patterns, and increasing temperature variability (Chiputwa et al., 2020). Soil organic matter is important because it improves water use efficiency by increasing the water holding capacity, infiltration, drainage, aeration, and biological activity (Altieri & Nicholls, 2017). Increasing organic matter in soils during droughts boosts water efficiency and reduces fertilizer and pesticide use (Kopittke et al., 2019).

Smallholder farmers in the study area stated that they employed crop rotation, which entailed alternating between planting maize and cotton or leguminous crops on an annual basis. This practice is effective in controlling weeds because it regularly alters the makeup of the root zone and the way nutrients are absorbed. Additionally, crop rotation can lead to increased productivity in cereal crops when legumes are planted after them. This is because cereal crops benefit from the nitrogen fixation and root and nodule rot provided by legumes, which can improve soil fertility and nutrition, leading to higher yields (Agula et al., 2018; Asmare *et al.*, 2019).

In Chamwino and Ingunga districts, drought, birds, and market constraints, have caused smallholder farmers to switch from sorghum to maize or vice versa. In Igunga, farmers moved from sorghum due to drought, pests, diseases, birds, and lack of market varieties. Simtowe & Mausch, (2019) reported similar findings, noting that local sorghum varieties were abandoned due to drought, low yields, and attacks by diseases, pests, and birds, as well as lack of market varieties. Switching to climate-friendly crops boosts productivity and climate resilience.

Few farmers in the study areas use agroforestry and minimal tillage (Figure 2). This is likely due to the initial investment costs and labour requirements of these practices (Rosa & Gabrielli, 2023). Despite these costs, agroforestry and minimum tillage bring long-term benefits, such as sustainable land management, increased profitability, and environmental improvement (Mwadzingeni et al., 2023; Rosa & Gabrielli, 2023). Water harvesting and terraces were the least popular agroecological CSA practices in all districts. Farmers often use community ponds to grow vegetables in dry seasons, which is essential for diversifying livelihoods and generating income until planting season. Similarly, (Mkonda et al., 2018 b) reported that Tanzanian farmers harvest rainwater, plant fruit trees and vegetable gardens, compost, and use plastic-lined rainwater collection and storage trenches to garden in dry lands. Household-level biogas, push-pull technology, and the utilization of vertiva grass were practices that were practised solely by lead farmers. The primary reason cited by farmers for this lack of usage was the costs associated with implementation. For example, the installation of household biogas systems in the study area amounts to approximately TZS 2,000,000/= per household. Additionally, the scarcity of vertiva grass seeds in Tanzania necessitates its direct importation from Kenya, which only a few farmers can afford.

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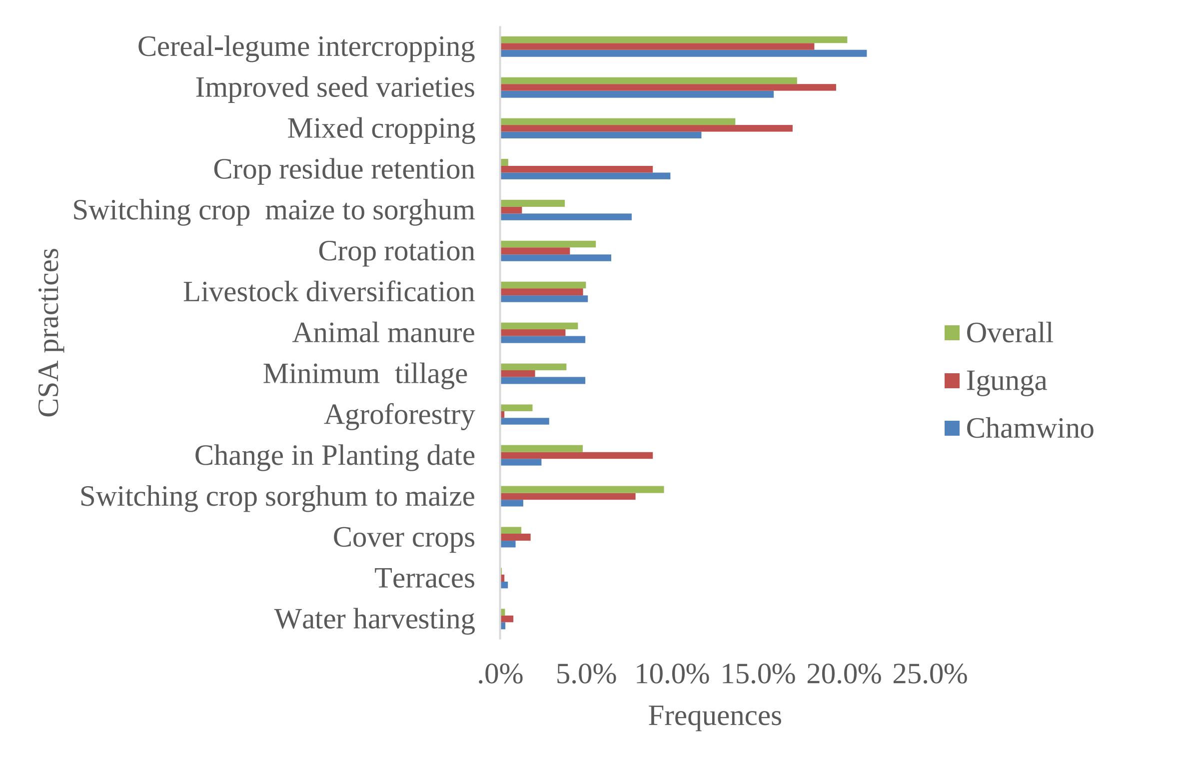
Figure 2: Agroecological climate-smart agriculture practices used in the study areas



Factors Influencing Usage of Agroecological Climate-Smart Agricultural Practices

The use of improved seed varieties by farmers was positively influenced by assistance from non-governmental organizations (NGOs), access to weather information, and training in climate-smart agriculture (CSA) practices (*Table 5*). However, farmers' experience in agriculture and Tropical livestock unit (TLU) had a negative influence on the usage of improved seed varieties. NGOs can play a significant role in supporting farmers by using CSA practices. They can provide improved seeds, training through farmers' field schools, and connections to agricultural markets. Training in CSA practices is also critical to promote the use of agroecological CSA practices. Various means, such as demonstration plots, farmer field schools, farmer field days, training manuals, radio/TV programs, agricultural exhibitions, and public meetings can be used to provide this training. Similarly, Midingoyi *et al.* (2019) found that inadequate technical training reduced the likelihood of using CSA practices. This highlights the importance of technical training to promote the use of these practices. Additionally, some CSA practices require specialized knowledge, and farmers may only gain an understanding of them through training or seeing them in practice. Therefore, training in CSA is crucial for promoting the adoption of these practices and improving agricultural productivity. The negative impact of farming experience and ownership of large numbers of livestock on the use of improved seed varieties can be explained by the fact that farmers may prioritize their attention and focus on their livestock rather than utilizing improved seed varieties.

Cereal legume intercropping was influenced by total household income and drought perception and negatively influenced by distance to the market. This implies that the higher the household income the higher the likelihood of the farmer intercrop cereal with a legume (*Table 5*). This is because intercropping involves combining more than two crops in space and time, which has cost implications in terms of purchasing seeds and labour, so this practice is limited to households with in sufficient income. The results contrast Mulwa et al. (2017), who reported that the higher the share of farm income, the lesser the livelihood diversification. This suggests that there are different factors such as access to markets and perception of droughts influencing farmers' decisions to diversify their livelihoods, and that income level is not always the only important factor. Likewise, Luu (2020), reported that access to the market is negatively and significantly associated with household decisions to employ CSA practices. This suggests that farmers who have market access may be more concerned with short-term profit maximization than investing in long-term sustainability.

Crop rotation was positively influenced by total household income and NGO assistance but negatively influenced by membership in the organisation. Unexpectedly, membership in the organisation was negatively associated with crop rotation, even though community organisations are critical routes for extension workers and non-governmental organizations (NGOs) to reach farmers and promote agroecological CSA usage. Farmers who participate in various social activities and research groups have a greater understanding of technology, which increases their use (Yokamo, 2020). This is because farmer groups serve as channels for NGOs and government extension services, allowing group members to obtain information and other services. Most households in the study areas were not involved in farming groups/organizations; instead, they had membership in credit and service groups through which individuals could acquire loans for a range of purposes, including agriculture.

The crop residue retained was significantly influenced by access to credit. This indicates that farmers are more likely to retain crop residues if they access credit. Similarly, (Sabasi et al., 2021) indicate that increased credit access is positively associated with residual returns to resources, including crop residues. Access to credit is an important factor affecting the amount of crop residue after harvest, especially for small-scale farmers. Crop residues, such as stalks and leaves, can be used for a variety of purposes, including livestock feed and to improve soil fertility. With credit, farmers are likely to afford modern agricultural practices and equipment to help them grow crops more efficiently. This can result in higher crop yields and less waste, leading to greater residue retention after harvest.

The use of mixed cropping was influenced by NGO assistance, training in CSA practices, and drought perception. Farmers can meet the diverse nutritional needs of their households and communities by cultivating a variety of locally adapted crops(Nicholls & Altieri, 2018). This is especially important in areas where there is a high level of food insecurity, as it can help to improve the availability and accessibility of nutritious foods. Furthermore, growing a variety of crops can improve soil fertility and promote biodiversity, both of which can benefit the environment and contribute to sustainable agricultural practices.

Livestock diversification was influenced by the total number of plots and negatively influenced by access to credit. This indicates that farmers were more likely to diversify their livestock if they owned more plots. Farmers with more plots tend to use a combination of agricultural technologies to prevent possible losses (Liang *et al.,* 2021). This is due to the differences in soil fertility, variability in temperature, humidity and rainfall, the prevalence of pests and diseases, birds, and the presence of soil salinity in some areas. Additionally, farmers with many plots may allocate additional plots for livestock keeping to shifting cultivation. This practice improves soil fertility and allows crop cultivation in previously livestock-occupied plots. Livestock diversification is regarded as insurance against emergencies or an investment due to low initial investment costs (Ogada et al., 2020).

The total number of plots, membership in an organisation, and CSA training in CSA practices all positively influenced animal manure usage. Farmers with a variety of plots can use manure, but this is typically only feasible for homestead plots because distant plots incur significant costs associated with labour and transportation. Few farmers could afford to use push carts, bicycles,

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and occasionally motorcycle circles to transport manure to far-off plots. Farmers who own multiple plots of land tend to use a combination of agricultural technologies to mitigate potential losses (Liang *et al.,* 2021). This strategy allows them to diversify their crop production while also lowering the risk of crop failure due to environmental factors, such as drought, pests, and diseases. Similarly, Mogaka et al. (2021) found that increasing years of agricultural expertise reduced the likelihood of adopting agroforestry and organic manure. Unexpectedly, the findings of this study indicated that farming experience does not influence the use of animal manure. These findings contradict those of (Onyeneke et al., 2021) who indicated that farming experience significantly increases the likelihood of adjusting agricultural production and management systems.

Extension advice is critical to increasing the use of CSA practices. This is because extension practitioners from government and non-governmental organisations (NGOs) act as primary sources of knowledge on new farmer technologies which can influence farmers' behaviour toward CSA practices (Kazal *et al.,* 2020). These results are similar to those of Kazal *et al.* (2020), who indicated that extension advice could help increase the usage of CSA practices. In Tanzania, there are no extension officers for every village. Therefore, the available extension officers appear to be preoccupied with other obligations by governments or non-governmental organizations.

Changes in planting date were influenced by the household head's gender, distance to the market, and Igunga district location. The gender of the household head can influence the decision to alter planting dates because of the roles and responsibilities of different genders in the families. This can affect access to resources, agricultural knowledge, and decision-making. Similarly, Rehima et al. (2013) indicated that gender plays a significant role in crop diversification, with female household heads showing a greater tendency to ensure food security for their families than their male counterparts. Distance to the market is also an important factor to consider when making farming decisions. Access farmers have to input and output markets affect their transaction costs and how likely they are to implement CSA practices (Liang et al., 2021). These findings contradict those of (Luu, 2020) who found that access to the market has a negative impact and is significantly connected with household decisions to employ yield management measures.

The study found that the use of agroforestry practices was influenced by the number of plots a household had and whether they received assistance from an NGO. This suggested that farmers who own multiple plots may be more willing to dedicate additional land for agroforestry practices. This can help them thoroughly analyse the potential impacts and outcomes of incorporating trees into their agricultural systems. Contrary to Kachaka et al. (2023) and Zerihun. (2021), who stated that smallholder farmers with larger landholdings were hesitant to adopt agroforestry as it may reduce field crop production and fail to meet their annual food demand. Furthermore, presence of NGOs in the community can provide training on agroforestry practices and supply farmers with seeds and seedlings of agroforestry trees.

Minimum tillage is influenced by distance to the market, membership in an organisation, and NGO assistance. Being a member of an organisation can also have an impact on the usage of minimum tillage practices because farmers can access information and support related to implementing these practices. Similarly, Osewe et al. (2020) found that the use of minimum tillage among smallholder horticultural crop producers in Southern Tanzania was influenced by factors such as distance to the market, membership in an organisation, and assistance from NGOs. These organisations provide resources, training, and expertise that can help farmers overcome barriers and effectively implement reduced tillage methods on their farms. NGOs can offer technical knowledge, financial support, and access to markets, thus making it easier for farmers to transition to minimum tillage practices.

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By providing guidance and resources, these organisations help farmers navigate the challenges associated with using and implementing minimum tillage practices.

Crop switching from sorghum to maize was influenced by training in climate smart agriculture practices, membership in an organisation, and NGO assistance. This indicates that farmers who have access to training and receive assistance from NGOS in the community are more likely to switch from sorghum farming to maize farming. Farmers trained in CSA are aware of the benefits of growing resilient crops. Likewise, Martey et al. (2021) found that participating in comprehensive agricultural training programs can significantly increase the adoption of climate-smart cowpea varieties and boost productivity and cowpea income by 75%, 15%, and 24%, respectively. Membership in an organisation, on the other hand, provides resources, knowledge, and support which can help farmers make informed decisions regarding crop switching and adapt to changing climatic conditions. Organisations can also provide a platform for knowledge sharing and collaboration, enabling farmers to learn from each other's experiences and to use climate-smart agriculture practices. This can help them negotiate better deals in the market and obtain inputs at reduced costs through collective action.

Improved seed varieties, changes in planting date, and crop switching from sorghum to maize were all positively influenced by Igunga district as a location variable. This indicates that, in Igunga district, a farmer is more likely to use these agroecological CSA practices. This is because the Igunga District is more accessible and receives greater support from the government and NGOs for climate change initiatives than the Chamwino District. Similarly, Mishra et al. (2022) showed that different regions and districts had unique agro-ecological conditions and different levels of support and resources for climate change initiatives.

Responses on climate smart agriculture usage in relation to factors influencing it

The results show that farmers are more likely to use specific agroecological CSA practices when certain factors, such as assistance from non-governmental organizations, CSA training, membership in organizations, access to credit, and distance to market exist (*Table 6).* Certain factors influence the use of multiple agroecological CSA practices for example, training in CSA practices influences the use of improved seed varieties, mixed cropping, crop rotation, animal manure use, and the switch from maize to sorghum. Similarly, membership in an organization influences crop rotation, the use of animal manure, livestock diversification, minimum tillage and the switch from of Sorghum to Maize. Addressing these factors has the potential to have a broader impact on various practices, resulting in more effective and sustainable agricultural outcomes.

Table 5: Binary logistic regression of factors influencing smallholder farmers' usage of climate-smart agriculture

Variables	Improved seed varieties	Cereal -legume Intercropping	Mixed cropping	Crop residue retention	Crop rotation	Change in Planting date	Animal manure use	Livestock diversification	Agroforestry	Minimum tillage	Water harvesting	Switch Sorghum to Maize	Switch Maize to sorghum
Household head gender	0.106 (0.744)	-0.356 (0.280)	-0.518 (0.091)	-0.00915 (0.977)	0.214 (0.598)	1.176 **(0.017)**	-0.677 (0.117)	0.166 (0.681)	-0.117 (0.872)	0.141 (0.748)		0.883 (0.113)	-0.111 (0.783)

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Variables	Improved seed varieties	Cereal -legume Intercropping	Mixed cropping	Crop residue retention	Crop rotation	Change in Planting date	Animal manure use	Livestock diversification	Agroforestry	Minimum tillage	Water harvesting	Switch Sorghum to Maize	Switch Maize to sorghum
Household head age	0.0196	-0.00124	-0.00442	-0.00362	-0.0264	-0.00723	-0.00166	0.00310	-0.0313	-0.00528	0.0766	0.00565	0.0170
	(0.168)	(0.930)	(0.720)	(0.795)	(0.146)	(0.670)	(0.922)	(0.856)	(0.341)	(0.754)	(0.130)	(0.803)	(0.349)
Education of household head	0.0690	0.0965	0.00986	-0.0124	-0.00748	-0.00287	-0.0744	-0.0535	0.0416	0.0780	-0.0439	-0.120	-0.0589
	(0.136)	**(0.035)**	(0.823)	(0.787)	(0.892)	(0.961)	(0.262)	(0.324)	(0.695)	(0.283)	(0.799)	(0.066)	(0.308)
Experience in farming	-0.0312	0.0156	-0.00369	0.0224	-0.000984	-0.0197	-0.0434	0.0303	-0.00000287	0.00662	-0.0583	-0.0130	-0.0191
	(0.042)	(0.321)	(0.786)	(0.128)	(0.961)	(0.337)	**(0.023)**	(0.081)	(1.000)	(0.718)	(0.248)	(0.585)	(0.309)
Tropical Livestock Unit (TLU)	-0.201	0.0749	-0.0121	0.127	0.0645	0.0167	0.0480	0.159	0.205	0.0506	-0.756	-0.213	-0.0200
	(0.038)	(0.544)	(0.908)	(0.218)	(0.548)	(0.880)	(0.705)	(0.140)	(0.214)	(0.736)	(0.414)	(0.171)	(0.875)
Log of Total Income	0.0132	0.0813	0.0382	0.0670	0.246	0.0399	-0.0739	0.0210	0.0339	0.00396	-0.0357	-0.0381	0.0995
	(0.688)	**(0.010)**	(0.216)	(0.070)	**(0.014)**	(0.387)	(0.083)	(0.623)	(0.744)	(0.930)	(0.765)	(0.371)	(0.087)
Total no. of Plots	0.175	0.144	0.178	0.0233	0.0615	-0.312	0.393	0.372	0.554	0.0415	0.171	-0.0348	0.212
	(0.117)	(0.268)	(0.127)	(0.820)	(0.615)	**(0.057)**	**(0.000)**	**(0.006)**	**(0.030)**	(0.775)	(0.606)	(0.785)	(0.147)
Total household acreage	0.00637	0.0254	0.0272	-0.00913	0.0185	0.0182	-0.0158	-0.0604	-0.0532	-0.0516	0.0290	-0.000517	-0.0201
	(0.801)	(0.421)	(0.353)	(0.700)	(0.460)	(0.474)	(0.678)	(0.177)	(0.550)	(0.409)	(0.879)	(0.988)	(0.626)
Distance to market	-0.0736	-0.152	0.0206	0.0403	0.141	0.242	-0.187	-0.249	-0.642	-0.546		-0.0674	0.183
	(0.348)	(0.052)	(0.785)	(0.611)	(0.125)	**(0.006)**	(0.157)	**(0.031)**	(0.114)	**(0.026)**		(0.544)	(0.077)
Access to credit	0.303	0.0950	-0.473	0.752	-0.253	-0.00921	0.427	-0.966	0.940	-0.0879	-0.759	0.621	0.780
	(0.391)	(0.789)	(0.143)	**(0.021)**	(0.573)	(0.984)	(0.345)	**(0.025)**	(0.227)	(0.849)	(0.675)	(0.242)	(0.067)
Membership in an organisation	0.0120	0.430	-0.288	-0.498	-0.849	-0.434	1.536	-0.749	-1.117	1.989	1.503	-0.415	-1.204
	(0.969)	(0.168)	(0.329)	(0.100)	**(0.027)**	(0.253)	**(0.002)**	**(0.048)**	(0.158)	**(0.000)**	(0.449)	(0.333)	**(0.004)**
Access to Extension services	-0.183	-0.0614	0.0798	-0.0418	-0.477	-0.721	1.419	0.268	6.526	-0.124	0.178	0.643	0.522
	(0.620)	(0.870)	(0.821)	(0.910)	(0.270)	(0.104)	**(0.034)**	(0.599)	(0.312)	(0.790)	(0.910)	(0.309)	(0.323)
Access to weather information	0.811	0.688	0.336	0.723	0.380	-0.365	0.413	0.276	-1.016	0.509		-0.225	0.178
	(0.030)	(0.069)	(0.362)	(0.063)	(0.421)	(0.459)	(0.495)	(0.557)	(0.232)	(0.327)		(0.698)	(0.714)
	1.565	0.285	1.318	-0.481	-1.007	0.561	1.893	-0.0861	-0.691	-0.302	-0.314	0.344	-1.331

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Variables	**Improved seed varieties**	**Cereal -legume Intercropping**	**Mixed cropping**	**Crop residue retention**	**Crop rotation**	**Change in Planting date**	**Animal manure use**	**Livestock diversification**	**Agroforestry**	**Minimum tillage**	**Water harvesting**	**Switch Sorghum to Maize**	**Switch Maize to sorghum**
Training in CSA practices	**(0.000)**	(0.347)	**(0.000)**	(0.104)	**(0.008)**	(0.169)	**(0.000)**	(0.820)	(0.354)	(0.472)	(0.803)	(0.457)	**(0.001)**
Drought perception	0.182	0.830	0.755	0.359	0.694	0.290	0.807	0.494	0.592	0.288	-3.087	-0.902	0.566
	(0.621)	**(0.020)**	**(0.043)**	(0.344)	(0.162)	(0.555)	(0.169)	(0.321)	(0.485)	(0.594)	(0.053)	(0.060)	(0.301)
NGO assistance	1.263	0.393	0.645	0.114	0.882	0.761	0.368	0.236	2.788	0.926	2.372	-1.491	1.085
	(0.000)	(0.222)	**(0.031)**	(0.720)	**(0.026)**	(0.060)	(0.396)	(0.546)	**(0.022)**	**(0.029)**	(0.180)	(0.004)	**(0.012)**
Igunga district	-0.617	-0.299	-0.432	-0.0676	0.476	1.031	-0.513	0.638	0.107	-0.783	-0.553	1.782	-0.0679
	(0.045)	(0.330)	(0.143)	(0.826)	(0.189)	**(0.004)**	(0.282)	(0.099)	(0.875)	(0.164)	(0.780)	**(0.000)**	(0.869)
Constant	-2.707	-2.710	-1.578	-2.036	-3.884	-3.636	-4.438	-3.106	-9.913	-6.071	-8.475	-2.606	-2.641
	(0.035)	**(0.031)**	(0.180)	(0.101)	**(0.045)**	**(0.028)**	**(0.014)**	(0.056)	(0.162)	**(0.001)**	(0.136)	(0.181)	(0.115)
-2(log-likelihood)	317.0	317.4	346.5	323.2	228.3	221.9	181.3	228.4	83.95	181.9	28.59	172.4	207.6

Note1: The numbers within and outside parentheses represent the standardized beta coefficients (β) and p-values, bold type indicates statistically significant regression.
Note 2: Terraces, cover crops, were not included in the binary regression analysis presented in this table because of their limited usage by the majority of households in the study sample. Only a small fraction of the households reported implementing these agricultural practices, making it challenging to draw meaningful statistical conclusions from their inclusion.

Table 6: Distribution of responses on climate smart agriculture usage in relation to factors influencing it

Factor	**CSA Practices**	**Response**	
		No	**Yes**
NGO assistance	Improved seed varieties	72(28.0)	111(31.4)
	Cereal -legume Intercropping	101(39.3)	112(31.6)
	Crop rotation	23(8.9)	35(9.9)
	Agroforestry	2(0.8)	18(5.1)
	Reduced tillage	14(5.4)	27(7.6)
	Switch Maize to sorghum	14(5.4)	42(11.9)
	Switch Sorghum to Maize	31(12.1)	9(2.5)
Training in CSA practices	Improved seed varieties	56(31.30)	127(40.7)
	Mixed cropping	39(21.8)	106(34.0)

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	Crop rotation	38(21.2)	21(6.7)
	Animal manure use	7(3.9)	41(13.1)
	Switch Maize to sorghum	39(21.8)	17(5.4)
Membership in an organisation	Crop rotation	26(17.4)	33(30.6)
	Animal manure use	41(27.5)	7(6.5)
	Livestock diversification	27(18.1)	26(24.1)
	Reduced tillage	39(26.2)	2(1.9)
	Switch Sorghum to Maize	16(10.7)	40(37.0)
Access to credit	Crop residue retention	54(59.3)	47(74.6)
	Livestock diversification	37(40.7)	16(25.4)
Access to weather information	Improved varieties	8(61.5)	175(79.2)
Drought perception	Mixed cropping	19(70.4)	126(73.7)
	Livestock diversification	8(29.6)	45(26.3)
	Cereal Legume- intercropping		
Total household income	< 1000000	68(80)	148(69.2)
	1000000-5000000	15(17.6)	56(26.2)
	> 5000000	2(2.4)	10(4.7)
Education of household head	<7	17(20)	23(10.7)
	>7	68(80)	191(89.3)
	Minimum Tillage		
Distance to market	0-3 Km	200(77.5)	41(100)
	3-6 Km	58(22.5)	0(0)
	Livestock diversification		
Distance to market	0-3 Km	192(78.0)	49(92.5)
	3-6 Km	54(22)	4(7.5)
	Change in planting date		
Distance to market	0-3 Km	208(83.9)	33(64.7)
	3-6 Km	40(16.1)	18(35.3)

Note: Only factors with statistically significant influence and sufficient observation to allow logistic regression in (Table 3) are shown. Yes, is for those that use the strategy while no is for those that did not
The number in brackets indicates percentages.

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CONCLUSIONS AND RECOMMENDATIONS

Climate change and variability affect agricultural production in the semi-arid areas of Tanzania, thereby impacting agricultural productivity. Therefore, it is crucial to assess agroecological CSA practices that adhere to the agroecological principles that farmers use to reduce the negative impact of climate change. According to the study findings, cereal-legume intercropping, improved seed varieties, mixed cropping, and crop residue retention are agroecological CSA practices used by most smallholder farmers in Tanzania's semi-arid regions.

Farmers are more likely to use improved seed varieties if they receive assistance from NGOs, access weather information, and receive CSA training. By contrast, farming experience and total livestock units did not positively affect the use of improved seed varieties. Additionally, farmers who perceive drought with a higher total household income are more likely to use cereal-legume intercropping; however, they are less likely to do so when considering distance to markets. Total household income and NGO assistance increase the likelihood of using crop rotation, while having a negative effect on organisation membership. NGO assistance, training in CSA practices, and perception of drought all had a positive impact on mixed cropping. The total number of plots, experience in farming, membership in an organisation, access to extension services and training in CSA practices had a positive impact on the use of animal manure, whereas farming experience had a negative impact.

The intercropping of cereal legumes with improved seed varieties and mixed cropping practices should be promoted, as they can help local communities adapt to and lessen the effects of climate change. The government and NGOs should also strongly emphasise agroecological CSA practice training to increase the use of these practices, so that farmers can access information through field days, demonstration plots, and discussion groups. Frequent extension services and easier access to credit for farmers should also be priorities for governments and non-governmental organizations. The government should provide subsidies to encourage widespread use of improved seed varieties.

Furthermore, by considering the costs, labour requirements, agroecological principles, and climate smartness of different practices, stakeholders can make informed choices regarding which CSA practices to use and promote. This knowledge can facilitate the transition towards more sustainable and resilient agricultural systems, contributing to food security and improving farmers' livelihoods. This study had some limitations. This study used a cross-sectional design and relied on self-reported data from the farmers. Using longitudinal designs can help establish causal relationships between different factors, and the use of CSA practices can help develop sustainable agricultural practices and improve food security in the country.

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