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# STRENGTHENING FOOD SECURITY THROUGH CLIMATE-SMART AGRICULTURE: THE CASE OF SMALLHOLDER LEAFY VEGETABLE AGRIPRENEURS IN SEMI-ARID TANZANIA

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## ABSTRACT

Food insecurity remains a major challenge in semi-arid regions, where climate variability and resource constraints threaten smallholder farming. Climate-Smart Agriculture (CSA) offers a sustainable solution by enhancing agricultural resilience and food security. This study examines CSA adoption among smallholder leafy vegetable agripreneurs in central Tanzania and its contribution to household food security. A mixed-methods approach was used to collect data from 385 farmers in the Dodoma and Singida regions. The Household Food Insecurity Access Scale (HFIAS) measured food security levels, while CSA adoption was analyzed through individual practices and grouped categories. Findings show that 53.5% of households were food insecure, with 30.5% mildly, 18.2% moderately, and 4.9% severely food insecure, while 46.5% were food secure. Generalized regression analysis indicates that mulching reduces food insecurity risk by 21% ($p < 0.05$), while integrated soil-water management practices lower risk by 22% ($p < 0.05$). Market access and government support were key enablers, enabling smallholder agripreneurs to generate stable income from leafy vegetable sales, strengthening household food security. Qualitative insights reinforce the dual role of leafy vegetables in direct consumption and income generation. Households adopting CSA practices, particularly mulching and organic fertilizers, reported improved food security outcomes. Enhancing access to organic fertilizers, especially cattle manure, is critical for scaling CSA adoption. Developing efficient manure collection, processing, and distribution systems can integrate livestock waste management into CSA expansion. Establishing structured cattle dung markets, promoting composting innovations, and implementing policy incentives can unlock the potential of organic fertilizers in sustainable food production and climate resilience.

**Keywords:** Climate-Smart Agriculture, Food Security, leafy vegetable agripreneurs, Market Access, Semi-Arid regions

## INTRODUCTION

Food insecurity remains a critical global issue, with over 820 million people experiencing hunger and an even larger population facing moderate to severe food insecurity (Alemu & Ashenafi, 2022; Kapari *et al.*, 2023). This challenge is particularly pronounced in arid and semi-arid regions, where erratic rainfall, rising temperatures, and resource limitations heighten smallholder farmers' vulnerabilities (Assenga & Kayunze, 2020; Masha *et al.,* 2024). In central Tanzania, particularly Dodoma and Singida, climate variability significantly hampers agricultural productivity and household food security, necessitating sustainable and adaptive farming practices (Adimassu *et al.,* 2024; Affoh *et al.,* 2024).

Climate-Smart Agriculture (CSA) has been widely promoted as a solution to enhance agricultural resilience under climate change. CSA improves resource efficiency, mitigates climate variability, reduces greenhouse gas emissions, and increases productivity, thereby supporting sustainable food systems (Mizik, 2021; Ng'ang'a *et al.,* 2021). Among smallholder farmers in semi-arid areas, CSA enhances productivity and income through drought-resistant crop varieties and efficient water management (FAO, 2013). Additionally, CSA strengthens adaptation and resilience by promoting soil conservation, agroforestry, and diversified farming systems that help withstand climate shocks such as droughts and erratic rainfall (World Bank, 2019). CSA also contributes to environmental sustainability by encouraging conservation tillage, optimized fertilizer use, and carbon sequestration (IPCC, 2019).

Existing research highlights CSA's role in enhancing food security among smallholder farmers. Amadu et al. (2020) found that CSA adoption improved household welfare, food security, and income levels. Similarly, Tesfaye *et al.,* (2023) demonstrated that CSA technologies in Ethiopia contributed to poverty reduction and strengthened food security. Nyanga *et al.,* (2023) further emphasized the positive link between CSA adoption and household food security, advocating for broader integration of CSA practices to support sustainable agricultural development. However, the effectiveness of CSA depends on crop selection and integration.

Leafy vegetables, known for their short production cycles, high nutritional value, and adaptability to semi-arid conditions, present an opportunity for improving food security in vulnerable regions (Alemu & Ashenafi, 2022; Habiyaremye *et al.,* 2021). Despite their potential, CSA research has largely focused on staple crops such as roots, tubers, legumes, and cereals, with limited attention to leafy vegetables (Alemu & Ashenafi, 2022; Habiyaremye *et al.,* 2021). Given their nutritional and economic significance, understanding how CSA practices influence leafy vegetable cultivation and food security outcomes among smallholder agripreneurs is essential (Boga *et al.,* 2020; Yusuph *et al.,* 2023).

This study analyzes CSA adoption patterns among smallholder leafy vegetable agripreneurs, assesses household food security levels using the Household Food Insecurity Access Scale (HFIAS), and examines the contributions of CSA practices in reducing food insecurity. Through integrating quantitative and qualitative data, the study provides a multidimensional perspective on CSA's effectiveness and its relevance in semi-arid regions.

The paper begins with the theoretical and conceptual frameworks guiding CSA adoption and food security analysis. The methodology section describes the mixed-methods approach, including data collection and analysis. The results and discussion sections integrate quantitative and qualitative findings to assess CSA's role in enhancing household food security. Finally, the

paper concludes with policy recommendations and future research directions to strengthen agricultural resilience in semi-arid regions.

## THEORETICAL FRAMEWORK

This study is guided by Expected Utility Theory (EUT), developed by von Neumann and Morgenstern (1944), which explains decision-making under uncertainty. According to EUT, individuals assess potential choices by weighing expected benefits against associated risks (Dossa *et al.*, 2023; Tinh *et al.*, 2021). In the context of this study, EUT provides a basis for understanding how smallholder farmers in semi-arid regions adopt Climate-Smart Agriculture (CSA) practices amid climate variability and resource constraints.

EUT is particularly relevant for analyzing the trade-offs between the immediate costs and long-term benefits of CSA adoption. Many CSA practices require an initial investment but offer long-term resilience and productivity gains. The theory also accounts for uncertainty, such as unpredictable climatic conditions, which influence decision-making (von Neumann & Morgenstern, 1944). Farmers' adoption of CSA practices is, therefore, assessed as a function of perceived utility, shaped by socio-demographic factors such as education, land ownership, and resource access. This framework facilitates a systematic evaluation of how farmers balance costs, benefits, and risks when adopting CSA under uncertain conditions.

### Conceptual Framework

Building upon Expected Utility Theory, the conceptual framework in this study explains how smallholder farmers make decisions under uncertainty. Farmers weigh the costs and benefits of various agricultural strategies while considering their likelihood of achieving food security outcomes. These decisions are influenced by socio-demographic and contextual factors that shape risk perception and adoption behavior.

The study examines the relationship between CSA practices and household food security among smallholder leafy vegetable agripreneurs in semi-arid central Tanzania. The independent variables include CSA practices, which aim to increase productivity, enhance climate resilience, and mitigate agricultural risks. Household food security, the dependent variable, is measured using the Household Food Insecurity Access Scale (HFIAS), categorizing households based on their food security levels.

Socio-demographic characteristics act as moderating variables, shaping the extent to which CSA practices influence household food security. These factors determine farmers' ability and willingness to adopt and effectively implement CSA techniques. The conceptual framework provides a structured approach to understanding CSA's role in improving food security in semi-arid regions.

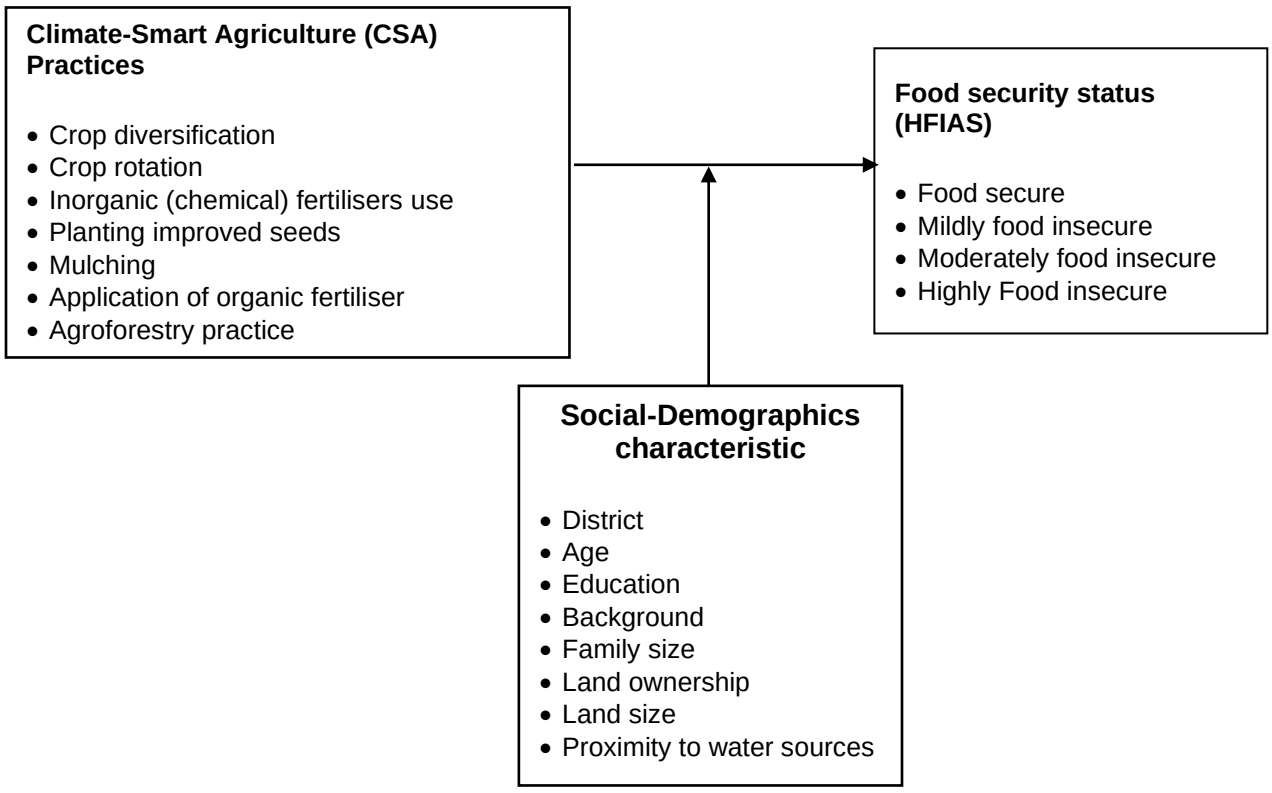


**Figure 1:** Conceptual framework showing the relationship between climate smart agriculture and food security status, modified by social-demographic characteristics among smallholder farmers.

## METHODOLOGY

### Study Area

The study was conducted in the Ihumwa and Iyumbu Wards of Dodoma City and the Uhamaka and Unyambwa Wards of Singida Municipality, located in central Tanzania's semi-arid zone. These wards were purposively selected because they are the primary producers of leafy vegetables in their respective districts, supplying both internal and external markets (Ekka & Mjawa, 2020; Swamila *et al.*, 2020). Dodoma City leads leafy vegetable production in the Dodoma Region, while Singida Municipality holds the same distinction in the Singida Region.

The study area's geographical and administrative locations are presented in Figure 2. Panel (A) shows Tanzania, with the study regions highlighted. Panel (B) outlines the Dodoma and Singida Regions, while Panels (C) and (D) provide detailed maps of the selected wards, illustrating their distribution and key administrative boundaries. Focusing on these areas provides an opportunity to examine Climate-Smart Agriculture (CSA) adoption in regions critical to leafy vegetable production. Insights from these wards are particularly relevant for informing strategies to enhance agricultural sustainability and food security in semi-arid areas.

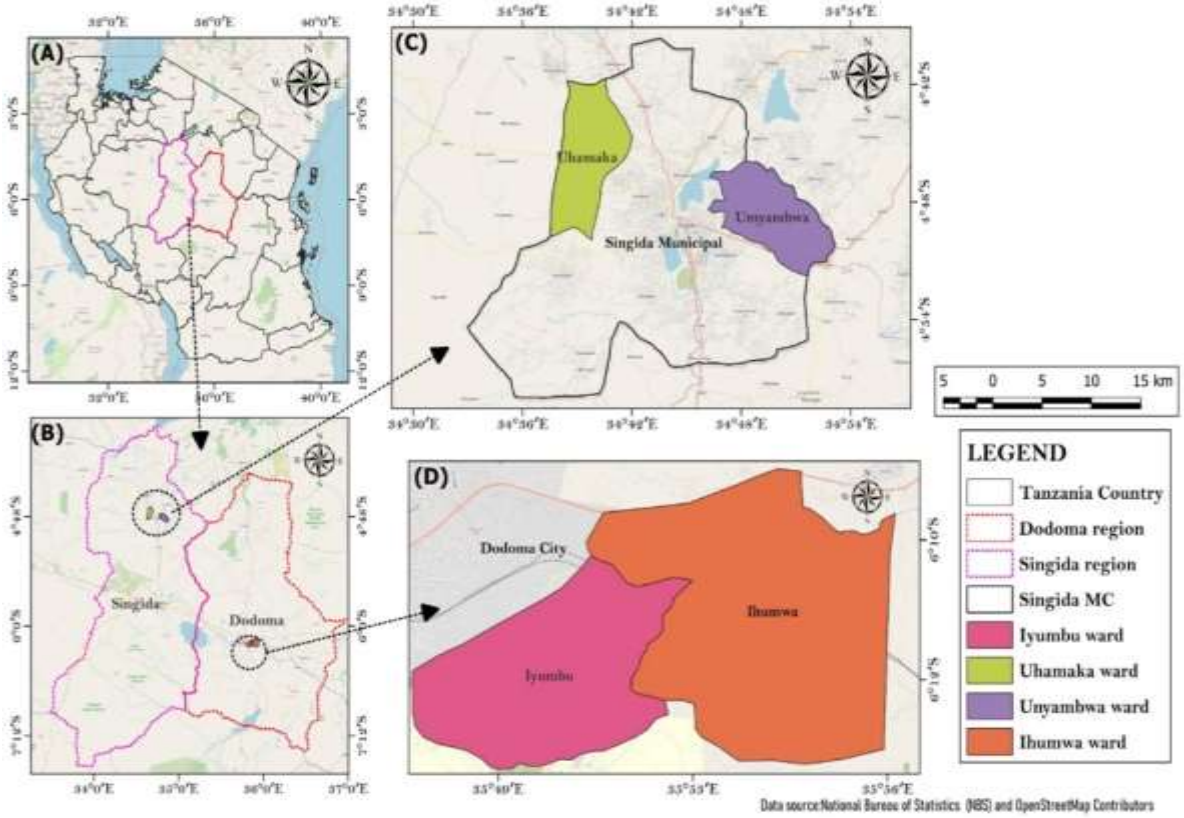


**Figure 2:** Maps showing Singida and Dodoma of Tanzania
**Source:** National Bureau of Statistics (NBS) and Open Street Map Contributors

## RESEARCH DESIGN AND SAMPLING

This study employed a mixed-methods cross-sectional design to examine the relationship between Climate-Smart Agriculture (CSA) practices and household food security among smallholder leafy vegetable agripreneurs in semi-arid central Tanzania. The mixed-methods approach combined quantitative and qualitative data, with quantitative analysis identifying statistical patterns and qualitative data capturing smallholder leafy vegetable agripreneurs' experiences on how integrating CSA practices into leafy vegetable production contributes to household food security.

### Sampling Procedure

A multistage sampling approach was used to select study participants. Dodoma City and Singida Municipality were purposively selected as major leafy vegetable production centers, supplying both internal and external markets. Within these districts, two wards from each were chosen based on their prominence in leafy vegetable farming. Individual leafy vegetable agripreneurs were randomly selected from producers' registers maintained by ward extension officers to ensure the inclusion of only active farmers. Stratified random sampling was applied to account for diversity in age, gender, and farm size.

The sample size was determined using Cochran's formula at a 95% confidence level with a 5% margin of error, yielding 385 respondents. These were proportionally distributed across the four wards: Ihumwa (116), Iyumbu (77), Uhamaka (75), and Unyambwa (117), ensuring adequate representation of each ward's contribution to the leafy vegetable supply chain.

To complement the quantitative survey, qualitative data were collected through focus group discussions (FGDs), in-depth interviews, and key informant interviews. A total of six FGDs were conducted. In Dodoma City, Ihumwa and Iyumbu had one mixed-gender FGD and one women-only FGD, respectively, to ensure balanced gender representation. In Singida Municipality, separate FGDs were conducted in Uhamaka and Unyambwa as these wards are not geographically close, necessitating distinct discussions to capture localized experiences. Each FGD comprised 6–8 participants to balance diversity while maintaining effective discussions.

**Data Collection Instrument and Pre-testing**

Data collection utilized structured questionnaires, interview guides, checklists, and bibliometric analysis tools to obtain both quantitative and qualitative data. These instruments were designed to align with the study's objectives, focusing on the adoption of Climate-Smart Agriculture (CSA) practices and their contributions to household food security among smallholder leafy vegetable agripreneurs in semi-arid central Tanzania (Creswell & Creswell, 2017).

**Quantitative Data Collection**

A structured questionnaire served as the primary tool for quantitative data collection, capturing socio-demographic characteristics, CSA adoption, and household food security levels. Household food security was assessed using the Household Food Insecurity Access Scale (HFIAS), measuring food access, availability, and stability over a 30-day recall period (Coates *et al.,* 2007). This facilitated a systematic evaluation of household food security status. Additionally, bibliometric analysis examined trends, themes, and research gaps in CSA's contribution to food security, contextualizing study findings within the broader academic discourse (Donthu *et al.,* 2021).

**Qualitative Data Collection**

Semi-structured interview guides were used in focus group discussions (FGDs), in-depth interviews, and key informant interviews to explore smallholder leafy vegetable agripreneurs' experiences with CSA adoption and its impact on food security. Six FGDs were conducted, comprising three women-only and three mixed-gender groups to capture diverse perspectives (Guest *et al.,* 2017). Participants were purposively selected based on their involvement in leafy vegetable production, willingness to participate, and representation across different demographic groups.

**Pre-testing of Instruments**

The data collection instruments were pre-tested with 30 smallholder leafy vegetable agripreneurs from Ikungi District, a neighboring area with similar agro-ecological conditions. Pre-testing ensured clarity, cultural appropriateness, and reliability of the instruments (Krosnick, 2018). Feedback was incorporated to refine the instruments, enhancing their validity and usability. The structured questionnaire achieved a Cronbach's alpha coefficient of 0.78, indicating acceptable

internal consistency (Tavakol & Dennick, 2011). Content validity was further established through expert reviews by agricultural extension officers and academics, ensuring alignment with the study's objectives (Bryman, 2016).

## DATA ANALYSIS

### Quantitative Data Analysis

Quantitative data were entered into Microsoft Excel and analyzed using STATA version 18.5. Descriptive statistics, including frequencies, percentages, and means, summarized socio-demographic characteristics, CSA adoption levels, and food security status. Household food security was assessed using the Household Food Insecurity Access Scale (HFIAS), categorizing households based on a 0–27 scale, with higher scores indicating greater food insecurity (Coates *et al.,* 2007). Households were classified as food secure, mildly food insecure, moderately food insecure, or severely food insecure. For inferential analysis, these categories were consolidated into two groups: food secure (score = 0) and food insecure (scores ≥1), as shown in Table 1.

**Table 1:** Responses in each food security category

| **Food security status** | **Household responses** |
|---|---|
| Food secure | Rarely anxious about food supply |
| Mildly food insecure | Frequently anxious about food supply, omission of preferred foods |
| Moderately food insecure | Eating disliked meals, eating smaller meals, eating fewer meals |
| Highly Food insecure | Little food in the house, sleeping hungry, eating just one meal a day |

Source: Adapted from (Coates *et al.,* 2007)

To assess the relationship between CSA adoption and household food security, a generalized logistic regression model was used, with food security as the dependent variable and CSA practices as predictors. The model accounted for seasonal variations and adjusted for potential confounders such as district, age, education, family size, land ownership, farm size, and proximity to water sources. Statistical significance was set at 5% to ensure robust results. The logistic regression model was specified as follows:

$$\text{Logit}(\text{P}(\text{Y} = 1|\text{x}) = \beta_0 + \beta_p(adf_p) + \sum \beta_\text{i} C_i \ldots\ldots\ldots (\text{p})$$

Whereby:

$\text{P}(\text{Y} = 1|\text{x})$ = is the probability of food security (Y)

$\beta_\text{i}$ = are the coefficients of the Confounders: i.e., District, Age, Education Background, Family size, Land ownership, Size of the land, and Proximity from farm to water sources

$\beta_p$= are the coefficient of the predictors of interest which formulate a model ($p = 1\ to\ 8$)

$adf_p$ = predictor i.e., Crop rotation=$adf_1$, Application of organic fertilizer=$adf_2$, Application of improved seeds=$afd_3$, Mulching=$adf_4$, Crop diversification=$adf_5$, Application of inorganic (chemical) fertilizers=$adf_6$, Agroforestry=$adf_7$, Composite variable=$adf_8$

Additionally, bibliometric analysis examined CSA adoption and food security literature, using data from the Scopus database via Publish or Perish (Version 8) software. VOSviewer software was used for analyzing relationships between key concepts, authors, and citations, identifying research trends and gaps relevant to this study (Donthu *et al.,* 2021).

### Qualitative Data Analysis

Qualitative data were analyzed thematically, complementing the quantitative findings. Transcribed data were coded to identify key themes, including CSA adoption challenges, benefits, and its contribution to household food security. In-depth interviews captured individual perspectives from lead farmers, while key informant interviews with ward extension officers, ward executive officers, and agripreneur leaders provided expert, and experience insights on CSA implementation. Thematic analysis facilitated data triangulation, ensuring a comprehensive understanding of CSA adoption and its impact on food security among smallholder leafy vegetable agripreneurs in semi-arid regions of central Tanzania.

## RESULTS

### Socio-Demographic Characteristics

The study included 385 smallholder farmers, with 50.1% (n = 193) from Dodoma and 49.9% (n = 192) from Singida. The majority were under 35 years of age (60.5%, n = 233), and 57.1% were female (n = 220). Most participants had primary education (60.0%, n = 231), and 65.1% (n = 251) owned land. Additionally, 51.2% (n = 197) cultivated plots larger than one acre. Boreholes were the main water source for 61.3% (n = 236) of respondents. Nearly all participants had market access for their leafy vegetable produce, emphasizing the economic significance of their farming activities (Table 2).

| Variable | n (%) |
|---|---|
| Region | |
| Dodoma | 193(50.1) |
| Singida | 192(49.9) |
| | |
| Wards | |
| Ihumwa | 116(30.1) |
| Iyumbu | 77(20.0) |
| Uhamaka | 75(19.5) |
| Unyambwa | 117(30.4) |
| | |
| Age | |
| Below 35 years | 233(60.5) |
| Above 35 years | 152(39.5) |
| | |
| Sex | |
| Female | 220(57.1) |
| Male | 165(42.9) |
| | |
| Household size (median, range) | |
| Less than 5 members | 182(47.3) |
| More than 5 members | 203(52.7) |
| | |
| Member aged above 18 years in the family | |
| Less than 3 members | 243(63.1) |
| More than 3 members | 142(36.9) |
| | |
| Member aged above 60 years in the family | |
| Less than 3 members | 372(96.6) |
| More than 3 members | 13(3.4) |
| | |
| Education background | |
| Informal education | 74(19.2) |
| Primary education | 231(60.0) |
| Secondary education | 57(14.8) |
| Certificate/diploma/bachelor's degree | 23(6.0) |
| | |
| Land ownership | |
| Family | 56(14.6) |
| Owner | 251(65.1) |
| Rented | 78(20.3) |

| Variable | n (%) |
|---|---|
| Land size | |
| Less than 1 acre | 188(48.8) |
| More than 1 acre | 197(51.2) |
| | |
| Type of water source | |
| Boreholes deep well | 236(61.3) |
| Boreholes spring | 70(18.2) |
| Public pipe | 79(20.5) |
| | |
| Proximity from farm to water sources | |
| Less than 100 meters | 352(91.4) |
| More than 100 meters | 33(8.6) |
| | |
| Market Access | |
| Average | 2(0.5) |
| Good | 98(25.5) |
| Very good | 285(74.0) |

**Table 2:** Socio-Demographic Characteristics Distribution of the Respondent

**Adoption Pattern of Climate-Smart Agriculture Practices**

Smallholder leafy vegetable agripreneurs in semi-arid central Tanzania adopted Climate-Smart Agriculture (CSA) practices at varying rates. The analysis considered both individual practices and grouped categories, revealing distinct adoption patterns, preferences, and barriers. Among individual practices, crop diversification (94.3%) and crop rotation (90.9%) had the highest adoption rates. These practices were widely regarded as simple, traditional, and resource-efficient, requiring minimal external inputs. Inorganic fertilizer application (88.3%) and improved seeds (65.2%) followed, with adoption driven by immediate productivity benefits and accessibility through government support programs. Moderate adoption rates were observed for mulching (60.8%) and organic fertilizers (59.5%), while agroforestry had the lowest adoption rate (23.1%), as shown in Figure 3.

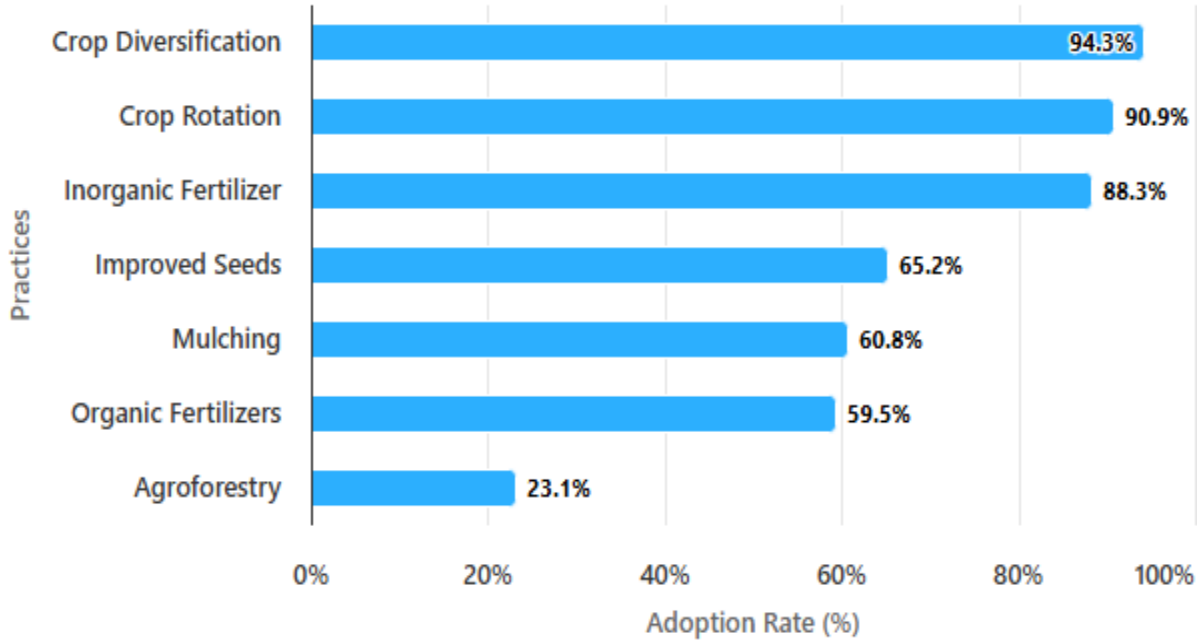


**Figure 3:** Adoption pattern of individual CSA practices

Qualitative findings provided context for these patterns. During a female-focused group discussion in Unyambwa Ward, Singida, in March 2024, participants described crop diversification and crop rotation as easy to implement and culturally embedded. The consensus from discussions was summarized as follows:

*"Crop diversification and crop rotation are simple to implement and more traditional practices, hence no complications in their implementation"* (FGD, 24 May 2024, Unyambwa).

Conversely, integrated soil-water management practices such as mulching, organic fertilizers, and agroforestry were perceived as resource-intensive and less accessible due to high costs, scarce materials, and delayed benefits. During discussions in Ihumwa Ward, Dodoma, participants emphasized the challenges related to resource scarcity and costs:

> *Mulching, organic fertilizer, and agroforestry are the best practices, but they are not affordable, and the materials are scarce and expensive. Additionally, it takes a long time to reap the results.* (FGD, 25 Apr 2024, Ihumwa, Dodoma)

When analyzed as grouped categories, soil management practices were adopted by 65.2% of farmers, whereas only 34.8% implemented integrated soil water management practices. The higher adoption rate of soil management practices, which include crop diversification, crop rotation, improved seeds, and inorganic fertilizers, is attributed to their immediate, visible benefits and lower implementation costs. Farmers frequently prioritized these practices due to their effectiveness in enhancing short-term productivity and food security, as presented in **Figure** 4.

Conversely, integrated soil water management practices, such as mulching, organic fertilizers, and agroforestry, faced notable adoption challenges. During in-depth interviews conducted in Ihumwa Ward, Dodoma, in April 2023, farmers acknowledged that inorganic fertilizers were more affordable and accessible than organic alternatives. One male farmer explained:

*"Inorganic fertilizer is accessible and affordable. Additionally, other types of inorganic fertilizers are provided by the government on a loan basis, and extension officers are daily encouraging us to use them." (In-depth Interview with Lead farmer Ihumwa ward Apr 2024)*

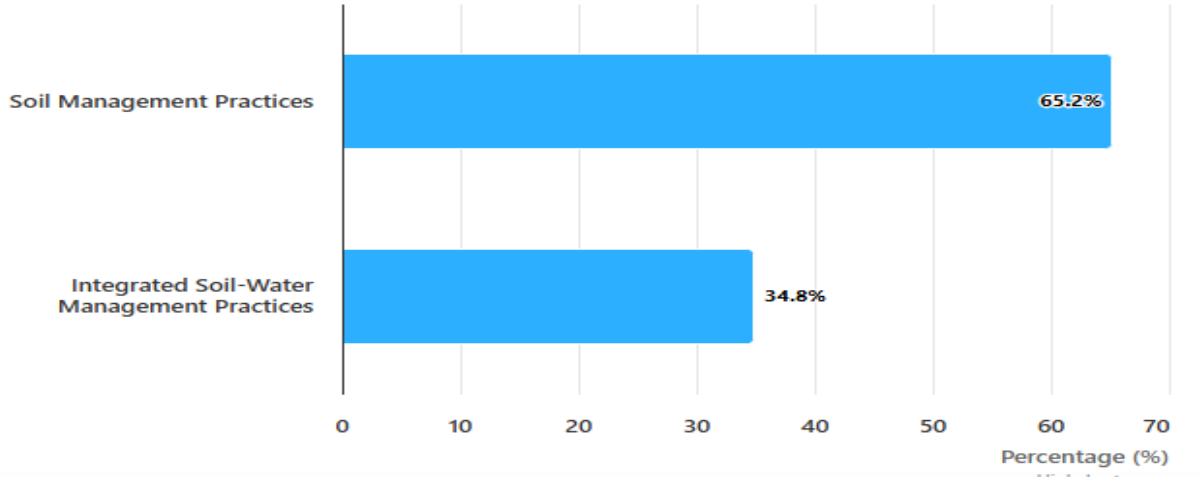


**Figure 4** presents the adoption pattern of grouped CSA practices.

**Food security status based on Household Food Insecurity Access Scale (HFIAS)**

The majority of smallholder leafy vegetable agripreneurs (53.5%, n = 206, 95% CI: 48.5%–58.5%) were identified as experiencing food insecurity contrariwise, 46.5% (n = 179, 95% CI: 41.5%–51.5%) were categorized as food secure (Figure 5). Among those classified as food insecure, 30.5% (n = 117, 95% CI: 25.9%–35.2%) were mildly food insecure; 18.2% (n = 70, 95% CI: 14.6%–22.4%) were moderately food insecure; and 4.9% (n = 19, 95% CI: 3.2%–7.6%) were severely food insecure (Figure 6).

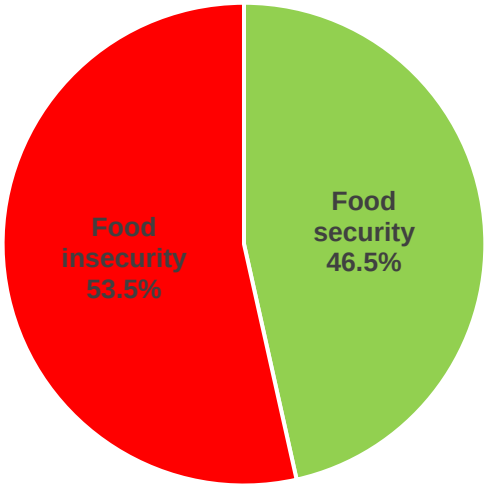


**Figure 5:** Food security status based on Household Food Insecurity Access Scale

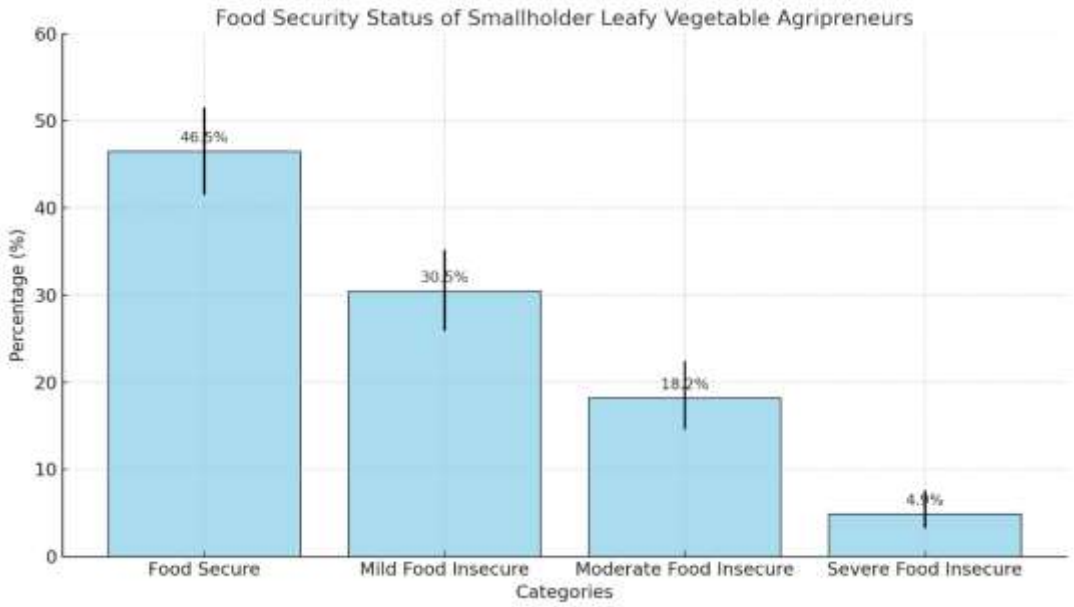


**Figure 6:** Household Food insecurity domains

Qualitative findings highlighted the critical role of leafy vegetables in enhancing household resilience to climate variability and food security. Participants reported that leafy vegetables contribute to food security in two primary ways: as a direct source of food during periods of limited staple crop availability and as a reliable source of income, enabling households to purchase other essential food items.

Participants across study areas emphasized the dual function of leafy vegetables in sustaining household food security. During a focus group discussion in Uhamaka Ward, Singida,

in May 2024, one participant described how income generated from selling leafy vegetables helps sustain food access:

> *"My family eats any type of food we wish because each week I sell my leafy vegetables twice, and that money earned is used to buy any type of food staff at the market."* (FGD, Uhamaka Ward, 22 May 2024)

Farmers in Singida specifically identified sweet potato leaves and cassava leaves as drought-resistant crops playing a critical role in food availability during dry seasons. A male farmer from Unyambwa Ward highlighted their importance:

> *"If I have sweet potato leaves during the dry season, my family will always have something to eat, as these leaves can survive harsh conditions when other crops fail. Additionally, their market price is higher during this season, allowing us to earn more income to buy other essential food items from the market."* (Lead Farmer, Unyambwa Ward, 23 May 2024)

Similarly, respondents in both Dodoma and Singida emphasized the consistent market demand for leafy vegetables, which provides economic stability and ensures continued access to staple foods. A key informant from Iyumbu Ward, Dodoma, explained:

> *"The market for leafy vegetables, especially Chinese cabbage and kale, is reliable in our area, and the income from selling them allows us to buy maize and other staples from the market."* (KII, Extension Officer, Iyumbu Ward, 19 April 2024)

**Association Between Food Security and Climate-Smart Agriculture Practices**

Quantitative analysis of individual CSA practices indicates that mulching has a statistically significant association with food security, reducing the risk of food insecurity by 21% (RR = 0.79, 95% CI: 0.65–0.95, $p < 0.05$). However, other individual practices, including improved seeds (RR = 0.87, 95% CI: 0.72–1.04), crop diversification (RR = 1.11, 95% CI: 0.67–1.82), and organic fertilizer application (RR = 1.03, 95% CI: 0.72–1.04), did not show statistically significant effects. Furthermore, analysis of grouped CSA practices reveals that households adopting integrated soil-water management practices, including mulching, organic fertilizers, and agroforestry, experienced a 22% lower risk of food insecurity compared to those relying solely on soil management practices (RR = 0.78, 95% CI: 0.63–0.96, $p < 0.05$). In contrast, soil management practices, such as crop rotation and inorganic fertilizer application, did not demonstrate a statistically significant association with reduced food insecurity (RR = 1.12, 95% CI: 0.77–1.63), as presented in Table 4.

**Table 4:** Contribution of CSA practices to household food security among smallholders agripreneurs (model 1 and model 2)

| Model Variable | Total | Food insecurity (n=206) | Adjusted Risk Ratio (δ) | | |
|---|---|---|---|---|---|
| | | | RR | 95% CI | p-value |
| **Crop rotation** | | | | | |
| No | 35 | 16(45.7) | 1 | | |
| Yes | 350 | 190(54.3) | 1.12 | 0.77-1.63 | 0.554 |
| **Application of organic fertiliser** | | | | | |
| No | 156 | 80(51.3) | 1 | | |
| Yes | 229 | 126(55.0) | 1.03 | 0.84-1.25 | 0.805 |
| **Application of improved seeds** | | | | | |
| No | 134 | 78(58.2) | 1 | | |
| Yes | 251 | 128(51.0) | 0.87 | 0.72-1.04 | 0.138 |
| **Mulching** | | | | | |
| No | 151 | 90(59.6) | 1 | | |
| Yes | 234 | 116(49.6) | 0.79 | 0.65-0.95 | **0.011** |
| **Crop diversification** | | | | | |
| No | 22 | 10(45.5) | 1 | | |
| Yes | 363 | 196(54.0) | 1.11 | 0.67-1.82 | 0.681 |
| **Application of inorganic (chemical) fertilisers** | | | | | |
| No | 45 | 20(44.4) | 1 | | |
| Yes | 340 | 186(54.7) | 1.12 | 0.78-1.62 | 0.531 |
| **Agroforestry** | | | | | |
| No | 296 | 156(52.7) | 1 | | |
| Yes | 89 | 50(56.2) | 0.86 | 0.68-1.09 | 0.214 |
| **Composite** | | | | | |
| Soil management practices | 251 | 140(55.8) | 1 | | |
| Soil water management practices | 134 | 66(49.3) | 0.78 | 0.63-0.96 | **0.020** |

*Hints: RR= Risk Ration; 95% CI= 95% Confidence Interval; p-value=Probability Valueδ = adjusted by District, Age, Education Background, Family size, Land ownership, Size of the land, and Proximity from farm to water source*

Qualitative findings indicate that smallholder leafy vegetable agripreneurs perceive CSA practices as essential for enhancing household food security. Across the study areas, participants consistently emphasized how adopting CSA practices improved food access, provided a reliable income, and increased resilience to climate variability. During a focus group discussion in Uhamaka Ward, Singida, in May 2024, a female farmer described how CSA practices, particularly improved seeds and crop rotation, helped her family maintain food security during productive seasons:

> *"When I use improved seeds and rotate them with other crops, I can harvest enough vegetables for my family within a short time. We never run out of food during good weather, and my children eat healthy meals every day. But when the rains fail, these seeds do not perform well, and we face challenges."* (Female Farmer, Uhamaka Ward, Singida, 22 May 2024)

Similarly, during a focus group discussion in May 2024 in Unyambwa Ward, Singida, farmers emphasized the importance of drought-resistant leafy vegetables, such as sweet potato leaves, cassava leaves, cowpea leaves, and pumpkin leaves, in ensuring consistent food access. A male participant highlighted the role of mulching in improving the productivity of these crops and enhancing household purchasing power:

> *"If I manage to apply mulching in the production of sweet potato leaves, cassava leaves, cowpea leaves, or pumpkin leaves, I am assured of the purchasing power to provide food for my family throughout the year because these crops grow even when the weather is bad, as long as soil moisture is maintained. However, under current climate variability, mulching materials, especially grasses and crop residues, are scarce, and buying them is very expensive."* (FGD, Unyambwa Ward, 24 May 2024)

Moreover, smallholder leafy vegetable agripreneurs recognized the critical role of improved seeds as a CSA practice in controlling pests and diseases exacerbated by climate change, thereby contributing to household food security. During a focus group discussion in Ihumwa Ward, Dodoma, a farmer highlighted the benefits of improved seeds in addressing pest and disease challenges:

> *"I produce Chinese cabbage and amaranth using improved seeds that are resistant to diseases and pests, which are some of the biggest challenges we face today. The market for these vegetables is always available. Chinese cabbage is transported to Dar es Salaam, while amaranth is consumed within our community. So, even when other sources of income face challenges, my leafy vegetables provide a reliable complement for household food security."* (Farmer, Ihumwa Ward, 22 April 2024)

Bibliometric analysis indicates that CSA practices are widely recognized for their role in improving household food security, particularly in relation to soil health, nutritional outcomes, and sustainable agricultural practices. These findings align with the results of this study, reinforcing the positive contributions of CSA practices in enhancing food security among smallholder agripreneurs.

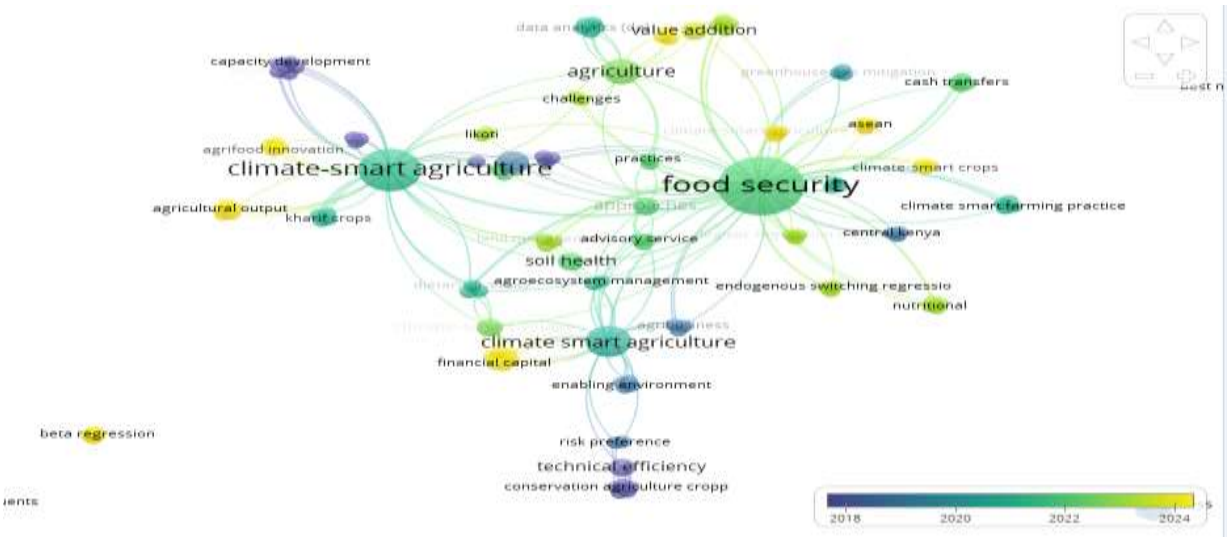


**Figure 7:** Bibliometric analysis

## DISCUSSION

### Adoption Patterns of CSA Practices

The study findings indicate that farmers prioritize CSA practices that offer immediate and tangible benefits, such as crop diversification and crop rotation, while resource-intensive practices like agroforestry and mulching remain less adopted. These preferences align with prior research suggesting that smallholder farmers are more likely to adopt low-cost, high-return interventions (Ng'ang'a *et al.*, 2021; Mizik, 2021). The tendency to prefer short-term gains over long-term sustainability measures underscores the importance of financial incentives and extension services to facilitate the adoption of more sustainable practices.

### Household food status

This study found that 53.5% of households were food insecure, with 30.5% mildly, 18.2% moderately, and 4.9% severely food insecure. These findings highlight ongoing challenges in ensuring stable food access among smallholder farmers in semi-arid regions, where climate variability and resource constraints increase vulnerability.

Qualitative insights emphasize the role of leafy vegetables in enhancing food security and income. Weekly sales provided purchasing power for staples like maize and rice, reducing food insecurity during lean periods. Drought-resistant crops, including sweet potato leaves, cassava leaves, cowpea leaves, and pumpkin leaves, were crucial for maintaining food access in dry seasons. One respondent noted, *"Sweet potato leaves always ensure we have something to eat, even when other crops fail."* These findings align with Alemu and Ashenafi (2022) and Kapari et al. (2023), who highlight leafy vegetables' dual role in direct consumption and income generation, reinforcing their importance in household resilience.

### Contribution of CSA Adoption to Household Food Security

This study confirms that CSA practices enhance food security by improving productivity, income stability, and climate resilience. Farmers using integrated soil-water management techniques, such

as mulching and organic fertilizers, reported higher yields and reduced vulnerability to climate shocks. These findings align with prior studies highlighting CSA's role in strengthening agricultural resilience and food security (Tesfaye *et al.,* 2023; Nyanga *et al.,* 2023). Qualitative insights further reinforce this link, as farmers emphasized CSA's role in stabilizing food supplies and increasing purchasing power. Drought-resistant leafy vegetables and improved seeds were particularly beneficial in sustaining food availability and reducing pest susceptibility.

Despite these benefits, CSA adoption faces challenges, including financial constraints, labor demands, and limited technical support. Farmers struggle to access organic inputs, and the high cost of mulching materials discourages widespread adoption. These findings are consistent with previous research identifying financial and technical barriers to CSA implementation (Adimassu *et al.,* 2024; Alemu & Ashenafi, 2022). Addressing these limitations through targeted policies, subsidies, and farmer education programs can enhance CSA adoption and maximize its benefits for smallholder farmers.

**Market Access as a Driver of CSA Practices Adoption**

Market access plays a crucial role in CSA adoption by providing farmers with a steady income stream to reinvest in improved seeds, fertilizers, and irrigation. Strong demand in urban centers like Dar es Salaam city and Dodoma city incentivizes production of high-market-leafy vegetable crops such as Chinese cabbage and amaranth, enhancing both income and household food security.

Regular vegetable sales reduce financial vulnerability and enable the purchase of staple foods during lean periods. Qualitative findings indicate that farmers prioritize crops with stable market demand, as they provide both direct food security and economic benefits. A key informant noted that market accessibility influences crop selection and investment in CSA practices. These findings align with studies by Alemu and Ashenafi (2022) and Kapari et al. (2023), which highlight that smallholder farmers with better market linkages are more likely to adopt CSA practices and improve food security outcomes.

**Role of Government Support in Enhancing CSA Adoption**

Government support plays a crucial role in promoting Climate-Smart Agriculture (CSA) among smallholder farmers. Extension services have been key in raising awareness and equipping farmers with essential skills, while government-backed loan programs have improved access to inorganic fertilizers, reducing financial barriers to adopting improved seeds and soil management practices. These findings align with research highlighting the impact of government interventions on CSA adoption and food security. Mizik (2021) and Ng'ang'a et al. (2021) emphasize that public-sector support in market access, value chains, and farmer training has increased CSA uptake. Expanding subsidies and extension services could further enhance adoption and agricultural sustainability.

**Theoretical Implications: Expected Utility Theory**

The study findings align with Expected Utility Theory (EUT), which suggests that farmers make decisions based on their expected benefits and associated risks. The preference for inorganic fertilizers and improved seeds over agroforestry and mulching reflects farmers' inclination toward practices that offer immediate, predictable returns. Similar observations were made by Tinh et al. (2021), who noted that farmers in risk-prone environments prioritize short-term gains over long-

term investments. The results suggest that policy interventions should focus on reducing the perceived risks of CSA practices through financial incentives and extension support.

**Limitations of the Study**

Despite its contributions, this study has several limitations. First, its cross-sectional design captures CSA adoption and food security at a single point in time, limiting the ability to assess long-term impacts. Future studies could adopt longitudinal approaches to track changes over time and better understand the sustained effects of CSA practices. Second, while integrating both quantitative and qualitative methods, the study relies on self-reported data, which may be affected by response biases. Farmers might overstate CSA adoption due to social desirability or underreport food insecurity due to cultural perceptions. Triangulating findings with objective farm productivity data and external food security assessments could enhance reliability.

Third, the study focuses on four wards in Dodoma and Singida, which, while representative of semi-arid regions, may not fully capture regional diversity. Expanding research to other agroecological zones could improve generalizability and provide a broader understanding of CSA adoption patterns. Despite these limitations, the study provides valuable insights into the relationship between CSA adoption and food security, offering a strong foundation for future research and policy interventions aimed at enhancing agricultural resilience in semi-arid regions.

**Policy implications**

The study highlights that soil-water management practices, including organic fertilizers, enhance climate resilience but remain underutilized due to availability challenges. Tanzania, ranking second in Africa in cattle population, presents a significant opportunity for organic manure production. However, the lack of structured markets and efficient distribution systems leads to cattle dung wastage, while horticultural agripreneurs struggle to access organic fertilizers. Addressing this gap requires integrating the livestock and horticulture sectors through market linkages, infrastructure investment, and policy coordination.

The Tanzania Agriculture and Livestock Policy (2013) and the Tanzania Horticulture Development Strategy (2021-2030) emphasize market access for agricultural inputs and outputs. Strengthening linkages between livestock keepers and horticultural agripreneurs can enable the systematic collection, processing, and distribution of cattle dung for organic fertilizer production. Establishing structured cattle dung markets through farmer cooperatives and private-sector partnerships can enhance accessibility, promote CSA adoption, and generate additional income for livestock farmers.

The Agricultural Sector Development Program Phase II (2017-2028) prioritizes infrastructure improvements that support efficient transport, storage, and composting of organic fertilizers. Investments in decentralized composting facilities near vegetable production hubs can streamline supply chains, while government-supported subsidies and incentives can encourage livestock keepers to commercialize dung. Given Tanzania's large cattle population, integrating livestock waste management with CSA expansion can improve soil fertility, reduce dependence on synthetic fertilizers, and strengthen climate resilience through a circular economy approach.

## CONCLUSION

This study provides empirical evidence on the adoption patterns and food security contributions of Climate-Smart Agriculture (CSA) among smallholder leafy vegetable agripreneurs in semi-arid central Tanzania. Findings reveal that despite CSA's potential, over half (53.5%) of households remain food insecure, with varying degrees of severity. Farmers widely adopt low-cost and immediately beneficial CSA practices, such as crop diversification (94.3%) and crop rotation (90.9%), while resource-intensive practices like mulching (60.8%) and agroforestry (23.1%) face adoption barriers due to high costs and limited input availability.

Statistical analysis indicates that mulching reduces food insecurity risk by 21%, while integrated soil-water management practices lower risk by 22%, highlighting their effectiveness in improving household resilience. Qualitative findings further emphasize CSA's role in enhancing adaptive capacity, with improved seeds and drought-resistant leafy vegetables ensuring stable food access and income generation. Market access plays a crucial role in CSA adoption, with steady demand in urban markets enabling farmers to reinvest in productivity-enhancing practices.

Guided by Expected Utility Theory, the study confirms that farmers prioritize practices with immediate and predictable returns while avoiding those perceived as risky or resource-intensive. These findings suggest that financial constraints, knowledge gaps, and limited resource availability hinder broader CSA adoption, despite its proven benefits for food security.

### Revised Recommendations for Future Studies

Future research should adopt longitudinal studies to assess the long-term effects of CSA practices on food security, soil fertility, and climate resilience. This approach would provide deeper insights into the sustainability and economic viability of CSA interventions in semi-arid regions of Tanzania.

Market access and value chain development are key drivers of CSA adoption and food security, yet there is limited understanding of how pricing structures, demand for CSA-grown produce, and supply chain efficiency influence smallholder farmers' decisions. Future studies should explore these dynamics to inform policies that enhance economic benefits and market incentives for CSA adoption.

Despite Tanzania's large cattle population, organic fertilizers, particularly cattle dung, remain underutilized. Research should focus on developing efficient manure collection, processing, and distribution models to integrate livestock waste management into CSA expansion. Examining cattle dung market systems, composting innovations, and policy incentives can help unlock the potential of organic fertilizers in promoting climate-smart food production.

## REFERENCES

Adimassu, Z., Tibebe, D., Abera, W., & Tamene, L. (2024). Integrating meta-analysis and experts' knowledge for prioritizing climate-smart agricultural practices in Ethiopia. *Farming System, 2*(4), 100110. https://doi.org/10.1016/j.farsys.2024.100110

Affoh, R., Zheng, H., Zhang, X., Wang, X., Dangui, K., & Zhang, L. (2024). Climate-smart agriculture as an adaptation measure to climate change in Togo: Determinants of choices and its impact on rural households' food security. *Agronomy, 14*(7), 1–18. https://doi.org/10.3390/agronomy14071540

Alemu, A., & Ashenafi, M. (2022). Household food security, child nutrition, and food safety among vegetable producers and non-producers in Dugda Woreda, Oromia region, Ethiopia. *Ethiopian Journal of Science and Technology, 15*(2), 101–124.

Amadu, F. O., McNamara, P. E., & Davis, K. (2020). Impact of climate-smart agriculture adoption on household welfare and food security: Evidence from sub-Saharan Africa. *Agriculture & Food Security, 9*(22), 1–12. https://doi.org/10.1186/s40066-020-00277-3

Assenga, E. A., & Kayunze, K. A. (2020). Socio-economic and demographic determinants of food security in Chamwino District, Tanzania. *Tanzania Journal of Population Studies and Development, 27*(1), 45–63.

Boga, N. P., Reddy, K. J., & Ankam, N. (2020). Impact of climate change on the quality of horticulture crops (fruits and vegetables). *International Journal of Agricultural Sciences, 12*(4), 78–85.

Coates, J., Swindale, A., & Bilinsky, P. (2007). *Household Food Insecurity Access Scale (HFIAS) for measurement of food access: Indicator guide*. Food and Nutrition Technical Assistance Project.

Creswell, J. W., & Creswell, J. D. (2017). *Research design: Qualitative, quantitative, and mixed methods approaches*. Sage publications.

Donthu, N., Kumar, S., Mukherjee, D., Pandey, N., & Lim, W. M. (2021). How to conduct a bibliometric analysis: An overview and guidelines. *Journal of Business Research, 133*, 285-296. https://doi.org/10.1016/j.jbusres.2021.04.070

Dossa, K. F., & Miassi, Y. E. (2023). Exploring the nexus of climate variability, population dynamics, and maize production in Togo: Implications for global warming and food security. *Farming System, 1*(3), 100053. https://doi.org/10.1016/j.farsys.2023.100053

Ekka, R., & Mjawa, B. (2020). Growth of Tanzania's horticulture sector: Role of TAHA in reducing food loss. *Journal of Agriculture & Food Systems, 8*(2), 57–69.

Food and Agriculture Organization (FAO). (2013). *Climate-smart agriculture: Policies, practices, and financing for food security, adaptation, and mitigation*. FAO. https://www.fao.org/climate-smart-agriculture/en/

Guest, G., Namey, E., & Mitchell, M. (2017). *Collecting qualitative data: A field manual for applied research*. Sage publications.

Habiyaremye, N., Ochieng, J., & Heckelei, T. (2021). Economic analysis of integrated vegetable–poultry production systems in the Babati District of Tanzania. *Agriculture and Food Security, 10*(1), 1–15. https://doi.org/10.1186/s40066-020-00272-8

Intergovernmental Panel on Climate Change (IPCC). (2019). *Climate change and land report*. https://www.ipcc.ch/srccl/

Kapari, M., Hlophe-Ginindza, S., Nhamo, L., & Mpandeli, S. (2023). Contribution of smallholder farmers to food security and opportunities for resilient farming systems. *Frontiers in Sustainable Food Systems, 7*, 1–12. https://doi.org/10.3389/fsufs.2023.1149854

Krosnick, J. A. (2018). Questionnaire design. In *The Palgrave handbook of survey research* (pp. 439-455). Palgrave Macmillan.

Masha, M., Bojago, E., & Ngare, I. (2024). Determinants of adoption of urban agriculture as climate-smart agriculture practices and its impact on food security: Evidence from Wolaita

Sodo City, South Ethiopia. *Discover Sustainability*, *5*(1), 1–15. https://doi.org/10.1007/s43621-024-00365-5

Mizik, T. (2021). Climate-smart agriculture on small-scale farms: A systematic literature review. *Agronomy*, *11*(6), 1096.

Ng'ang'a, S. K., Miller, V., & Girvetz, E. (2021). Is investment in climate-smart agricultural practices the option for the future? Cost and benefit analysis evidence from Ghana. *Heliyon*, *7*(4), e06653.

Nyanga, P. H., Kamwi, J. M., & Shitima, M. (2023). Climate-smart agricultural practices and household food security: A case study of smallholder farmers in sub-Saharan Africa. *Food and Energy Security*, *12*, e70021. https://doi.org/10.1002/fes3.70021

Swamila, M., Yusuf, Z., & Kimambo, B. (2020). *Agricultural adaptation strategies in the context of climate change: Insights from Tanzania*. African Journal of Agricultural Economics, 8(1), 23–41.

Tesfaye, W., Habtemariam, L. T., & Solomon, D. (2023). The role of climate-smart agriculture in enhancing food security and reducing poverty among smallholder farmers in Ethiopia. *Environmental Challenges*, *11*, 100754. https://doi.org/10.1016/j.envc.2023.100754

Tinh, L., Que, N. D., Hien, N. H., Le, D. T., & Manh Trung, V. H. (2021). Combining the Theory of Planned Behavior, Expected Utility Theory, and Diffusion of Innovation Theory to analyze factors affecting farmers' intention to use pesticides. *International Journal of Agriculture and Technology*, *1*(1), 1–7.